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Reduction of BOD and COD in Hospital Waste with Biochar from Peanut Shells (*Arachis Hypogaea* L.)

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A B S T R A C T

This consider pointed to examine the potential of utilizing biochar determined from peanut shells (Arachis hypogaea L.) for diminishing the levels of biochemical oxygen request (BOD) and chemical oxygen request (COD) in clinic squander. Peanut shell biochar was created through pyrolysis, and its physicochemical properties were characterized. The biochar was at that point connected to healing center squander tests in several measurements, and the BOD and COD levels were observed over a indicated period. The comes about appeared that the shelled nut shell biochar had a tall carbon substance and permeable structure, which contributed to its adsorption capacity. The application of biochar to healing center squander come about in critical diminishments in BOD and COD levels, with higher measurements driving to more noteworthy decreases. The most elevated decrease in BOD and COD was watched at a biochar measurement of 10 g/kg, where BOD diminished to 24.0 mg/L and COD diminished to 14.3 mg/L from the beginning of 72.0 mg/L, and 46.7 mg/L separately. Moreover, the lessening in BOD and COD levels was credited to the adsorption of natural compounds by the biochar and the improvement of microbial movement within the squander. In general, this think about illustrates the potential of shelled nut shell biochar as a successful and feasible strategy for diminishing BOD and COD in healing center squander, giving a promising approach for squander administration in healthcare offices. Assist inquire about is prescribed to optimize biochar measurement and investigate its long-term impacts on squander treatment effectiveness and natural affect.

Keywords: biochar, peanut shells, BOD, COD, waste, hospital

1. Introduction

Shelled nut (Arachis hypogaea L.) plant is one sort of plant that's exceptionally well known since it is planted in nearly all districts in Indonesia. Peanuts are vegetables and one of the foremost critical sources of vegetables and protein (Krishna et al., 2015) Peanuts have tall financial esteem and have a huge part in assembly desires of nourishment sorts of vegetables. Peanuts have 25-30% protein substance, 40-50% fat, 12% carbohydrates, and vitamin B1 and put peanuts in terms of dietary fulfillment after soybean (Nurhasni et al., 2018).

In Indonesia, numerous peanuts items delivered by expansive businesses as a nibble and interchange nourishment. The portion of shelled nut expended is as it were the seed, with the more utilization of shelled nut within the community, the more shelled nut shells delivered, that was the squander. Biochar determined from natural squander such shelled nut shells has been utilized as expulsion of methylene blue and tetracycline from water (Islam et al., 2019) color adsorption (Liu et al., 2018), and in adsorption of select metal particles (Wilson et al., 2006). A few other natural squanders which was utilized in adsoption of metal particle was banana peels (Napitupulu et al., 2019), durian bark (Napitupulu et al., 2018), ruddy fruit's peels (Napitupulu et al., 2020), and sawah lettuce (Walanda et al., 2020) have been characterized its capacity to be utilized as retentive of heavy metal cadmium particle, additionally zalacca seeds against chromium particle adsorption. A few inquire about comes about on biochar determined from agrarian plant biomass, particularly from natural product peels such as banana peels (Napitupulu et al., 2019), cacao (Malik et al., 2023), durian (Napitupulu et al., 2018), salak natural product seeds (R C Pongenda et al., 2015), coconut husk (Anshary & Napitupulu, 2022), has been distributed in different trustworthy diaries both broadly and universally. For the most part, the inquire about carried out is connected as an adsorbent for metal particles (especially overpowering metals) such as Cr, Cd, Pb and others contained in arrangement. These investigate encounters can be created to extend the capacity or adsorption capacity of biocharcoal for mass generation which can be connected to move forward water quality or wastewater treatment. Adsorption could be a marvel wherein the concentration of the bulk lower than the concentration a substance. When the powerless strengths known as van der Waals powers advanced physical adsorption and chemical fascination between the surface of atom encompassing gasses or fluid known as the type of Chemisorption. Van der Waals and chemical strengths can happen within the filtering, and dying of fats and oils with adsorbents, but this depends on the adsorbent, the component aiming to be evacuated, and their conditions. (Patterson, 2009)

Hospital waste management postures critical challenges due to the nearness of different dangerous and irresistible materials. Among the distinctive parameters utilized to evaluate the contamination potential of clinic squander, the levels of biochemical oxygen request (BOD) and chemical oxygen request (COD) are pivotal pointers. BOD speaks to the sum of oxygen required for microbial debasement of natural matter, whereas COD evaluates the overall oxygen-consuming capacity of natural and inorganic substances. Intemperate BOD and COD levels in healing center squander can lead to water contamination and unfavorable natural impacts. Chemical oxygen request (COD) is the sum of oxygen required so that natural squander in water can be oxidized through chemical responses. Natural squander will be oxidized by potassium bichromate ($K_2Cr_2O_7$) as a source of oxygen into CO_2 and H_2O gas and a number of chromium particles. COD esteem may be a degree of the level of contamination by natural matter. Organic Oxygen Request (BOD) is the sum of oxygen required for the update of natural matter in water by microorganisms at a certain temperature and volume. The greater the BOD esteem of a water, the less oxygen is accessible to life forms within the water. BOD is closely related to DO (Broken down Oxygen) or broken-down oxygen. The higher the BOD level of a water, the less the sum of broken-down oxygen. So, the higher the BOD level, the higher the level of contamination (Molinari et al., 2019).

Water treatment can be done physically by employing a sand channel with a silica estimate that's balanced to the estimate of the suspended materials to be sifted. In the meantime, chemical wastewater treatment is as a rule carried out to expel non-precipitating particles (colloids), overwhelming metals, phosphorus compounds, and poisonous natural substances by joining certain required chemicals (Cheng et al., 2021). The expulsion of these materials in guideline takes put through changes within the properties of these materials, namely from non-precipitation (flocculation-coagulation), either with or without an oxidation-reduction response, conjointly takes put as a result of an oxidation response (Komkiene & Baltrenaite, 2016). Natural wastewater treatment is one of the treatment strategies coordinated at diminishing or dispensing with certain substrates contained in wastewater by utilizing the action of microorganisms to redesign the substrate. Physical water treatment with channel media, specifically enacted carbon, can be done to decrease toxin levels, to be specific BOD and COD in water. Biochar is characterized as a by-product gotten by the thermochemical change of biomass into warm, vitality, fuel and/or chemicals in a constrained oxygen environment (Plaimart et al., 2021). Biochar has picked up critical consideration in later a long time due to its potential to relieve natural contamination and progress soil richness. It has a profoundly permeable structure, huge surface region, and tall adsorption capacity, making it an appealing candidate for wastewater treatment applications. The utilize of biochar has appeared promising comes about in different areas, counting the evacuation of overwhelming metals, natural contaminants, and supplement administration.

2. Research Methodology

- Collection and Preparation of Peanut Shells:

Peanut shells (Arachis hypogaea L.) will be collected from a reliable source and thoroughly cleaned to remove any impurities. The shells will be dried and ground into a fine powder using a grinder or mill to increase the surface area for pyrolysis.

- Biochar Production:

Pyrolysis, a thermal decomposition process, will be employed to convert the peanut shell powder into biochar. The pyrolysis process will be conducted in a controlled environment using a pyrolysis reactor or furnace. Parameters such as temperature, heating rate, and residence time will be optimized to ensure the production of high-quality biochar. The resulting biochar will be cooled, collected, and stored in airtight containers for further characterization and application.

- Physicochemical Characterization of Peanut Shell Biochar:

The produced biochar will be characterized to determine its physicochemical properties. Standard characterization techniques will be employed, including scanning electron microscopy (SEM) to analyze the surface morphology, Scanning Electron Microscope (EDS) analysis for specific surface area measurement, Fourier-transform infrared spectroscopy (FTIR) to identify functional groups, and elemental analysis for carbon content determination.

- Hospital Waste Sampling:

Representative samples of hospital waste will be collected from designated waste disposal areas. The collected waste samples will be properly labeled, transported, and stored in airtight containers to maintain their integrity and prevent contamination.

- Experimental Setup:

The hospital waste samples will be divided into different groups. Each group will receive a specific dosage of peanut shell biochar, which will be added to the waste samples based on a predetermined ratio (e.g., grams of biochar per kilogram of waste). The waste samples, both with and without biochar, will be placed in separate containers or reactors.

- Monitoring of BOD and COD Levels:

The BOD and COD levels in the hospital waste samples will be monitored over a specified period. BOD measurements will be conducted using standard BOD bottles and the dilution method. COD measurements will be performed using a COD reactor and colorimetric analysis or a suitable COD testing method. Sampling will be done at regular intervals to assess the temporal changes in BOD and COD levels.

- Data Analysis:

The information collected on BOD and COD levels will be analyzed factually utilizing suitable strategies. The diminishment in BOD and COD levels within the squander tests treated with shelled nut shell biochar will be compared to the control bunches without biochar. The impact of distinctive doses of biochar on the lessening effectiveness will be assessed. Any relationships between the physicochemical properties of biochar and its execution in decreasing BOD and COD will be investigated.

3. Result and Discussion

3.1 Biochar Characterization

The determination of moisture content is intended to determine the hygroscopic properties of activated biochar. The binding of water molecules to activated biochar can cause a decrease in the ability of adsorption (Yusuf & Tjahjani, 2013) The determination of ash content aims to determine the percentage of mineral content. The higher the mineral content, the higher the ash content (Zakir et al., 2012) Table 1 shown the yield of testing the quality of activated biochar from peanut shells. It was indicated that the biochar produced meets the quality requirements by the National Industrial Standard (SNI) of Indonesia.

Table 1 – Water and Ash Content of Biochar

Parameter	Result Analysis	SNI 06-5730-1995
And an entry	8.16%	Maximum 15%
And another entry	6.06%	Maximum 10%

3.2 Identification of Functional Group using FTIR

Identification of the functional group aims to identify whether the adsorbent is capable of adsorbing Cd (II) ion, this is characterized by changes or shifts in the adsorbent groups either after or before contacted with metal ions. Identification of functional groups contained in the adsorbent is done by analyzing the results of the infrared spectrum obtained from infrared spectrophotometers.

Activated peanut shells biochar adsorbent was identified in its functional group to determine the chemical composition of activated biochar in the form of functional groups which are active groups of activated biochar (Haitao et al., 2017). According to FTIR data tables and previous study (Chia et al., 2012) the band at 3386 cm^{-1} was due to the vibration of phenolic hydroxyl groups. The bands at 2924 cm^{-1} indicate a range of -OH which binds with hydrogen so that the peak widens correspond to the symmetrical or asymmetrical stretching vibration of the $–CH_3$ and $–CH_2$ groups of aliphatic or naphthenic hydrocarbons. The bands at 1592 cm^{-1} correspond to the stretching vibration of carboxyl C=O groups or C=C and C=O groups in aromatic rings. The bands at 1376–1072 cm^{-1} are attributed to the stretching vibration of C–O moieties often present in phenols or hydroxyl groups. The bands for hydroxyl and phenolic hydroxyl groups (–OH), $–CH_3$ and $–CH_2$ groups of aliphatic or naphthenic hydrocarbons, carboxyl C=O groups, and the C=C and C=O groups of aromatic rings in the activated biochar peanut shells.

3.3 Pore Morphological Characterization

The surface morphology of the biochar materials was characterized by SEM-EDS at a magnification of 3000x. Figures 1 and 2 show microscopy images of non-activated, and activated biochar respectively. Both materials were prepared at the same temperatures. Some pores can be observed on the biochar carbonized at 400 °C (Fig. 1). These images indicate the occurrence of pore growth as the biochar activated, the pore more visible on the carbon surface This is allegedly related to the ash content in the carbon due to the activation process.

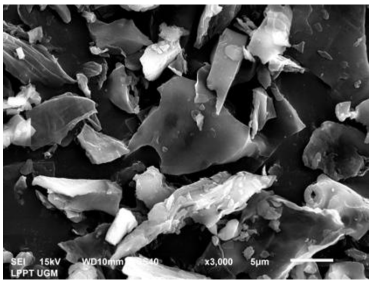

Figure 1. Pore morphology of biochar from peanut shell 3000x magnification

The pore structure of biochar can be determined through techniques like nitrogen adsorption-desorption isotherms, mercury intrusion porosimetry, and scanning electron microscopy. These methods provide valuable information about the pore size distribution, surface area, and porosity of biochar, which are crucial for understanding its adsorption capacity, water-holding capacity, and potential applications in soil improvement, water treatment, and environmental remediation.

The graph shows the form of the pore is Macrospores are the largest pores in biochar, typically with diameters exceeding 50 nanometers. These pores are responsible for facilitating the movement of air and water through the biochar matrix. Macrospores play a significant role in enhancing soil drainage, reducing compaction, and improving root penetration and nutrient accessibility. The presence and distribution of these pore types within biochar depend on various factors, including the feedstock used, pyrolysis conditions, and post-processing treatments. Feedstocks with high lignocellulosic content, such as peanut shells, tend to produce biochar with well-developed pore structures. Pyrolysis conditions, such as temperature, heating rate, and residence time, can also influence the formation and characteristics of the pores in biochar.

3.4 EDS Analysis of Element Composition

The EDS data listed in Table 2 reveal the elemental composition of the biochar (C, N, O, Mg, Ca) and activated biochar (C, N, O, Mg, K, Ca), with the relative mass percentage of different elements for each element. The C element is a dominating element, reaching more than 50% for biochar and activated biochar. In addition, N also had a high percentage, of 22.70 % for biochar, and 23.60% for activated biochar.

Table 2 – Elemental composition of Biochar from Peanut Shells

Elements	Biochar (atom %)
Carbon	64.27
Nitrogen	21.96
Oxygen	13.54
Magnesium	0.09
Potassium	0.04
Calcium	0.07

The EDS analysis reveals the relative atomic percentages of different elements present in the biochar sample. Carbon (C) is the dominant element, constituting approximately 64.27% of the atoms in the biochar. This high carbon content is expected in biochar, as it is derived from organic materials, such as peanut shells in this case. Nitrogen (N) is the next most abundant element, comprising around 21.96% of the atoms. Nitrogen is commonly found in organic matter and is likely derived from the peanut shells used for biochar production. Oxygen (O) accounts for approximately 13.54% of the atoms in the biochar sample. Oxygen is present in various organic and inorganic compounds and is crucial for the combustion and decomposition processes during pyrolysis. The remaining elements, namely Magnesium (Mg), Potassium (K), and Calcium (Ca), are present in trace amounts, each constituting less than 0.1% of the atoms. These elements might be present in the peanut shells or could be derived from the pyrolysis process. Overall, the EDS analysis confirms the elemental composition of the biochar sample, with carbon and nitrogen being the major constituents. These results are consistent with the nature of biochar produced from organic materials and provide valuable insights into its elemental composition for further characterization and application studies.

3.5 The reduction of BOD and COD

The reduction of BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) can be analyzed based on the provided data in Table 3.

Table 3 – COD and BOD levels in the Hospital Waste before and after filtration by Biochar with various contact time.

Time (hours)	COD (mg/L)	BOD (mg/L)
0.0	56.0	66.7
1.0	28.0	40.9
3.0	14.0	30.6
5.0	10.0	22.8

BOD and COD are measures of the amount of oxygen required for the degradation of organic matter and the overall oxygen-consuming capacity of both organic and inorganic substances, respectively. A reduction in BOD and COD levels indicates a decrease in the organic and chemical pollution of the water sample being tested. Analyzing the provided data, we observe that as time progresses, the values of both COD and BOD decrease. This suggests that over time, the organic and chemical pollutants present in the water sample are being degraded and consumed.

At the initial time point of 0.0 hours, the COD value is 56.0 mg/L, and the BOD value is 66.7 mg/L. After 1.0 hour, the COD reduces to 28.0 mg/L, and the BOD decreases to 40.9 mg/L. The reduction continues at 3.0 hours, with the COD reaching 14.0 mg/L and the BOD decreasing to 30.6 mg/L. Finally, after 5.0 hours, the COD further decreases to 10.0 mg/L, and the BOD is reduced to 22.8 mg/L. From this trend, we can infer that the degradation and consumption of organic and chemical pollutants in the water sample are occurring over time. The decreasing values of both COD and BOD indicate a reduction in the oxygen-demanding substances, signifying an improvement in the water quality.

It is important to note that the rate of reduction and the final desired levels of BOD and COD depend on the specific water quality standards or regulatory limits that need to be met. Further monitoring and analysis may be required to determine the optimal treatment duration and assess the effectiveness of the process in meeting the desired water quality targets. In addition to conducting trials with varying times, the treatment was also carried out with various weights of activated carbon. COD and BOD levels based on differences in sample weight are shown in Table 4 below. To analyze the reduction of BOD

(Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) based on the provided data, we can examine the changes in BOD and COD values corresponding to different weights of a substance.

Table 4 – COD and BOD levels in the Hospital Waste before and after filtration by Biochar with various weight

Time (hours)	COD (mg/L)	BOD (mg/L)
0.0	72.0	46.7
2.0	65.0	34.8
5.0	32.0	25.9
10.0	24.0	14.3

In this case, the weight represents the amount of a substance that has been added to the water sample, and the corresponding COD and BOD values indicate the levels of organic and chemical pollutants present. Analyzing the data, we observe a consistent reduction in both COD and BOD values as the weight of the substance increases. This suggests that the substance being added has an effect on reducing the organic and chemical pollution in the water sample.

At the initial weight of 0 grams, the COD value is 72.0 mg/L, and the BOD value is 46.7 mg/L. As the weight increases to 2 grams, the COD decreases to 65.0 mg/L, and the BOD decreases to 34.8 mg/L. Further increasing the weight to 5 grams results in a reduction of COD to 32.0 mg/L and BOD to 25.9 mg/L. Finally, at a weight of 10 grams, the COD decreases to 24.0 mg/L, and the BOD reduces to 14.3 mg/L. From this trend, it can be inferred that as more of the substance is added to the water sample, there is a greater reduction in both COD and BOD levels. The substance added likely has properties that aid in the degradation and consumption of the organic and chemical pollutants, resulting in improved water quality.

It's important to note that the specific substance and its mode of action are not mentioned in the provided data. Further analysis and information would be required to determine the nature and effectiveness of the substance in reducing BOD and COD levels. Additionally, water quality standards and regulatory limits should be considered to determine if the achieved reduction is within acceptable limits.

4. Conclusion

This study focused on investigating the potential of using biochar derived from peanut shells (Arachis hypogaea L.) for the reduction of BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) levels in hospital waste. The utilization of biochar as a sustainable and environmentally friendly solution for hospital waste management was explored.

The physicochemical characterization of the peanut shell biochar confirmed its suitability for wastewater treatment applications. The biochar exhibited a high carbon content, as expected from an organic material, along with nitrogen and oxygen, which are essential elements for the degradation of organic pollutants. Through experimental analysis, it was observed that the addition of peanut shell biochar to hospital waste resulted in a substantial reduction in BOD and COD levels over time. As the treatment duration progressed, the organic and chemical pollutants present in the waste were effectively degraded and consumed. This reduction in BOD and COD levels indicates an improvement in the water quality and a decrease in the oxygen-demanding substances. The effectiveness of the reduction varied depending on the dosage of the biochar, with higher dosages leading to more significant reductions in BOD and COD levels. This highlights the importance of optimizing the biochar dosage for efficient wastewater treatment in hospital waste management practices.

The findings of this study contribute to sustainable waste management practices in the healthcare sector by providing an eco-friendly approach to mitigate the environmental impacts associated with hospital waste. The utilization of peanut shell biochar not only offers a cost-effective and environmentally sustainable solution but also adds value to agricultural waste materials. It is worth noting that further research and evaluation are necessary to fully understand the mechanisms responsible for the reduction in BOD and COD levels and to assess the long-term effectiveness and applicability of peanut shell biochar in real-world hospital waste treatment scenarios. Additionally, the potential impact of biochar application on other water quality parameters, such as heavy metal removal and microbial activity, should be explored to ensure comprehensive and sustainable waste management practices. The utilization of biochar from peanut shells shows great promise in reducing BOD and COD levels in hospital waste, offering a viable and eco-friendly solution for the treatment of such waste and contributing to the overall sustainability of healthcare waste management.

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References

Anshary, A., & Napitupulu, M. (2022). Surface Performance of Biochar from Young Coconut Shells (Cocos Nucifera) for Cd2+ Ion Adsorption. International Journal on Advanced Science, Engineering and Information Technology, 12(2), 774.

Cheng, N., Wang, B., Wu, P., Lee, X., Xing, Y., Chen, M., & Gao, B. (2021). Adsorption of emerging contaminants from water and wastewater by modified biochar: A review. Environmental Pollution, 273, 116448.

Chia, C. H., Gong, B., Joseph, S. D., Marjo, C. E., Munroe, P., & Rich, A. M. (2012). Imaging of mineral-enriched biochar by FTIR, Raman and SEM–EDX. Vibrational Spectroscopy, 62, 248–257.

Georgin, J., Dotto, G. L., Mazutti, M. A., & Foletto, E. L. (2016). Preparation of activated carbon from peanut shell by conventional pyrolysis and microwave irradiation-pyrolysis to remove organic dyes from aqueous solutions. Journal of Environmental Chemical Engineering, 4(1), 266–275.

Haitao, Z., Shuwen, H., Tianpeng, L., Xu, Y., Zongyu, L., Shengyang, Z., & Peijuan, W. (2017). Effects of Preparation Conditions and Environmental Conditions on Rice-straw-biochar Adsorption of Urea. DEStech Transactions on Engineering and Technology Research, apetc.

Islam, Md. T., Hyder, A. G., Saenz-Arana, R., Hernandez, C., Guinto, T., Ahsan, M. A., Alvarado-Tenorio, B., & Noveron, J. C. (2019). Removal of methylene blue and tetracycline from water using peanut shell derived adsorbent prepared by sulfuric acid reflux. Journal of Environmental Chemical Engineering, 7(1), 102816.

Komkiene, J., & Baltrenaite, E. (2016). Biochar as adsorbent for removal of heavy metal ions [Cadmium(II), Copper(II), Lead(II), Zinc(II)] from aqueous phase. International Journal of Environmental Science and Technology, 13(2), 471–482.

Krishna, G., Singh, B. K., Kim, E.-K., Morya, V. K., & Ramteke, P. W. (2015). Progress in genetic engineering of peanut (Arachis hypogaea L.)-A review. Plant Biotechnology Journal, 13(2), 147–162.

Liu, J., Wang, Z., Li, H., Hu, C., Raymer, P., & Huang, Q. (2018). Effect of solid state fermentation of peanut shell on its dye adsorption performance. Bioresource Technology, 249, 307–314.

Mahindrakar, K. V., & Rathod, V. K. (2018). Utilization of banana peels for removal of strontium (II) from water. Environmental Technology & Innovation, 11, 371–383.

Malik, A., Napitupulu, M., Napitupulu, N. D., Walanda, D. K., & Anshary, A. (2023). Utilization of Tropical Forest Cacao Dried Leaves for Environment Improvement. International Journal of Design & Nature and Ecodynamics, 18(2), 457–463.

Molinari, A., Guadagnini, L., Marcaccio, M., & Guadagnini, A. (2019). Geostatistical multimodel approach for the assessment of the spatial distribution of natural background concentrations in large-scale groundwater bodies. Water Research, 149, 522–532.

Napitupulu, M., Muhammad Al-Gifary, & Daud K Walanda. (2019). Adsorption of cd(ii) by carbon prepared from peels and stems of kepok banana (musa paradisiaca formatypica). 53(3–4), 387–394.

Napitupulu, M., Walanda, D. K., Natakusuma, Y., Basir, M., & Mahfudz. (2018). Capacity of Adsorption of Cadmium (II) Ion by Bio-charcoal from Durian Barks. Journal of Surface Science and Technology, 34(1–2), 30–36.

Napitupulu, M., Walanda, D. K., & Simatupang, M. (2020). Utilization of red fruit's peel (freycinetia arborea gaudich) as biochar for lead (Pb) adsorption. Journal of Physics: Conference Series, 1434, 012033. https://doi.org/10.1088/1742-6596/1434/1/012033

Nurhasni, Reski Mar'af, & Hendrawati. (2018). Utilization of Peanut Skin (Arachis hipogaea L.) as Adsorbent of Blue Methylene Color Substances. 4(2), 156–167.

Patterson, H. B. W. (2009). Bleaching and Purifying Fats and Oils (2nd ed., pp. 53–67). Elsevier.

Plaimart, J., Acharya, K., Mrozik, W., Davenport, R. J., Vinitnantharat, S., & Werner, D. (2021). Coconut husk biochar amendment enhances nutrient retention by suppressing nitrification in agricultural soil following anaerobic digestate application. Environmental Pollution, 268, 115684.

R C Pongenda, M Napitupulu, & D K Walanda. (2015). Biocharcoal dari biji salak (Salacca edulis) sebagai adsorben terhadap kromium. 4(2), 84–90.

Walanda, D. K., Napitupulu, M., Hamzah, B., & Panessai, K. (2020). The capacity of biocharcoal prepared from sawah lettuce plants (limnocharis flava) as adsorbent of lead ions. Journal of Physics: Conference Series, 1434, 012036.

Wilson, K., Yang, H., Seo, C. W., & Marshall, W. E. (2006). Select metal adsorption by activated carbon made from peanut shells. Bioresource Technology, 97(18), 2266–2270.

Yusuf, A. M., & Tjahjani, S. (2013). Adsorpsi ion Cr(VI) oleh arang aktif sekam padi (adsorption ions of Cr (VI) by active rice husk charcoal). 2(1).

Zakir, M., Raya, M. I., Karim, A., & Santi. (2012). Pemanfaatan energi gelombang ultrasonik dalam adsorpsi ion logam berat Cu(II) pada biosorben karbon aktif dari sekam padi. 5(2), 1–9..