Journal of Academia Vol. 13, Issue 1 (2025) 34 – 42

PERFORMANCE OF ACTIVATED CARBON FROM CASSAVA PEEL FOR THE REMOVAL OF Pb (II) IN Pb SOLUTION

Nur Azzatul Farisya Zurizam, Nor Hafizah Che Ismail*, Faiezah Hashim

School of Applied Chemistry, Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM), Cawangan Perlis, Kampus Arau 02600 Arau, Perlis, Malaysia

**Corresponding author: hafizah477@uitm.edu.my*

Abstract
This study aimed to investigate the potential of cassava peel-activated carbon for the removal of Pb (II) ions from a Pb synthetic solution. Cassava peels are rich in carbohydrates (cellulose and hemicellulose) and lignin, which work well to remove heavy metals. Cassava peel has a high carbon content and a low ash content, and activated carbon may be made from it. Dried cassava peels were carbonised in a muffle furnace at 350°C for one hour and treated with zinc chloride acid ($ZnCl_2$). Activated carbon produced and its physiochemical characteristics, including ash content, iodine number, volatile matter, methylene blue adsorption, moisture content, and pH, were assessed. Results showed that the proximate analysis for the determination of macronutrients of cassava peelings consisted of 77% moisture content, 1% ash content, 2.6 % volatile matter, and 850.43 mg/g iodine number. The result showed that the materials are good precursors for the production of activated carbon and suitable adsorbents for the removal of heavy metals such as Pb (II). The findings of this study will be useful in developing a cost-effective and efficient alternative to activated carbon.

Keywords: Activated carbon, Cassava peels, Heavy metals, Adsorption

Article History:- Received: 8 December 2024; Revised: 29 January 2025; Accepted: 5 February 2025; Published: 30 April 2025

DOI: 10.24191/joa.v13i1.4582

Introduction
Heavy metal pollution is a threat to human health and the environment worldwide. It became more prevalent as industries and human activities have been expanded, such as in the sector of plating and electroplating industry, battery production, pesticides, mining, and dyeing industry. The primary industrial activity that releases heavy metals into the environment has trouble during removal and cleanup. As these heavy metals are not biodegradable and have varying degrees of toxicity, their harmful effects may take a long time to manifest. This is prevalent in cases of closed mines and abandoned, dilapidated mining sites. Because of their lengthy half-lives, the harmful effects of exposure through various channels are amplified over an extended period.

In wastewater bodies, among these heavy metals, Pb (II), lead, a poisonous and nonbiodegradable metal, is highly distributed and principally found in varying amounts. Prolonged exposure to lead particles can potentially induce encephalopathy, cognitive decline, and anaemia (Adekunle et al., 2014) and heighten the chance of developing liver cancer (Sudaryanto, Y. et al., 2006). Due to the toxic implications of this metal, numerous treatment techniques, such as electrodialysis, reverse osmosis, ion exchange, membrane filtration, and solvent extraction, have been documented in the literature as methods to remove these metal ions from wastewater (Núñez-Regueiro, 2010).

However, most of these methods suffer from drawbacks such are high capital, operational costs, and disposal of sludge. Adsorption is the finest option because it is a quick, easy, and inexpensive procedure that does not require complicated equipment to experiment. Adsorption by activated carbon (AC) is a common adsorbent for treating wastewater, and it has been shown to be highly effective in removing heavy metals. However, the high cost of the commercially available AC is a challenge. Hence, a need for alternative, cheaper methods is critical. The search for low-cost and easily available adsorbents has led to the investigation of agricultural waste materials as potential adsorbents as they are readily available, eco-friendly, and have high removal efficiency. Therefore, this study introduced AC prepared from cassava peels to remove lead from the Pb solution.

Cassava peels are rich in carbohydrates (cellulose and hemicellulose) and lignin, which work well to remove heavy metals. They are highly availability and possess high potential to treat wastewater. From an economic point of view, cassava peel as activated carbon is a sustainable alternative compared with conventional treatment methods because it can remove metals to very low concentrations at a low cost. Cassava peel has high carbon and low ash percentage, and these are strong indicators of its use as activated carbon

Methods

Material

The Cassava peels, or Manihotesculenta for this study, were bought at a nearby market in Perlis. The peels were then thoroughly cleaned with distilled water, dried, and crushed. For turning these peels into activated carbons, the procedures for carbonisation/activation were observed. Activated cassava peels were selected over un-actuated ones for this investigation since previous research clearly demonstrated that activation of cassava peels considerably improves their adsorption ability compared to un-actuated ones.

Chemicals and Reagents

In this study, zinc chloride, hydrochloric acid, methylene blue, iodine solution, starch, and 0.1N sodium thiosulphate were used. The study was carried out in Makmal Kimia Star Complex, Uitm Perlis Branch.

Preparation of cassava peel based activated carbon

Cassava peelings were gathered from a nearby garbage facility. The peelings were dried and ground up in the lab after they were transported in distilled water. A predefined amount of the ground-up sample was put into a muffle furnace, which runs at 350°C for 30 to 60 minutes with a constrained supply of air. The Mansfield approach was then used to activate the carbonised material with a minor change, as follows: 250 ml of a 5.5 M $ZnCl2$ solution was soaked with 25 g of the burned sample (Ilaboya, 2013). All ingredients were combined until they formed a paste. After that, the mixture was moved to an evaporating dish and put in a furnace to be heated at 200°C for 30 minutes. Next, the sample was filtered to remove water from the paste. It was cooled to room temperature before being rinsed with distilled water to remove any residual salt. Then, it was dried in the oven at 150°C for one hour before being grounded using a mortar and pestle and sifted through a 100 µm standard Tyler sieve. After that, the activated carbon was evaluated for particle size, moisture content, ash content, volatile matter, and methylene blue number (Ilaboya, 2013). Figures 1 and 2 show the preparation of activated carbon from cassava peel.

Figure 1. Prepared cassava peel sample

Figure 2. Carbonized cassava peel

Characterization of Cassava Peel Activated Carbon

Methylene Blue Number

The maximum quantity of dye adsorbent on 1.0 g of adsorbent was specified as the methylene blue number. One gram of cassava peel activated carbon was exposed to 10.0 ml of 25 mg/l methylene blue solution for 24 hours at room temperature, with the use of intermittent shaking. During filtering using Whatman number one filter paper, the solution was present, and an aliquot was collected for analysis. An atomic adsorption spectrophotometer (AAS) was used to determine the residual concentration of methylene blue. The mass balance equation was used to compute the quantity of methylene blue adsorbed.

Ash Content Determination (AC%)

The ash content of the processed cassava peel-activated carbon was evaluated using the ASTM D2866-94 standard. At 105°C, 1.0 g of cassava peel-activated carbon sample was heated in an oven until it reached a consistent ash weight. The obtained ash was weighted, and the activated carbon's ash content was calculated using the formula below.

$$\mathrm{AC}(\%) = \frac{\text{Ash weight (g)}}{\text{Oven dry weight(g)}} \times 100$$

Volatile Matter Determination (VM%)

The volatile matter content of the processed cassava peel-activated carbon was evaluated by using the ASTM D2866-94 standard. At 105°C, 1.0 g of a cassava peel-activated carbon sample was heated in an oven until a consistent ash weight was achieved. The obtained ash was weighted, and the activated carbon's ash content was calculated using the formula below.

$$\text{VM (\%)} = \frac{\text{Oven dry weight (g)} - \text{Ash weight (g)}}{\text{Oven dry weight (g)}} \times 100$$

Determination of pH

One gram of cassava peel-activated carbon was weighed and transferred to the beaker. Then, 100 ml of distilled water was weighed out, and the mixture was stirred for 1 hour to determine the pH, following the ASTM D3838-80 procedure. Next, a digital pH meter was used to measure the sample. The sample was given time to settle before the pH was determined.

Iodine Number

During this stage, 10 ml of 5% by weight HCl was added to 1 g of cassava peel activated carbon and allowed to boil for 30 seconds to calculate the iodine number. Then, 100 ml of 0.1N iodine solution was added when the solution had reached room temperature. The material was violently shaken and filtered. Using starch as an indicator, 25 ml of the filtrate was titrated against 0.1N sodium thiosulphate. The amount of iodine adsorbed in (mg/g carbon) was then used to determine the iodine number as the residual iodine concentration, following the ASTM D4607-94 procedure.

Moisture Content Determination (MC%)

The moisture content of the processed cassava peel-activated carbon was evaluated using a thermal drying method. One gram of the dried activated carbon sample was weighed and placed in a washed, dried, and weighed crucible. The crucible was placed in an oven and dried at 105°C to constant weight for 1 hour. The percentage moisture content (MC%) was calculated using the formula shown below.

$$\text{MC (\%)} = \frac{\text{Loss in weight on drying}}{\text{Initial weight of sample}} \times 100$$

Result and Discussion

Methylene Blue Number

Methylene blue synthetic dye has many uses in industrial, laboratory, and medical procedures. Due to its enormous surface, activated carbon, a porous carbon, is frequently used for adsorption and purification. An intriguing use involves mixing methylene blue with activated carbon made from cassava peel. The outer covering of the cassava tuber, known as the cassava peel, can be transformed into activated carbon, which can be used in various processes including eliminating impurities from water and other solutions. Methylene blue experiences adsorption, or the adherence of molecules or particles to the surface of the activated carbon, when it comes into contact with impurities. Methylene blue can be effectively removed from a solution due to the porous nature of activated carbon, which offers various places for molecules to attach. The methylene blue sample was from the MB and activated carbon filtration. Five concentrations (50, 75, 100, 125, and 150 ppm) were prepared from a stock solution. After that, the five concentrations were mixed with nitric acid into a 50ml volumetric flask until it reached the calibration mark. The solutions were shaken vigorously, and the samples were used to determine the residue concentration of the MB solutions. The adsorptions of MB in five sample concentrations were determined using the AAS instrument. An analytical tool used for determining the concentration of individual elements in a sample is an atomic absorption spectrometer (AAS). It works based on the absorption spectroscopy concept, which entails measuring the amount of light absorbed by atoms in the gas phase.

Table 1. AAS values of the various standard concentration

Standard	Standard Conc. (mg/L)	Mean signal (Abs)	Entered Conc. (mg/L)	Calculated Conc. (mg/L)
Blank	0.00	0.000	0	0.000
Standard 1	50	0.137	50.0	32.632
Standard 2	75	0.332	75.0	79.046
Standard 3	100	0.427	100.0	101.822
Standard 4	125	0.540	125.0	128.684
Standard 5	150	0.617	150.0	147.197

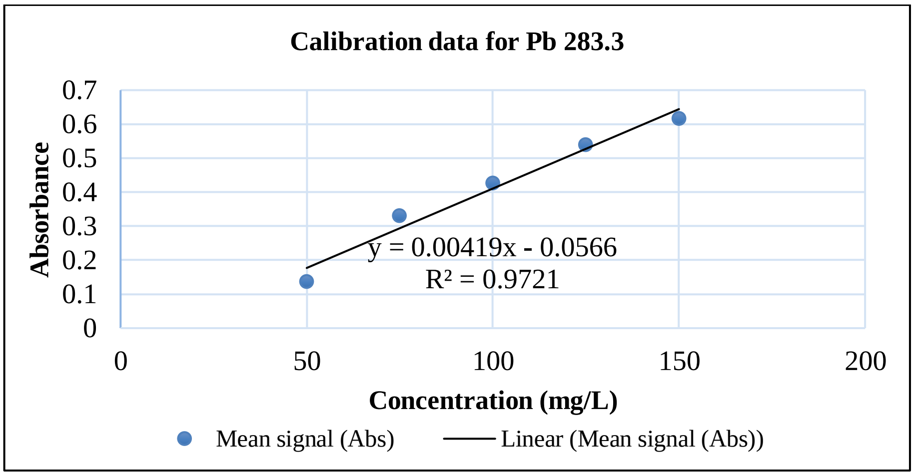


Figure 3. AAS calibration data for Pb

Based on the result, the calibration curve was used to determine the concentration of the element in the sample based on the absorbance reading. The standard solution usually contains a concentration range that corresponds to the anticipated concentrations in the unidentified samples. Next, using the AAS instrument, the absorbance of each standard solution at the precise wavelength that corresponds to the element's absorption peak was determined. Once the absorbance values are recorded, these data points are shown on a graph with concentration on the x-axis and absorbance on the y-axis. The linearity of the calibration curve can be verified by analysis, and the significant parameters can be determined. The slope of the calibration curve represents the molar absorptivity or the sensitivity of the AAS method for the analysed elements. The slope is typically determined through linear regression analysis. Table 2 shows the result of the sample on AAS.

Table 2. AAS sample data for Pb 283.3

Sample Conc. (mg/L)	Sample Conc. (mg/L)
0.168	0.168
0.153	0.153
0.014	0.014

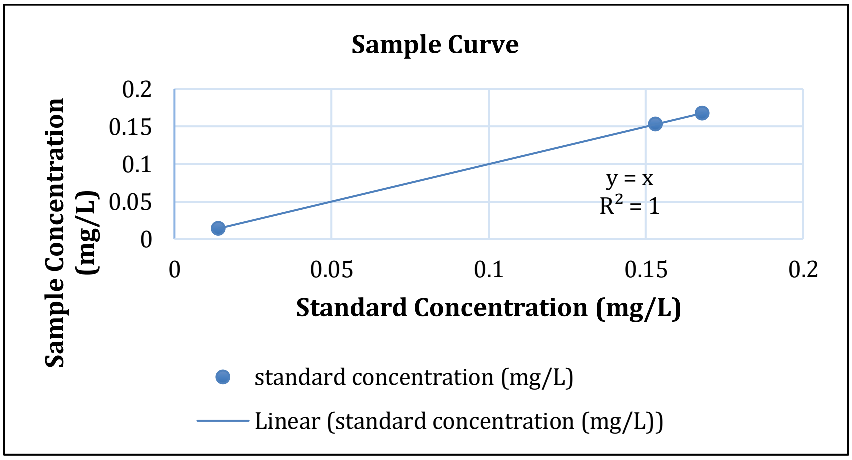


Figure 4. AAS sample curve

Ash Content Determination (AC%)

Ash content is an important index of the quality of activated carbon. The lower the ash content, the better the adsorption performance of activated carbon. Ash concentration can also determine the purity and quality of the activated carbon product. Ash content is calculated by weighing a representative sample of activated carbon, burning the organic material on it at high temperatures in a furnace, and then weighing the residue of ash. By dividing the weight of the ash by the weight of the initial sample and multiplying it by 100, the ash content is estimated as a percentage.

Figure 5. Activated carbon after heated at 500°C

The mass of the crucible before and after heating was compared, and the ash content of the powdered carbon was calculated to be 1%. Therefore, this result indicates that the used powdered carbon complies with the quality standards of activated carbon according to the Indonesian National Standard, SNI (06 - 3730 - 1995), which requires the ash content of powdered carbon to be less than 10%.

Volatile Matter Determination (VM%)

The adsorption capacity of activated carbon depends on its physical and chemical properties, including the presence of volatile matter. Removing volatile matter is crucial for optimising the adsorption capacity and stability of activated carbon in various applications. The result of volatile matter was 2.6%, and the volatile matter content value was lower than the values reported by Takele Sime et al. while studying the activated carbon from Arrowroot (Canna indica) Stem. This indicates that cassava peel AC may have better removal potential due to its lower volatile matter. This is because high levels of volatile matter can lead to excessive outgassing, trapped impurities, and loss of adsorption capacity.

pH
Activated carbon can change the pH of a solution when it comes into contact with it—due to the porosity and wide surface area of adsorption ions from the solution that are acidic, lowering their concentration and perhaps raising the pH of the mixture. Meanwhile, if the solution contains basic species, the activated carbon can adsorb these ions, lowering the concentration of OH- and perhaps lowering the pH of the solution. The pH obtained was 6.98, which is the recommended pH before being used as an adsorbent.

Iodine Number Determination
The iodine number determines the adsorption effectiveness of activated carbon made from cassava peel. It shows how much iodine can adsorb onto the surface of activated carbon for every unit of mass. After titration with sodium thiosulphate, the colour changes from deep brown to colourless, as seen in Figure 6. By using the formula, the iodine number calculated was 850.431 mg/g per 1.0 g of activated carbon. This result signifies the development of micropores on the adsorbent surface, thus increasing their adsorption capacity since the adsorption capability of activated carbon increases with increasing iodine number.

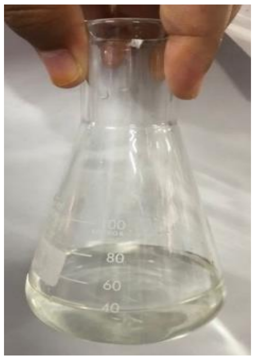
Before titration with 0.1N sodium thiosulphate	After titration with 0.1N sodium thiosulphate
	

Figure 6. Before and after titration with 0.1N sodium thiosulphate

Moisture Content Determination (MC%)
Moisture content significantly impacts the characteristics and uses of activated carbon made from cassava peel. Therefore, with a very low moisture level, the activated carbon might become excessively brittle and breakable. In this study, the calculated moisture content was 77%. This result signifies that activated carbon from cassava peel has a higher moisture content, which can lower its adsorption capacity.

Conclusion
The result indicates the proximate analysis for the determination of macronutrients of cassava peelings consists of 77% moisture content, 1% ash content, 2.6 % volatile matter, and 850.43 mg/g iodine number. Based on the result, this study has demonstrated that activated carbon produced from cassava peel could be one of the potential activated carbon in removing Pb(II).

Acknowledgement/Funding
The authors would like to thank Universiti Teknologi MARA Perlis Branch, Arau Campus for the support towards this project.

Author Contribution

Nur Azzatul Farisya – Conceptualization, data duration, formal analysis, methodology, writing – original draft;
Nor Hafizah – Supervision, Writing – review & editing.
Faiezah Hashim – Supervision, Writing – review & editing.

Conflict of Interest

Authors declare no conflict of interest.

References

Adekunle, A.S.; Oyekule, J.A.O.; Baruwa, S.O; Ogunfowokan, O.A. and Ebenso, E.E. (2014). Speciation study of the heavy metals in commercially available recharge cards coatings in Nigeria and the health implications. Toxicology Reports, 1: 243-251

Ahmad, A., & Azam, T. (2019). Water purification technologies. In *Elsevier eBooks* (pp. 83–120).

Astuti, W., Hidayah, M., Fitriana, L., Mahardhika, M. A., & Irchamsyah, E. F. (2020). Preparation of activated carbon from cassava peel by microwave-induced H3PO4 activation for naphthol blue-black removal. *AIP Conference Proceedings*. 2243, 020003. https://doi.org/10.1063/5.0001464

Aulia, S., Wijayanti, A., & Hadisoebroto, R. (2021). The effect of mixing speed and contact time on dye removal using Cassava Peel adsorbents. *IOP Conference Series: Earth and Environmental Science*, *737*(1), 012013.

Bożęcka, A., Orlof-Naturalna, M., & Kopeć, M. (2021). Methods of Dyes Removal from Aqueous Environment. *Journal of Ecological Engineering*, *22*(9), 111–118. https://doi.org/10.12911/22998993/141368

Budianto, A., Kusdarini, E., Effendi, S. S. W., & Aziz, M. (2019). The Production of Activated Carbon from Indonesian Mangrove Charcoal. *IOP Conference Series: Materials Science and Engineering*, *462*, 012006. https://doi.org/10.1088/1757-899x/462/1/012006

Das, D., Samal, D. P., & Bc, M. (2015). Preparation of Activated Carbon from Green Coconut Shell and its Characterization. *Journal of Chemical Engineering & Process Technology*, *06*(05), 248. https://doi.org/10.4172/2157-7048.1000248

De Jesús Soria Aguilar, M., Martínez-Luévanos, A., Sánchez-Castillo, M. A., Pedroza, F. R. C., Toro, N., & Narváez-García, V. M. (2021). Removal of Pb(II) from aqueous solutions by using steelmaking industry wastes: Effect of blast furnace dust's chemical composition. Arabian Journal of Chemistry, 14(4), 103061. https://doi.org/10.1016/j.arabjc.2021.103061

Egbeocha, C.C, & N.A.A Okereke (2016). A Review on Performance of Cassava Peeling Machines in Nigeria, 2(1), 140–168.

Gautam, R. K., Mudhoo, A., Lofrano, G., & Chattopadhyaya, M. C. (2014). Biomass-derived biosorbents for metal ions sequestration: Adsorbent modification and activation methods and adsorbent regeneration. Journal of Environmental Chemical Engineering, 2(1), 239–259. https://doi.org/10.1016/j.jece.2013.12.019

Hashem, F. S., & Amin, M. S. (2016). Adsorption of methylene blue by activated carbon derived from various fruit peels. Desalination and Water Treatment, 57(47), 22573–22584. https://doi.org/10.1080/19443994.2015.1132476

Hock, P. E., & Zaini, M. a. A. (2018). Activated carbons by zinc chloride activation for dye removal – a commentary. Acta Chimica Slovaca, 11(2), 99–106. https://doi.org/10.2478/acs-2018-0015

Ilaboya, I. R., Oti, E., Ekoh, G., & Umukoro, L. O. (2013). Performance of Activated Carbon from Cassava Peels for the Treatment of Effluent Wastewater. Iranica Journal of Energy and Environment, 4(4), 361–375.doi: 10.5829/idosi.ijee.2013.04.04.08

Ismanto, A. E., Wang, S., Soetaredjo, F. E., & Ismadji, S. (2010). Preparation of capacitor's electrode from cassava peel waste. Bioresource Technology, 101(10), 3534–3540. https://doi.org/10.1016/j.biortech.2009.12.123

Johnson, C. H. (2014). Advances in pretreatment and clarification technologies. In Elsevier eBooks (pp. 60–74). https://doi.org/10.1016/b978-0-12-382182-9.00029-3

Kayiwa, R., Kasedde, H., Lubwama, M., & Kirabira, J. B. (2021). The potential for commercial scale production and application of activated carbon from cassava peels in Africa: A review. Bioresource Technology Reports, 15, 100772. https://doi.org/10.1016/j.biteb.2021.100772

Králik, M. (2014). Adsorption, chemisorption, and catalysis. Chemical Papers, 68(12), 1625–1638. https://doi.org/10.2478/s11696-014-0624-9

Ma, P., Ma, M., Wu, J., Qian, Y., Wu, D., & Zhang, X. (2019). The effect of plastic on performance of activated carbon and study on adsorption of methylene blue. Journal of Materials Research, 34(17), 3040–3049. https://doi.org/10.1557/jmr.2019.193

Maulina, S., & Iriansyah, M. (2018). Characteristics of activated carbon resulted from pyrolysis of the oil palm fronds powder. IOP Conference Series, 309, 012072. https://doi.org/10.1088/1757-899x/309/1/012072

Moreno–Piraján, J. C., & Giraldo, L. (2010). Adsorption of copper from aqueous solution by activated carbons obtained by pyrolysis of cassava peel. Journal of Analytical and Applied Pyrolysis, 87(2), 188–193. https://doi.org/10.1016/j.jaap.2009.12.004

Núñez-Regueiro, M. (2010). Fusing visual and clinical information for lung tissue classification in HRCT data. HAL (Le Centre Pour La Communication Scientifique Directe), 50(1), 13–21 https://doi.org/10.1016/j.artmed.2010.04.006

Omotosho, O. A., & Sangodoyin, A. Y. (2013). Production and utilization of cassava peel activated carbon in treatment of effluent from cassava processing industry. Water Practice & Technology, 8(2), 215–224. https://doi.org/10.2166/wpt.2013.023

Ospino-Orozco, J., Parra-Barraza, J., Cervera-Cahuana, S., Coral-Escobar, E. E., & Vargas-Ceballos, O. (2020). Activated carbon from cassava peel: A promising electrode material for supercapacitors. Revista Facultad De Ingenieria Universidad De Antioquia, 842(102), 88–95. https://doi.org/10.17533/udea.redin.20200803

Owamah, H. (2013). Biosorptive removal of Pb (II) and Cu (II) from wastewater using activated carbon from cassava peels. Journal of Material Cycles and Waste Management, 16(2), 347–358. https://doi.org/10.1007/s10163-013-0192-z

Qasem, N. A., Mohammed, R. H., & Lawal, D. U. (2021). Removal of heavy metal ions from wastewater: a comprehensive and critical review. Npj Clean Water, 4(1), 36. https://doi.org/10.1038/s41545-021-00127-0

Rashed, M. N. (2013). Adsorption Technique for the Removal of Organic Pollutants from Water and Wastewater. In InTech eBooks. (pp. 240). https://doi.org/10.5772/54048

Sudaryanto, Y., Hartono, S. B., Irawaty, W., Hindarso, H., & Ismadji, S. (2006). High surface area activated carbon prepared from cassava peel by chemical activation. Bioresource Technology, 97(5), 734–739. https://doi.org/10.1016/j.biortech.2005.04.029

Utsev, J.T. (2020). Journal of Materials and Environmental Science. www.jmaterenvironsci.com.

Widiarto, S., Pramono, E., Suharso, Rochliadi, A., & Arcana, I. M. (2019). Cellulose Nanofibers Preparation from Cassava Peels via Mechanical Disruption. Fibers, 7(5), 44. https://doi.org/10.3390/fib7050044

Wołowiec, M., Komorowska-Kaufman, M., Pruss, A., Rzepa, G., & Bajda, T. (2019). Removal of Heavy Metals and Metalloids from Water Using Drinking Water Treatment Residuals as Adsorbents: A Review. Minerals, 9(8), 487. https://doi.org/10.3390/min9080487