Proceeding of International Joint Conference on UNESA
Homepage : https://proceeding.unesa.ac.id/index.php/pijcu
e-ISSN : 3032-3762

PIJCU, Vol. 3, No. 1, December 2025
Page 1-8

Utilization of Biomass Extraction Waste for Filter Cartridge Production to Improve Water Quality Based on Total Alkalinity and Total Hardness Parameters

Rachmawati[1*], Ahmad Misbakhus Sururi[1], Idah Diana Wati[1], Ani Sa'adah[2]
[1*] Department of Chemistry, Faculty of Mathematics and Natural Sciences Universitas Negeri Surabaya, Surabaya, Indonesia
[2]Department of Science Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya

Keywords:
Biomass waste
Water quality
Total alkalinity
Total Hardness

ABSTRACT

Biomass waste from extraction consists of waste with a relatively high carbon content derived from cellulose, hemicellulose, and lignin. Despite its potential for conversion into activated carbon to enhance water quality, this waste is rarely utilized. This research aims to investigate the use of biomass waste as activated carbon to improve water quality, specifically focusing on total alkalinity and total hardness metrics. The study employed charcoal produced from previous research, which was applied to water samples collected from Universitas Negeri Surabaya. Alkalinity was measured using acidimetric titration, while hardness was assessed through complexometric titration. The results indicate that Unesa bozem water has an alkalinity level of 240.09 mg/L $CaCO_3$ (high) and a hardness value of 214.71 mg/L $CaCO_3$ (hard). The use of the filter led to a significant reduction in these metrics, with total alkalinity decreasing to 110.33 mg/L $CaCO_3$ (ideal) and hardness reduced to 117.63 mg/L $CaCO_3$ (slightly hard). These findings demonstrate that the activated charcoal produced effectively decreases both total alkalinity and total hardness. Additionally, the production of filter paper from biomass waste charcoal after extraction may be optimized by modifying the activation process to produce different forms of activated charcoal with improved absorption capacity.

INTRODUCTION

Water is a fundamental element of life on Earth. Water constitutes over 71% of the Earth's surface, with seas and oceans comprising the majority of the water volume (nearly 96.5%). Minor quantities are present as groundwater (1.7%), within glaciers and the ice sheets of Antarctica and Greenland (1.7%), and in the sky as vapor, clouds (comprising ice and liquid water suspended in the air), and precipitation (0.001%). Water perpetually moves through the hydrological cycle, encompassing evaporation, transpiration (evapotranspiration), condensation, precipitation, and runoff, which generally concludes in the seas (Douville et al., 2021). The accessibility of potable water continues to be a significant global issue. Water is deemed clean if it is visually clear. It possesses no odor. It lacks flavor. Clean water is characterized as water that satisfies health standards for consumption, bathing, washing, and similar uses (Ali et al., 2018). Water quality pertains to the understanding of the qualitative and quantitative composition of chemical substances, physical characteristics, and microorganisms found in water. Water quality measures indicate the suitability of water for its intended purposes and needs (Manna & Biswas, 2023). Water quality metrics vary among distinct types of water. Water quality criteria for bathing and sanitation are distinct from those for potable water. Likewise, water utilized for industrial applications, recreational swimming pools, aquaculture, agricultural irrigation, and the range from home to industrial waste demonstrates varying quality standards. Parameters that define clean water include pH, turbidity, total dissolved solids (TDS), and color, as illustrated in Table 1, in accordance with ISO 10500:2012 for potable water (ISO, 2012). he necessity for potable water is imperative in a world where water problems are often encountered. This necessitates novel advancements in water purification to provide potable water for everyday consumption. The developing breakthrough is the utilization of activated charcoal for water purification.

Characteristics	Desirable limit	Permissible limit
Essential Characteristics		
Colour, Hazen Units, Max	5	25
Odour	Unobjectionable	-
Taste	Agreeable	-
Turbidity, NTU, Max	5	10
PH value	6.5 to 8.5	-
Total Hardness (as $CaCo_3$), mg/l, Max	300	600
Iron (as Fe), mg/l, Max	0.3	1.0
Chlorides (as Cl), mg/l, Max	250	1,000
Residual free chlorine, mg/l, Max	0.2	-
Desirable Characteristics		
Dissolved solids, mg/l, Max	500	2,000
Calcium as (Ca), mg/l, Max	75	200
Magnesium (as Mg), mg/l, Max	30	75
Copper (as Cu), mg/l, Max	0.05	1.5

Table 1. ISO 10500:2012 (Drinking Water).

Water quality is evaluated according to specified environmental parameters. The cited standard conditions pertain to water that is appropriate for its designated function and purpose. Any variation from conventional conditions results in the classification of water as contaminated and inappropriate for its intended use (Mohammadpour et al., 2024). Contaminated situations are defined by water quality that diverges from set standards, potentially resulting in detrimental effects on the environment and its vicinity (Sudsandee et al., 2017). his study used total alkalinity and total hardness as the primary reference metrics. Total hardness refers to the cumulative concentration of calcium and magnesium ions present in water in the form of carbonate. This overall hardness influences water quality. Increased water hardness impedes foaming and may lead to health issues, particularly affecting the liver and kidneys (Bykowska-Derda et al., 2023; Liu et al., 2022). Total alkalinity is associated with total hardness, defined as the quantity of alkaline compounds that can neutralize acid, evaluated in terms of calcium carbonate content. This alkalinity is crucial as it functions as a pH buffer, ensuring that the pH remains stable and does not fluctuate easily (Liu et al., 2022). ISO 10500:2012 stipulates that the allowable total hardness and total alkalinity of clean water must not exceed 600 mg/L as $CaCO_3$. Given the previously outlined backdrop, the researcher aims to innovate a straightforward water filtration device. Previous research indicates that activated charcoal derived from extraction residue waste exhibits optimal absorption capabilities for heavy metals such as Fe, Pb, and Cu (Rachmawati et al., 2024). Consequently, this study aims to develop a prototype based on prior findings to enhance water quality concerning total alkalinity and total hardness parameters.

RESEARCH METHOD

Water Sampling

The water samples utilized were Unesa bozem water samples (Ketintang boozem with sampling coordinates: -7.314088302706351, 112.7261878220625), located on the Ketintang Campus of Unesa Surabaya. The water samples utilized for the assessment were initially filtered to evaluate the total alkalinity and total hardness levels.

Filtration using Catridge

Unfiltered soil water samples were processed through pre-fabricated cartridges. The cartridges comprised activated carbon cartridges sourced from prior research and cartridges with 1 μm filters. Activated carbon from prior study was produced using chemical activation, wherein biomass waste was burned and activated using NaOH as a delignification agent and HCl as an activator to enhance porosity and dissolve metals (Rachmawati et al., 2024). The initial 10 mL of filtrate was utilized to rinse the Erlenmeyer flask and subsequently discarded. The filtrate was subsequently collected for the assessment of total alkalinity and total hardness.

Figure 1. The Catridge Filter with Activated Charcoal

Alkalinity Assay

Total alkalinity was assessed titrimetrically via acidimetry with a 0.05 N H_2SO_4 secondary standard. The standardization of H_2SO_4 was conducted using Na_2CO_3 that had been subjected to heating at 275 °C for 2 hours. The procedure commenced with the pipetting of a 10 mL sample, followed by the addition of phenolphthalein (PP) indicator. Titration with an acid standard continued until a color transition from pink to colorless was observed, with the corresponding volume noted as alkalinity P (phenolphthalein). Subsequently, methyl orange indicator was introduced, and titration resumed with the acid standard until a color change from yellow to orange was detected, with the volume recorded as alkalinity T. The test was conducted in triplicate, and total alkalinity was determined using the following equation:

$$T_{alkalinity} \text{as } CaCO_3 (mg/L) = \frac{N_{acid} \times V_{acid} \times 5000}{V_{sample}}$$

Hardeness Assay

The total hardness test was conducted titrimetrically by complexometry with a secondary standard of 0.01 M Na_2EDTA. The standardization of Na_2EDTA was performed using $CaCO_3$ that had been heated at 110 °C for 2 hours. The test commenced with the volumetric pipetting of a 10 mL sample, followed by the addition of 10 mL of pH 10 buffer solution, 10 mL of 10% hydroxylamine HCl solution, and 10 mL of 5% triethanolamine. The indicator employed was Eriochrome Black T (EBT) (1% in ethanol); the endpoint of the titration was signified by a color transition from pink to blue. The test was conducted in triplicate, and the total hardness was determined using the following equation:

$$\text{Hardness as } CaCO_3 (mg/L) = \frac{M_{Na_2EDTA} \times V_{Na_2EDTA} \times 50000}{V_{sample}}$$

RESULTS AND DISCUSSION

Laboratories serve as venues for scientific training employed in diverse scientific and engineering endeavors (Sulman & Irawan, 2016). Research and practical activities produce considerable waste potential. Organic waste resulting from maceration is a type of trash that is infrequently examined and utilized. This study is a continuation in which charcoal derived from prior research is utilized as a filter for the adsorption of Unesa Ketintang's bozem water samples, focusing on total alkalinity and total hardness characteristics. The result on Figure 2 and Table 2 showed that activated charcoal synthesized from biomass waste can improve the quality of water on alkalinity and hardness parameter.

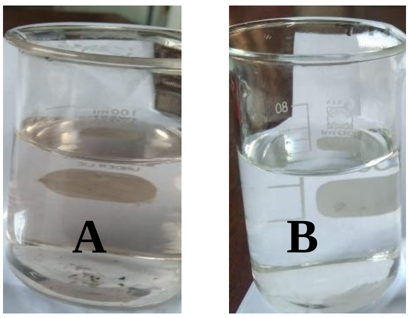

Figure 2. (A) Water Before Treatment; (B) Water After Treatment.

Table 2. Result of Total Alkalinity and Total Hardness.

Parameter	Before Treatment	After Treatment

Total Alkalinity (mg/L $CaCO_3$)	241.08	239.10	240.09	108.68	110.66	111.65
Average		240.09			110.33	
			Reduced 54.05%			
Total Hardness (mg/L $CaCO_3$)	214.87	214.87	214.39	118.08	117.11	117.60
Average		214.71			117.60	
			Reduced 45.23%			

Alkalinity refers to water's capacity to resist acidity. Drinking water generally contains 20-200 mg/L as $CaCO_3$ (Liu et al., 2022); The findings showed on Table 2 indicated that Unesa's water had an alkalinity of 240.09 mg/L, which could be diminished to 110.33 mg/L, deemed acceptable for potable use. Total alkalinity was assessed using acidimetric titration using an acid standard. It can be defined as the quantitative ability of an aqueous medium to react with hydrogen ions to pH 8.3 (phenolphthalein alkalinity) and thereafter to pH 3.7 (total alkalinity or methyl orange alkalinity) (Ahmad et al., 2024). The reaction in this examination is:

$$CO_3{}^{2-} + H^+ \rightleftharpoons HCO_3{}^- \quad \text{(pH 8.3)}$$

$$HCO_3{}^- + H^+ \rightleftharpoons H_2CO_3 \quad \text{(pH 8.3 to 3.7)}$$

Tamanna Kabir et al., 2018 specifically showed alkalinity reduction from 74 to 22 mg/L of $CaCO_3$, while Nudžejma Jamaković et al., 2019 noted that activated charcoal removes carbonates very well (Jamaković et al., 2019; Kabir et al., 2018). Hatuwal et al., (2025) further supported these findings by demonstrating activated charcoal's ability to significantly improve water quality parameters. The mechanism works through adsorption, where the charcoal's porous structure captures and removes alkaline compounds. Adejumobi et al. (2022) further confirmed this capability by reducing water pH from 9.94 to 7.92, bringing water closer to neutral levels.

Hardness is the cumulative assessment of water hardness resulting from the presence of calcium and magnesium metals, which contribute to water's hardness (Divya et al., 2025). Water is classified as hard when its hardness exceeds 120 mg/L $CaCO_3$; conversely, it is considered soft if the hardness is below 60 mg/L. The findings indicate that Unesa's bozem water is classified as extremely hard water (> 180 mg/L) and can be diminished to a moderately hard category (60-120 mg/L). This test relies on the complexometric reaction between Na_2EDTA and the metals Ca and Mg inside the sample matrix. EDTA will chelate calcium and magnesium in the sample, forming a stable compound. The utilized indicator is the EBT indicator, which forms an unstable wine-red compound with calcium and magnesium (Boyd, 2015; Liang et al., 2023). EDTA-chelated Ca and Mg will liberate EBT, revealing its native purplish-blue hue. The response process is outlined as follows:

$$M^{2+} + EBT \rightarrow [M - EBT] \text{ (wine red unstable complex)}$$

$$[M - EBT] + EDTA \rightarrow [M - EDTA] + EBT \text{ (blue color)}$$

Note: M is the metal ion Ca^{2+} or Mg^{2+}

Activated charcoal effectively reduced water hardness by approximately 45.2% in this case, from 214.71 mg/L to 117.60 mg/L. Multiple studies confirm activated charcoal's potential as an adsorbent for calcium and magnesium ions causing water hardness. For instance, Mustaqim et al. (2021) demonstrated coffee grounds activated charcoal could reduce water hardness from 565.17 mg $CaCO_3$/L to 56 mg $CaCO_3$/L. Yanti et al. (2023) found peanut shell activated charcoal could remove up to 88.91% of magnesium ions. On Muljadi report, active carbon reduces water hardness from 14.2 mg/L to 5.6 mg/L (upstream) and from 16.48 mg/L to 6.4 mg/L (downstream) (Muljadi et al., 2021). The effectiveness varies based on charcoal source, contact time, and specific water conditions, but the consistent theme is activated charcoal's potential as a water softening technique. The results suggest that activated charcoal derived from prior research may serve as an effective agent for enhancing water quality, particularly for total hardness and total alkalinity. A 54.05% decrease in alkalinity and a 45.23% decrease in hardness signify a substantial reduction in the Unesa Ketintang beverage water. The reduction in alkalinity and water hardness is facilitated by the adsorption of activated charcoal, which binds carbonate and bicarbonate in water. The primary method is chemisorption, wherein metal ions Ca^{2+} and Mg^{2+} and alkali compounds are chemically affixed to the carbon surface (Amosa, 2016). Surface functional groups are essential, as oxygen-containing groups enable binding via cation exchange and direct interaction (Mosley et al., 2015). Physical adsorption in micropores also helps, although chemisorption dominates the process. Studies indicate that bifunctional activated carbon possesses a substantial surface area and ion exchange capabilities, with alkalinity and hardness adsorption conforming to the Langmuir isotherm model and pseudo-second-order kinetics, suggesting that chemisorption is the predominant process (Amosa, 2016). Activated carbon efficiently eliminates carbonate from water (Jamaković et al., 2019), however research involving strong bases suggests that hydroxide ions interact with acidic oxidized groups on the carbon surface. Additional research is required to elucidate the potential of activated carbon produced from biomass waste.

CONCLUSION

Based on the research results, it can be concluded that the activated charcoal obtained has the potential as an alkalinity reducing agent (54.05% reduction) and hardness (45.23%). The alkalinity of Unesa bozem water has an initial value of 240.09 mg/L $CaCO_3$ and is treated with charcoal chips to 110.33 mg/L $CaCO_3$; while the hardness has an initial value of 214.71 mg/L $CaCO_3$ and becomes 117.60 mg/L $CaCO_3$. Further research can be conducted to identify the potential and develop activated charcoal from waste as a larger-scale water quality improving agent.

ACKNOWLEDGEMENTS (OPTIONAL)

The researcher would like to thank Unesa for providing the research opportunity with contract number B/40078/UN38.III.1/LK.04.00/2025.

REFERENCES

Adejumobi, M. A., Olaoye, R. A., Adebayo, T. B., & Onofua, O. E. (2022). Quality Minimization of Agricultural Drainage Water for Irrigation Water Reuse Using

Coconut Shell Activated Carbon. *Archives of Current Research International*, 34–44. https://doi.org/10.9734/acri/2022/v22i530291

Ahmad, M., Ahmad, A., Omar, T. F. T., & Mohammad, R. (2024). Current trends of analytical techniques for total alkalinity measurement in water samples: A review. *Critical Reviews in Analytical Chemistry*, *54*(8), 2734–2744.

Ali, F., Lestari, D. L., Putri, M. D., & Azmi, K. N. (2018). Identification of the characteristics and patterns of clean water consumption at the household level. *Civil Engineering*, *9*(7), 1–12.

Amosa, M. K. (2016). Sorption of water alkalinity and hardness from high-strength wastewate r on bifunctional activated carbon: process optimization, kinetics and equilibrium studies. *Environmental Technology*, *37*(16), 2016–2039. https://doi.org/10.1080/09593330.2016.1139631

Boyd, C. E. (2015). Total hardness. In *Water Quality: An Introduction* (pp. 179–187). Springer.

Bykowska-Derda, A., Spychala, M., Czlapka-Matyasik, M., Sojka, M., Bykowski, J., & Ptak, M. (2023). The Relationship between Mortality from Cardiovascular Diseases and Total Drinking Water Hardness: Systematic Review with Meta-Analysis. *Foods*, *12*(17), 3255.

Divya, M. P., Krishnamoorthi, S., Ravi, R., Jenner, V. G., Baranidharan, K., Raveendran, M., & Hemalatha, P. (2025). Preparation and characterization of activated carbon from commercially important bamboo species in north eastern India. *Advances in Bamboo Science*, *11*, 100148. https://doi.org/https://doi.org/10.1016/j.bamboo.2025.100148

Douville, H., Raghavan, K., Renwick, J., Allan, R. P., Arias, P. A., Barlow, M., Cerezo-Mota, R., Cherchi, A., Gan, T., & Gergis, J. (2021). *Water cycle changes*.

Hatuwal, S., Aryal, G., & Giri, J. (2025). Efficacy of Activated Charcoal Prepared from Livistona chinensis Seeds for Water Purification. *Journal of Nepal Chemical Society*, *45*(2), 1–10. https://doi.org/10.3126/jncs.v45i2.82914

ISO. (2012). *ISO 10500: Drinking water — Specification*.

Jamaković, N., Karahmet, E., & Varešić, B. (2019). Assessment of Activated Charcoal Efficiency with Filter Paper in the W ater Purification Process. In *Lecture Notes in Networks and Systems* (pp. 758–771). Springer International Publishing. https://doi.org/10.1007/978-3-030-18072-0_87

Kabir, T., Hasan, M. S., & Das, P. (2018). *Applicability of Activated Carbon Filtration in Surface Water Treatmen t*.

Liang, W., Wang, X., Zhang, X., Niu, L., Wang, J., Wang, X., & Zhao, X. (2023). Water quality criteria and ecological risk assessment of lead (Pb) in China considering the total hardness of surface water: A national-scale study. *Science of The Total Environment*, *858*, 159554.

Liu, Q., Zhuang, Y., Zhang, Y., Qi, Z., Edwards, M. A., & Shi, B. (2022). Stability of cement mortar lining in drinking water supply pipelines under different hardness and alkalinity conditions. *ACS ES&T Water*, *2*(12), 2519–2527.

Manna, A., & Biswas, D. (2023). Assessment of drinking water quality using water quality index: a review. *Water Conservation Science and Engineering*, *8*(1), 6.

Mohammadpour, A., Gharehchahi, E., Gharaghani, M. A., Shahsavani, E., Golaki, M., Berndtsson, R., Khaneghah, A. M., Hashemi, H., & Abolfathi, S. (2024). Assessment of drinking water quality and identifying pollution sources in a chromite mining region. *Journal of Hazardous Materials*, *480*, 136050.

Mosley, L. M., Willson, P., Hamilton, B., Butler, G., & Seaman, R. (2015). The capacity of biochar made from common reeds to neutralise pH and re move dissolved metals in acid drainage. *Environmental Science and Pollution Research*, *22*(19), 15113–15122. https://doi.org/10.1007/s11356-015-4735-9

Muljadi, M., Samun, S., & Rusdiansyah, R. (2021). *PENENTUAN KONSTANTA FREUNDLICH PADA PENURUNAN KESADAHAN AIR DENGAN MENGGUNAKAN KARBON AKTIF*. https://doi.org/10.20961/EKUILIBRIUM.V3I2.49629

Mustaqim, A. K., Sutanto, S., & Syahputri, Y. (2021). COFFEE GROUND ACTIVATED CHARCOAL AND ITS POTENTIAL AS AN ADSORBENT OF Ca2+ AND Mg2+ IONS IN REDUCING WATER HARDNESS. *Helium: Journal of Science and Applied Chemistry*, *1*(2), 42–45. https://doi.org/10.33751/helium.v1i2.4537

Rachmawati, R., Wati, I. D., & Sa'adah, A. (2024). *Production of Activated Charcoal from Natural Material Extraction Laboratory Waste Residue as an Effort for Laboratory Waste Utilization and Reduction, and Heavy Metal Absorption Activities BT - Proceedings of the International Joint Conference on Scienc*. 32–38. https://doi.org/10.2991/978-94-6463-626-0_5

Sudsandee, S., Tantrakarnapa, K., Tharnpoophasiam, P., Limpanont, Y., Mingkhwan, R., & Worakhunpiset, S. (2017). Evaluating health risks posed by heavy metals to humans consuming blood cockles (Anadara granosa) from the Upper Gulf of Thailand. *Environmental Science and Pollution Research*, *24*(17), 14605–14615. https://doi.org/10.1007/s11356-017-9014-5

Sulman, L., & Irawan, J. (2016). Pengelolaan Limbah Kimia di Laboratorium Kimia PMIPA FKIP UNRAM. *Jurnal Pijar Mipa*, *11*(2).

Yanti, W., Sosidi, H., Indriani, Prismawiryanti, Puspitasari, D. J., Mirzan, M., Abdul Rahim, E., & Irmawati Inda, N. (2023). Pemanfaatan Karbon Aktif Kulit Kacang Tanah untuk Menurunkan Kadar Ion logam Ca2+ dan Mg2+ dalam Air. *KOVALEN: Jurnal Riset Kimia*, *9*(2), 157–163. https://doi.org/10.22487/kovalen.2023.v9.i2.16397