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# Performance of Activated Carbon from Water Chestnut (*Eleocharis Dulcis*) as Fe Adsorbent

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**Abstract**

*This research aims to investigate the performance of activated carbon from water chestnut (WC) as an Fe adsorbent on river water samples in South Kalimantan. The WC was carbonized at a temperature of 400 °C. Then the carbon was activated with two types of activators, KOH and $H_2SO_4$ solutions. The carbonization and the activation time were also varied in two different times, 1 and 2 hours. The electrical conductivity of Martapura River water was measured to investigate its condition or quality, and yielded about 0.56 $(\Omega m)^{-1}$ or 5600 µS/cm. It is quite large compared to the standard 1000 µS/cm. After activated carbon treatment, the electrical conductivity is reduced by about 6.67 – 13.81%. For Fe adsorption, the reduction efficiency and adsorption capacity were in the range of 7.73 % – 22.94 % and 0.50 – 1.47 mg/g. The results showed that the prepared activated carbon is effective in adsorption and decreases the Fe metal content at room temperature.*

## Introduction

The Martapura River plays an important role for the people of South Kalimantan because it is a source of livelihood and is used for daily activities, and even becomes a water source for *PDAM Bandarmasih*. Based on Sudarningsih's research, the Martapura River has been polluted by heavy metals that may come from mining, industrial, agricultural, and household activities. According to the Indonesian Government Regulation No. 32 of 2017 [1], water quality standards have been established, setting the maximum allowable concentration of iron (Fe) at 1 mg/L. However, studies have reported that Fe concentrations in the Martapura River exceed this limit at multiple sampling points [2]. Measurements have shown that Fe content in the Martapura River water can reach up to 2.8 mg/L, nearly three times the regulatory limit [3]. Long-term exposure to heavy metals has been associated with serious health risks in humans because of their non-degradable nature and progressive accumulation [4]. Furthermore, long-term exposure to elevated levels of Fe in drinking water or through the food chain can lead to serious health issues in humans, including liver damage, pancreatic dysfunction, and neurological disorders, particularly among vulnerable populations such as children and the elderly [5].

The presence of heavy metals in aquatic ecosystems has been proven to significantly disrupt the ecological balance of aquatic organisms. It is believed that the presence of heavy metals correlates with a 17% decline in the diversity of freshwater macroinvertebrate species due to selective environmental pressures [6]. The measurement of electrical conductivity can serve as an early indicator to detect rising levels of heavy metals in water, providing a timely warning of potential damage to aquatic ecosystems [7].

Several approaches have been utilized to remove heavy metals from water [8], such as: photocatalysis [9], ultrafiltration [10], and adsorption with activated carbon [11]. Adsorption is a promising technique due to its low cost, easy operation, excellent efficiency, little sludge production, and adsorbent regeneration. Some popular adsorbents, including activated carbon, can remove dyes and heavy metals [12].

Activated carbon has good adsorption properties and excellent performance in the application as a water treatment process for the removal of natural organic matter, small organic compounds (e.g., pesticides), and inorganic compounds (e.g., heavy metals) [13]. Commercial activated carbon is a form of adsorbent widely utilized in adsorption processes. However, the use of commercial carbon in wastewater treatment remains limited due to the scarcity of precursors and their high cost. Activated carbon can be produced from agricultural residues, wood, and biomass materials [14].

Several studies have explored biomass-based activated carbon for heavy metal and contaminant removal, such as those derived from rice straw [12] and sesame straw [13] for Cd(II) removal, cauliflower leaves for Cu(II) [15] and water hyacinth leaves [16] (*Pontederia crassipes*) leaves for fluoride adsorption in groundwater.

Water chestnut (*Eleocharis dulcis)* (commonly known as "*purun tikus*") grows naturally in swamp areas in South Kalimantan [17]. This plant is classified as a weed. The WC plant in South Kalimantan is still limited in use, namely, as swamp buffalo feed, making mats [17] and biofilter [18]. In other research, WC has also been used as a composite material [19]. Therefore, the WC was chosen for this study due to its unique metal absorption capabilities, wide availability, and cost-effectiveness in environmental remediation [20]

The physicochemical properties of the activated carbon depend on several parameters, such as temperature and time of carbonization, activator types, activator time, and particle size [21], [22], [23], [24]. The carbonization process in this study was carried out at 400°C. This temperature was selected with reference to previous studies and the botanical similarity between the selected biomass and other related plant materials. Carbonization at 400°C using a pellet mixture of elephant grass and *nyamplung* shell has been reported to successfully produce carbon materials with desirable properties. Elephant grass shares taxonomical similarities with water chestnut (Eleocharis dulcis), including both being classified as angiosperms, monocots, and members of the order Poales [25].

The selection of the carbonization durations is based on the previous studies demonstrating that carbonization time significantly affects the physical and chemical characteristics of the resulting carbon. Lignite carbonized at 900°C for 2 hours produced activated carbon with a high iodine number of 1274.8 mg/g, indicating excellent adsorption capacity [26].

Additionally, Eleocharis dulcis was used as a raw material for supercapacitor electrode carbon through a carbonization process at 600°C for 1 hour [27]. Drawing from these findings, this study adopted 1 and 2-hour carbonization periods to potentially optimize the surface area and porosity of activated carbon, enhancing its performance in adsorption applications.

The charcoals were crushed and filtered to sizes of 60 and 120 mesh. The selection of 60 and 120 mesh particle sizes was based on their influence on adsorption efficiency. These particular mesh sizes were selected based on previous studies highlighting the impact of particle fineness on surface area and adsorption efficiency. Finer particles of 120 mesh derived from oil palm empty fruit bunches exhibited enhanced adsorption of methylene blue due to increased surface area and porosity [28]. Similarly, activated carbon from coconut shells with approximately 60 mesh particle size effectively removed heavy metals from wastewater, indicating sufficient surface exposure while maintaining structural stability [29]. Based on these findings, both 60 and 120 mesh sizes were used in this research to examine how granule fineness affects the adsorption behavior of water chestnut-based activated carbon.

In this study, 1 M KOH and 1 M $H_2SO_4$ were used as chemical activating agents to enhance the adsorption properties of the activated carbon. These activators were selected based on their proven effectiveness in previous studies. Rice husk activated with KOH, followed by carbonization at 600°C, achieved a high iodine adsorption capacity of 458.109 mg/g after 90 minutes, indicating increased porosity and surface area [21]. Similarly, activated carbon made from pineapple leaves and treated with 1 M $H_2SO_4$ exhibited the highest iodine number (382.1576 mg/g) compared to other acids, demonstrating strong activation potential [30]. Based on these findings, KOH and $H_2SO_4$ were considered suitable for producing high-quality activated carbon from biomass in this study.

This study offers a new approach using water chestnut (*Eleocharis dulcis*). This wetland plant has not been widely explored, especially for its use as a raw material for making activated carbon as Fe adsorbent. Water chestnut, also known as *purun tikus* in the local language, grows in swampy areas of South Kalimantan [31]. This study will hopefully pave the way to producing a more sustainable and environmentally conscious activated carbon and provide added value for using wetland plants.

Previous work on activated carbon from water chestnuts provided preliminary data on physical-chemical properties such as water content, ash content, and volatile and fixed carbon, delivering the framework for future research [11]. However, these studies did not comprehensively address the adsorption capabilities of Fe metal and the electrical conductivity of the activated carbon. This article aims to fill this gap by presenting an analysis of the reduction efficiency of Fe metal, adsorption capacity, and electrical conductivity, thereby offering a more complete understanding of the functional properties of activated carbon.

In parallel, assessing the adsorption capacity is essential to determine a material's effectiveness in removing metal ions from contaminated water. Combined with conductivity measurements, it offers a comprehensive view of pollutant removal efficiency and ionic changes, supporting the development of sustainable water treatment technologies in metal-contaminated areas.

## Experimental Method

### Sample Preparation

Water chestnut plants were collected in the Barito Kuala Regency of South Kalimantan. In this research, the drying of water chestnut stems, which ranged from 100 to 160 cm in length, was carried out under direct sunlight for two days. During the drying process, the average ambient temperature ranged from 32°C to 35°C. After that, the water chestnuts were chopped into pieces about 2 cm long and then crushed with a blender.

### Carbonization

The water chestnuts were carbonized at 400°C. Carbonization times varied between 1 and 2 hours. The charcoals were crushed and filtered to sizes of 60 and 120 mesh. This aims to homogenize particle size.

### Chemical Activation

In this study, the raw material was first carbonized to obtain char, and subsequently, chemical activation was performed by impregnating the char with either 1 M KOH or 1 M $H_2SO_4$ (char/activating agent = 1/4). The mixture was stirred using a magnetic stirrer at 500 rpm for 20 minutes to ensure uniform contact, then immersed for 24 hours to complete the activation process. This activation duration was selected based on previous studies indicating that prolonged soaking enhances the development of porosity and surface area in activated carbon. For example, research on the chemical activation of date seed carbon using $H_3PO_4$, $HNO_3$, and $H_2SO_4$ involved soaking the carbonized material in a 1 N solution of the activating agent for 24 hours [32], resulting in effective activation and improved adsorption properties.

The activated material was then filtered using Whatman filter paper, and the resulting solid was washed repeatedly with deionized water until the filtrate reached a neutral pH, ensuring the removal of residual activating agents and by-products. The pH of the filtrate was monitored using a pH meter to confirm neutrality. A schematic diagram of the entire activated carbon production process is shown in Figure 1.

**Figure 1**. Activated carbon production method

### Adsorption Fe Metal

Water samples for this research were collected from the Martapura River in South Kalimantan. For Fe adsorption, 100 ml of sample in the Erlenmeyer flask was added 0.08 grams of activated carbon, then soaked for 30 minutes. After that, the sample is filtered to separate the adsorbent. In the last step, initial and residual concentration tests are conducted.

The selection of 0.08 grams of activated carbon per 100 mL of water in this study was informed by prior research demonstrating effective adsorption at similar dosages. For instance, a study on methylene blue dye removal utilized 0.05 g of activated carbon in 100 mL of solution, achieving a 94.10% removal efficiency [33]. Additionally, research on chemically activated carbon from rice husks reported optimal chemical oxygen demand (COD) removal at adsorbent dosages around 0.08 g per 100 mL [34]. These findings suggest that using 0.08 g of activated carbon per 100 mL provides sufficient surface area for effective contaminant adsorption without excessive material use, aligning with established practices in adsorption studies.

### Characterization

Removal of Fe metals by activated carbon was observed with AAS (Atomic Absorption Spectroscopy). The electrical conductivity measurement using a conductivity meter at *UPT Laboratorium Lingkungan*, South Kalimantan. The experiment was conducted using three measurements, and the average of each sample variation was obtained.

## Results and Discussion

### Electrical Conductivity Measurement

The condition or quality of water can be determined by measuring electrical conductivity. Electrical conductivity in water is the ability of water to conduct electricity, which is related to water temperature and total concentration, mobility, valence, and relative concentration of ions. Increased electrical conductivity can indicate that there has been a decrease in water quality that can be harmful to fish or aquatic biota [35]. The electrical conductivity of Martapura River water before and after the addition of activated carbon is presented in Table 1. The initial electrical conductivity of Martapura River water is 0.56 $(\Omega m)^{-1}$ or 5.600 µS/cm. The normal electrical conductivity value of most large rivers is in the range of 200 to 1000 µS/cm. Electrical conductivity outside this range may indicate that the water is not suitable for certain species of fish. Based on this, the Martapura River has an indication of high conductivity (1000 to 10.000 µS/cm), which is included in the category of salinity conditions [36]. However, electrical conductivity measurements cannot indicate the type of pollutant present.

Before conducting research on the electrical conductivity, observations were first made on the electrical conductivity of Martapura River water that passes through the filter paper. The purpose of measuring is to determine whether there is a change in the electrical conductivity after passing through the filter paper. In Table 1, the electrical conductivity decreased after the river water passed through the filter paper. The results of this study show that filtering with filter paper can reduce the electrical conductivity by 0.016 $(\Omega m)^{-1}$. This data is used as control data, where the final electrical conductivity data will be reduced by a value equal to the electrical conductivity control data.

**Table 1.** The Electrical Conductivity Reduction Efficiency Using Filter Paper

| **No** | **Concentration before treatment $(\Omega m)^{-1}$** | **Concentration after treatment $(\Omega m)^{-1}$** | **Difference $(\Omega m)^{-1}$** | **Efficiency (%)** |
|---|---|---|---|---|
| 1 | 0.5600 | 0.5440 | 0.0160 | 2.86 |

**Table 2**. Electrical Conductivity

| **Carbonization Time** | **Activator** | **Particles Size** | **Inital Electrical conductivity $(\Omega m)^{-1}$** | **Final Electrical Conductivity before treatment $(\Omega m)^{-1}$** | **Final Electrical Conductivity after treatment $(\Omega m)^{-1}$** | **Efficiency (%)** |
|---|---|---|---|---|---|---|
| 1 Hour | KOH | 60 Meshs | 0.5600 | 0.5130 | 0.4970 | 11.25 |
| | | | 0.5600 | 0.4940 | 0.4780 | 14.64 |
| | | | 0.5600 | 0.4990 | 0.4830 | 13.75 |
| | | **Average** | **0.5600** | **0.5020** | **0.4860** | **13.21** |
| | | **Standard Deviation** | 0 | 0.01 | 0.01 | 1.758 |
| | | 120 Meshs | 0.5600 | 0.5030 | 0.4870 | 13.04 |
| | | | 0.5600 | 0.5010 | 0.4850 | 13.39 |
| | | | 0.5600 | 0.4940 | 0.4780 | 14.64 |
| | | **Average** | **0.5600** | **0.4993** | **0.4833** | **13.69** |
| | | **Standard Deviation** | 0 | 0.005 | 0.005 | 0.841 |
| | $H_2SO_4$ | 60 Meshs | 0.5600 | 0.5230 | 0.5070 | 9.46 |
| | | | 0.5600 | 0.5360 | 0.5200 | 7.14 |
| | | | 0.5600 | 0.5390 | 0.5230 | 6.61 |
| | | **Average** | **0.5600** | **0.5327** | **0.5167** | **7.74** |
| | | **Standard Deviation** | 0 | 0.009 | 0.009 | 1.516 |
| | | 120 Meshs | 0.5600 | 0.5250 | 0.5090 | 9.11 |
| | | | 0.5600 | 0.5400 | 0.5240 | 6.43 |
| | | | 0.5600 | 0.5380 | 0.5220 | 6.79 |
| | | **Average** | **0.5600** | **0.5343** | **0.5183** | **7.44** |
| | | **Standard Deviation** | 0 | 0.008 | 0.008 | 1.45 |
| 2 Hours | KOH | 60 Meshs | 0.5600 | 0.5070 | 0.4910 | 12.32 |
| | | | 0.5600 | 0.4930 | 0.4770 | 14.82 |
| | | | 0.5600 | 0.5050 | 0.4890 | 12.68 |
| | | **Average** | **0.5600** | **0.5017** | **0.4857** | **13.27** |
| | | **Standard Deviation** | 0 | 0.008 | 0.008 | 1.351 |
| | | 120 Meshs | 0.5600 | 0.5060 | 0.4900 | 12.50 |
| | | | 0.5600 | 0.4960 | 0.4800 | 14.29 |
| | | | 0.5600 | 0.4940 | 0.4780 | 14.64 |

| | | | | | |
|---|---|---|---|---|---|
| | **Average** | **0.5600** | **0.4987** | **0.4827** | **13.81** |
| | Standard Deviation | 0 | 0.006 | 0.006 | 1.148 |
| $H_2SO_4$ | 60 Meshs | 0.5600 | 0.5370 | 0.5210 | 6.96 |
| | | 0.5600 | 0.5330 | 0.5170 | 7.68 |
| | | 0.5600 | 0.5460 | 0.5300 | 5.36 |
| | **Average** | **0.5600** | **0.5387** | **0.5227** | **6.67** |
| | Standard Deviation | 0 | 0.007 | 0.007 | 1.187 |
| | 120 Meshs | 0.5600 | 0.5300 | 0.5140 | 8.21 |
| | | 0.5600 | 0.5430 | 0.5270 | 5.89 |
| | | 0.5600 | 0.5310 | 0.5150 | 8.04 |
| | **Average** | **0.5600** | **0.5347** | **0.5187** | **7.38** |
| | Standard Deviation | 0 | 0.007 | 0.007 | 1.293 |

After activated carbon treatment, the electrical conductivity of Martapura river water decreased, reaching a maximum reduction of 0.0773 $(\Omega m)^{-1}$. The efficiency of activated carbon in terms of electrical conductivity was 6.67 – 13.81 %. However, this efficiency is still relatively low. This indicates that although the treatment was partially effective, additional treatment steps or higher carbon dosage may be necessary to meet the required standards. The remaining high conductivity implies that significant dissolved ions persist [37], which could limit the water's suitability for applications requiring low ionic content, such as drinking water or certain industrial uses.

The highest electrical conductivity value was found in 120 mesh activated carbon. In this study, small-sized activated carbon exhibited the lowest conductivity compared to other sizes. Recent studies have demonstrated that reducing the particle size of activated carbon enhances its adsorption capacity due to increased surface area and porosity. However, this can also lead to higher electrical conductivity in treated water samples, as the finer particles may release more dissolved ions into the solution. According to a study by Takaesu found that micro-milling super-fine powdered activated carbon introduced oxygen/hydrogen-containing functional groups on the carbon surface, which could increase the conductivity of the treated water [38].

This research shows, the highest electrical conductivity value was observed in samples treated with activated carbon produced at the longest carbonization time. The length of the carbonization process affects the development of the pore structure within the activated carbon. Prolonged carbonization can lead to a more extensive pore network, enhancing the material's capacity to adsorb impurities that contribute to water's electrical conductivity. Parameters such as activation time and temperature have a major impact on the yield and properties of activated carbons. However, overly extended carbonization times may cause structural degradation or excessive burn-off, reducing the overall yield and effectiveness of the activated carbon [39].

In this study, it was observed that water treated with $H_2SO_4$-activated carbon exhibited higher electrical conductivity compared to water treated with KOH-activated carbon. This can be attributed to the differences in the chemical interactions and pore structures developed by each activating agent. Sulfuric acid ($H_2SO_4$) introduces various functional groups onto the carbon surface, enhancing its adsorption capacity for organic and inorganic contaminants. However, residual acidic groups or the release of adsorbed ions back into the water may increase electrical conductivity, as observed with $H_2SO_4$-activated carbon, which showed a slight rise in conductivity after treatment [40].

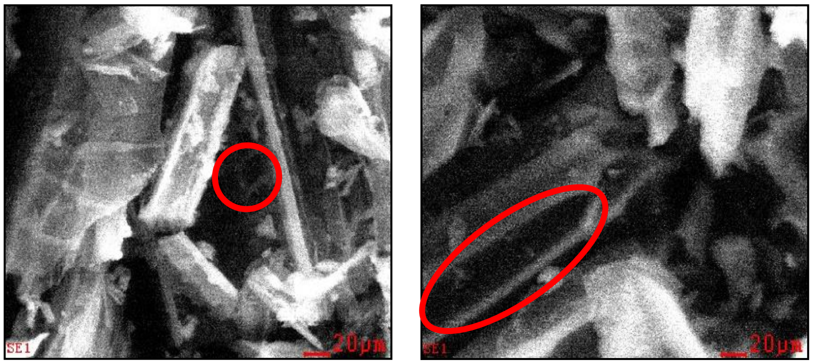

**Figure 2.** SEM images of (a) 60 mesh and (b) 120 mesh water chestnut 2 hours carbonization.

The results of the morphology of the activated carbon with the particle size of 120 mesh have larger pores in comparison with the particle size of 60 mesh, as shown in Figure 2. When it correlates with the carbon element contained in the activated carbon [41], the carbonization process increases the quantity of carbon. Based on the variation of carbonization time for 2 hours, the highest carbon element is found in activated carbon with a particle size of 120 mesh. The element of carbon from activated carbon at 60 mesh particle size was 41.53 % of weight, while at size 120 mesh was 71.73 % of weight. Similarly, research on sargassum-based activated carbon revealed that carbonization temperature significantly influences the specific surface area and pore volume of the material [42]. Since adsorption efficiency is strongly influenced by surface characteristics, it is essential to correlate the surface properties with adsorption performance. Despite this increase in carbon composition, the overall performance of the activated carbon remains relatively low. This limitation can be attributed to the surface morphology observed in the SEM analysis, where the pore structures are not well-developed, the pore distribution is non-uniform, and some pores appear to be blocked. These factors indicate that the activation process has not yet produced an optimal pore network for adsorption. The development of pore structures and surface chemistry is also strongly influenced by the intrinsic composition of the precursor material.

### Fe Adsorption of Activated Carbon from Water Chestnut

In Fe adsorption measuring, a similar way was conducted as in the electrical conductivity investigation. After filtering, the Fe concentration in Martapura river water also showed a decrease (see Table 3). This result shows the correlation with the electrical conductivity measurement. The results of this study show that filtering with filter paper can reduce the Fe content by 0.128 mg/L. This data is used as control data, where the final concentration data after the adsorption process by activated carbon will be reduced by a value equal to the Fe content retained on the filter paper.

**Table 3.** Fe Reduction Efficiency Using Filter Paper

| No | Concentration before treatment (mg/L) | Concentration after treatment (mg/L) | Difference (mg/L) | Efficiency (%) |
|---|---|---|---|---|
| 1 | 5.175 | 5.047 | 0.128 | 2.47 |

**Table 4**. Reduction efficiency and adsorption capacity of activated carbon

| Carbonization Time | Activator | Particles Size | Initial Concentration (mg/L) | Final Concentration Before treatment (mg/L) | Final Concentration After treatment (mg/L) | Reduction Efficiency (%) | Adsorption Capacity (mg/g) |
|---|---|---|---|---|---|---|---|
| 1 Hour | KOH | 60 Mesh | 5.047 | 4.589 | 4.461 | 13.80 | 0.88 |
| | | | 5.047 | 4.482 | 4.354 | 15.86 | 1.02 |
| | | | 5.047 | 4.632 | 4.504 | 12.97 | 0.83 |
| | | **Average** | **5.047** | **4.568** | **4.440** | **14.21** | **0.91** |
| | | **Standard Deviation** | 0 | 0.077 | 0.077 | 1.488 | 0.098 |
| | | 120 Mesh | 5.047 | 4.394 | 4.266 | 17.57 | 1.13 |
| | | | 5.047 | 4.302 | 4.174 | 19.34 | 1.24 |
| | | | 5.047 | 4.519 | 4.391 | 15.15 | 0.98 |
| | | **Average** | **5.047** | **4.405** | **4.277** | **17.35** | **1.12** |
| | | **Standard Deviation** | 0 | 0.109 | 0.109 | 2.103 | 0.131 |
| | $H_2SO_4$ | 60 Mesh | 5.047 | 4.790 | 4.662 | 9.91 | 0.64 |
| | | | 5.047 | 4.745 | 4.617 | 10.78 | 0.69 |
| | | | 5.047 | 4.643 | 4.515 | 12.75 | 0.82 |
| | | **Average** | **5.047** | **4.726** | **4.598** | **11.15** | **0.72** |
| | | **Standard Deviation** | 0 | 0.075 | 0.075 | 1.455 | 0.093 |
| | | 120 Mesh | 5.047 | 4.917 | 4.789 | 7.46 | 0.48 |
| | | | 5.047 | 4.867 | 4.739 | 8.43 | 0.54 |
| | | | 5.047 | 4.925 | 4.797 | 7.30 | 0.47 |
| | | **Average** | **5.047** | **4.903** | **4.775** | **7.73** | **0.50** |
| | | **Standard Deviation** | 0 | 0.031 | 0.031 | 0.611 | 0.038 |
| 2 Hours | KOH | 60 Mesh | 5.047 | 4.523 | 4.395 | 15.07 | 0.97 |
| | | | 5.047 | 4.358 | 4.230 | 18.26 | 1.17 |
| | | | 5.047 | 4.325 | 4.197 | 18.90 | 1.21 |
| | | **Average** | **5.047** | **4.402** | **4.274** | **17.41** | **1.12** |
| | | **Standard Deviation** | 0 | 0.106 | 0.106 | 2.052 | 0.129 |
| | | 120 Mesh | 5.047 | 4.285 | 4.157 | 19.67 | 1.26 |
| | | | 5.047 | 4.241 | 4.113 | 20.52 | 1.32 |
| | | | 5.047 | 3.822 | 3.694 | 28.62 | 1.83 |
| | | **Average** | **5.047** | **4.116** | **3.988** | **22.94** | **1.47** |
| | | **Standard Deviation** | 0 | 0.256 | 0.256 | 4.94 | 0.313 |

| | | | | | | |
|---|---|---|---|---|---|---|
| $H_2SO_4$ | 60 Mesh | 5.047 | 4.945 | 4.817 | 6.92 | 0.44 |
| | | 5.047 | 4.619 | 4.491 | 13.22 | 0.85 |
| | | 5.047 | 4.732 | 4.604 | 11.03 | 0.71 |
| | **Average** | **5.047** | **4.765** | **4.637** | **10.39** | **0.67** |
| | **Standard Deviation** | 0 | 0.166 | 0.166 | 3.198 | 0.208 |
| | 120 Mesh | 5.047 | 4.672 | 4.544 | 12.19 | 0.79 |
| | | 5.047 | 4.665 | 4.537 | 12.33 | 0.79 |
| | | 5.047 | 4.737 | 4.609 | 10.94 | 0.71 |
| | **Average** | **5.047** | **4.691** | **4.563** | **11.82** | **0.76** |
| | **Standard Deviation** | 0 | 0.04 | 0.04 | 0.765 | 0.046 |

The activated carbon prepared by increasing the carbonization time had a higher adsorption capacity. Based on the data from Table 4, the longer the carbonization time, the higher the absorption capacity and the reduction efficiency of the activated carbon are. Activated carbon derived from rice husk also showed increased adsorption capacity with increasing carbonization time in different investigations [21]. This is because the longer the carbonization period is, the more time steam has to burn the organic compounds, causing low yields but rather high specific pore volumes and surface areas [39]. The low quantity of Impurities such as water content, ash content, and volatiles result in activated carbon that is capable of adsorbing a concentration of Fe metal.

As can be seen in Table 4, the average reduction efficiency and adsorption capacity of activated carbon were consistently increased as the particle size became smaller. The particle size of 120 mesh has the largest carbon element, 71.73% of weight, which results in a higher reduction efficiency (22.94%) and adsorption capacity (1.47%) of Fe metal components than the 60 mesh particle size variation. [11]. Smaller particles allow water to evaporate quickly, resulting in almost all the samples burning perfectly and producing a minimal quantity of ash [45]. The heat would also burn the other compounds, such as cellulose and lignin, and increase the carbon concentration.

The base activator (KOH) delivered the best adsorption results in this research. [46] Correa revealed that the chemical activation process with KOH was conducted to increase the surface area and micropore volumes. In the process of chemical activation, the carbon is in contact with a chemical solution, and oxidation occurs, causing damage to the carbon's structure and resulting in an increased number of pores [47], and described that the presence of tar residue in activated carbon can block the pores [48]. Therefore, it requires chemical activation that can dissolve the tar when soaked with an activator.

Activated carbon derived from *Eleocharis dulcis* (water chestnut) achieved Fe adsorption efficiencies ranging from 7.73% to 22.94%, corresponding to an average Fe adsorption capacity of 0.91 mg/g. The optimal performance was observed in samples carbonized for 2 hours, activated with KOH, and sieved to 120 mesh. The relatively low Fe adsorption efficiency obtained from *Eleocharis dulcis*–derived activated carbon can be attributed to several factors. The accessibility of hydrated Fe ions is highly dependent on the pore structure of the adsorbent material. Structures dominated by micropores with limited mesoporous volume can restrict ion diffusion and reduce the availability of active adsorption sites [49].

Furthermore, another factor influencing the adsorption capacity of activated carbon is its surface chemistry, particularly the type and distribution of oxygen-containing functional groups. The concentration of the chemical activating agent plays a crucial role in pore development. However, when the concentration is too high, the stronger alkaline environment accelerates the corrosion and deoxygenation of the carbon structure, thereby reducing the amount of oxygen-containing functional groups [50]. A decrease in these functional groups may negatively impact the surface reactivity and lower the specific capacitance of carbon materials. Previous studies have reported that an optimal amount of oxygen-containing functional groups can positively contribute to improving the specific capacitance of carbon materials [51].

**Table 5**. Comparison of Fe adsorption performance between activated carbon derived from water chestnut and sugar cane bagasse

| **No** | **Biomass Source** | **Fe Adsorption Capacity (mg/g)** |
|---|---|---|
| 1 | Water Chestnut | 0.91 |
| 2 | Sugar Cane Bagasse | 0.69 |

This observation suggests that a reduction in oxygen-containing functional groups can contribute to lower Fe adsorption performance. Similar low adsorption efficiency has also been reported for activated carbon derived from other biomass sources. A comparison of Fe adsorption performance between water chestnut-derived activated carbon and other reported activated carbons is presented in Table 5, indicating that low adsorption efficiency is not only observed for *E. dulcis* but also for activated carbons from sugar cane bagasse [52].

These findings highlight that the relatively low Fe adsorption performance of water chestnut-derived activated carbon may be strongly influenced by its surface chemistry and pore structure. Although carbonization and activation processes improve porosity, the presence of sufficient oxygen-containing functional groups remains critical for effective Fe adsorption. Nevertheless, the discussion of surface functional groups in this study is constrained, as FTIR characterization was not conducted. Therefore, future studies should not only explore surface modification techniques, but also include detailed spectroscopic analyses (e.g., FTIR or XPS) to provide a more comprehensive understanding of the relationship between functional groups and adsorption performance.

## Conclusion

In conclusion, the measurement of electrical conductivity indicates that Martapura River water is polluted, with a value of 0.56 $(\Omega m)^{-1}$. Water chestnut-based activated carbon reduced the conductivity by 6.67–13.81% and achieved Fe adsorption efficiencies of 7.73–22.94%, with the best performance observed in samples carbonized for 2 hours, activated with KOH, and sieved to 120 mesh. Although the adsorption performance is lower compared to some other biomass-derived activated carbons, these findings indicate that water chestnut-derived activated carbon can be further explored for water treatment applications. Further optimization of synthesis parameters and detailed characterization of surface chemistry and porosity are necessary to understand its adsorption mechanism and potential better.

## Reference

[1] Menteri Kesehatan RI, *Peraturan Menteri Kesehatan Tentang Persyaratan Kualitas Air Minum*. Indonesia, 2010.

[2] E. I. Ulmi and N. Amal, “Kajian Ekohidraulik Sungai Martapura,” 2015.

[3] H. Wijayanti, H. Wahdi, and W. Nooryanto, “Utilization of Chitosan from Shrimp Shells Waste for Reduction of Iron (Fe) Metal Content in Martapura River” *Konversi*, vol. 9, Aug. 2020.

[4] S. Özdemir, M. S. Yalçın, and E. Kılınç, “Preconcentrations of Ni(II) and Pb(II) from water and food samples by solid-phase extraction using Pleurotus ostreatus immobilized iron oxide nanoparticles,” *Food Chem*, 2021.

[5] M. Jaishankar, T. Tseten, N. Anbalagan, B. B. Mathew, and K. N. Beeregowda, “Toxicity, mechanism and health effects of some heavy metals,” Jun. 01, 2014, *Slovak Toxicology Society*.

[6] B. Alric, O. Geffard, and A. Chaumot, “Metal bioavailable contamination engages richness decline, species turnover but unchanged functional diversity of stream macroinvertebrates at the scale of a French region,” *Environmental Pollution*, vol. 308, p. 119565, 2022.

[7] E. Leiva, M. Cayazzo, and M. Torres, “Real-time electrical conductivity monitoring and correlation with sulfate release and acid mine drainage potential from a gold/silver paste tailing storage,” *Minerals*, vol. 11, no. 12, Dec. 2021.

[8] M. Mariana *et al.*, “Recent advances in activated carbon modification techniques for enhanced heavy metal adsorption,” Oct. 01, 2021, *Elsevier Ltd*.

[9] B. Li, Y. Zhang, D. Ma, Z. Shi, and S. Ma, “Mercury nano-trap for effective and efficient removal of mercury(II) from aqueous solution,” *Nat Commun*, vol. 5, 2014.

[10] D.-Q. Cao *et al.*, “Removal of heavy metal ions by ultrafiltration with recovery of extracellular polymer substances from excess sludge,” *J Memb Sci*, vol. 606, p. 118103, 2020.

[11] Suryajaya, N. H. Haryanti, S. Husain, and M. Safitri, “Preliminary study of activated carbon from water chestnut (Eleocharis dulcis),” in *Journal of Physics: Conference Series*, Institute of Physics Publishing, Jul. 2020.

[12] B. Wang, J. Lan, C. Bo, B. Gong, and J. Ou, “Adsorption of heavy metal onto biomass-derived activated carbon: review,” Jan. 31, 2023, *Royal Society of Chemistry*.

[13] A. Larasati, G. D. Fowler, and N. J. D. Graham, “Insights into chemical regeneration of activated carbon for water treatment,” *J Environ Chem Eng*, vol. 9, no. 4, p. 105555, 2021.

[14] N. S. Bentsen, C. Felby, and B. J. Thorsen, “Agricultural residue production and potentials for energy and materials services,” *Prog Energy Combust Sci*, vol. 40, pp. 59–73, 2014.

[15] Z. Ahmad *et al.*, “Removal of Cu(II), Cd(II) and Pb(II) ions from aqueous solutions by biochars derived from potassium-rich biomass,” *J Clean Prod*, vol. 180, pp. 437–449, 2018.

[16] E. M. Muchunku, P. K. Ndiba, and E. A. Omondi, "Defluoridation of Groundwater by Activated Carbon Derived from Water Hyacinth (Pontederia crassipes) by Phosphoric Acid Activation," *American Journal of Water Science and Engineering*, vol. 9, no. 4, pp. 97–107, Nov. 2023.

[17] E. Maftu'ah, *Potensi berbagai bahan organik rawa sebagai sumber biochar*. 2015.

[18] N. H. Haryanti and H. Wardhana, "Purun tikus (Eleocharis dulcis) fiber composition as cement board composite material," *Journal of Biodiversity and Environmental Sciences (JBES)*, vol. 11, no. 3, pp. 137–142, 2017.

[19] S. Wibowo, W. Syafii, and G. Pari, "Karakteristik Arang Aktif Tempurung Biji nyamplung (Calophyllum inophyllum Linn)," 2009.

[20] H. Aulia, N. Tanzerina, E. Junaidi, and S. Triwardana, "Effectiveness of Waterchestnut (Eleocharis dulcis (Burm.f.) Trin. ex Henschel) in Phytoremediation of Coal Mine Acid Drainage in Constructed Wetlands," *Journal of Scientific Development and Research*, p. 1768, 2023, [Online]. Available: www.ijsdr.org

[21] P. M. Rohmah and A. S. Redjeki, "Pengaruh Waktu Karbonisasi Pada Pembuatan Karbon Aktif Berbahan Baku Sekam Padi Dengan Aktivator KOH," vol. 3, 2014.

[22] F. Zulkipli and N. H. Jamian, "Correlation and Exploratory Factor Analysis on Awareness of Solid Waste Management in Malaysia," *International Journal of Academic Research in Business and Social Sciences*, vol. 11, no. 10, p. Pages 1151–1164, Jun. 2021

[23] A. S. Reyra, S. Daud, and S. R. Yenti, "Pengaruh Massa dan Ukuran Partikel Adsorben Daun Nanas Terhadap Efisiensi Penyisihan Fe Pada Air Gambut," vol. 4, p. 9, 2017.

[24] A. Triyanto, "Peningkatan Kualitas Minyak Goreng Bekas menggunakan Arang Ampas Tebu Teraktivasi dan Penetralan dengan NaHSO3," 2013.

[25] S. Wibowo, D. P. O. Laia, M. Khotib, and G. Pari, "Karakterisasi Karbon Pelet Campuran Rumput Gajah (Pennisetum Purpureum Scumach) Dan Tempurung Nyamplung (Calophyllum Inophyllum Linn)," *Jurnal Penelitian Hasil Hutan*, vol. 35, no. 1, pp. 73–82, 2017.

[26] S. Suliestyah and I. P. Sari, "Effect of temperature and time of carbonization on coal-based activated carbon adsorption," *IOP Conf Ser Mater Sci Eng*, vol. 1098, no. 6, p. 062020, Mar. 2021.

[27] S. Awal Pemanfaatan Purun Tikus Sebagai Elektroda Superkapasitor Menggunakan Aktivasi Uap Air, A. dan Erman Taer Jurusan Fisika, F. Matematika dan Ilmu Pengetahuan Alam, and U. Riau, "The Preliminary Study of Utilization of Water Chestnut as Supercapacitor Electrode Using Steam Activation," *J. Aceh Phys. Soc*, vol. 7, no. 1, pp. 30–34, 2018, [Online]. Available: http://www.jurnal.unsyiah.ac.id/JAcPS

[28] N. Intarachandra, S. Siriworakon, and T. Sangmanee, "Preparation of oil palm empty fruit bunch-based activated carbon for adsorption of dye from aqueous solution," *MATEC Web of Conferences*, vol. 268, p. 06008, 2019.

[29] E. Bernard, A. Jimoh, and J. Obofoni Odigure, "Heavy metals removal from industrial wastewater by activated carbon prepared from coconut shell," 2013. [Online]. Available: https://www.researchgate.net/publication/289401355

[30] A. A. Setiawan, A. Shofiyani, and I. Syahbanu, "Pemanfaatan Limbah Daun Nanas (Ananas comosus) Sebagai Bahan Dasar Arang Aktif Untuk Adsorpsi Fe (II)," vol. 6, no. 3, pp. 66–74, 2017.

[31] E. Maftu'ah and D. Nursyamsi, "Potensi berbagai bahan organik rawa sebagai sumber biochar Potency of various organic materials from swampland as a source of biochar," vol. 1, pp. 776–781, 2015.

[32] H. Al Subhi, M. S. Adeeb, M. Pandey, H. Al Sadeq, D. Kumar, and S. K. Shukla, "Effect of different activation agents on the pollution removal efficiency of date seed activated carbon: process optimization using response surface methodology," *Appl Water Sci*, vol. 10, no. 7, Jul. 2020.

[33] A. Chaudhari, "Adsorption Capacity of Activated Carbon Prepared by Chemical Activation of Lignin for the Removal of Methylene Blue Dye," *International Journal of Advanced Research in Chemical Science (IJARCS)*, vol. 2, no. 8, pp. 1–13, 2015, [Online]. Available: https://www.researchgate.net/publication/303767251

[34] W. I. Mortada, R. A. Mohamed, A. A. A. Monem, M. M. Awad, and A. F. Hassan, "Effective and Low-Cost Adsorption Procedure for Removing Chemical Oxygen Demand from Wastewater Using Chemically Activated Carbon Derived from Rice Husk," *Separations*, vol. 10, no. 1, Jan. 2023.

[35] S. Aziz, R. Ullah, M. S. Alwahibi, M. Soliman Elshikh, and J. Alkahtani, "Profiling of toxic metals from fish (tor putitora), water and sediments with microbial and chemical water quality appraisals," *Saudi J Biol Sci*, vol. 28, no. 4, pp. 2527–2533, Apr. 2021.

[36] H. Prihatno, R. F. Abida, and S. L. Sagala, "Korelasi antara Konduktivitas dengan Jumlah Mineral Terlarut pada Perairan Selatan Pulau Madura," *Jurnal Kelautan Nasional*, vol. 16, no. 3, p. 211, Dec. 2021.

[37] B. M. Saalidong, S. A. Aram, S. Otu, and P. O. Lartey, "Examining the dynamics of the relationship between water pH and other water quality parameters in ground and surface water systems," *PLoS One*, vol. 17, no. 1 1, Jan. 2022.

[38] H. Takaesu, Y. Matsui, Y. Nishimura, T. Matsushita, and N. Shirasaki, "Micro-milling super-fine powdered activated carbon decreases adsorption capacity by introducing oxygen/hydrogen-containing functional groups on carbon surface from water.," *Water Res*, vol. 155, pp. 66–75, 2019, [Online]. Available: https://api.semanticscholar.org/CorpusID:73462710

[39] D. Bergna, T. Varila, H. Romar, and U. Lassi, "Comparison of the Properties of Activated Carbons Produced in One-Stage and Two-Stage Processes," *C (Basel)*, vol. 4, no. 3, p. 41, Jul. 2018.

[40] M. Jawaduddin and U. T. Brunei, "Synthesis of activated carbon via sulphuric acid and iron chloride and its potential application synthetic grey water in combination with sand

bed filter Mubarak N Mujawar," 2018. [Online]. Available: https://www.researchgate.net/publication/332140467

[41] M. S. , T. H. , T. F. R. , & R. A. M. Pongajow, "Konstanta : Jurnal Matematika dan Ilmu Pengetahuan Alam," vol. 2, 2024.

[42] S. Li *et al.*, "Pore Structure Regulation and Electrochemical Performance Characterization of Activated Carbon for Supercapacitors," *Front Energy Res*, vol. 9, May 2021.

[43] N. Hadi Haryanti, L. Banowati, M. Rahmah, A. Safi, and J. Fisika dan Aplikasinya, "SPEKTRA: Jurnal Fisika dan Aplikasinya Modification Of Purun Tikus (Eleocharis Dulcis) As A Natural Fiber Composite Using KMnO 4 And NaOH.

[44] A. Etale, A. J. Onyianta, S. R. Turner, and S. J. Eichhorn, "Cellulose: A Review of Water Interactions, Applications in Composites, and Water Treatment," Mar. 08, 2023, *American Chemical Society*.

[45] A. M. H. Musthofa, M. Syafila, and Q. Helmy, "Effect of Activated Carbon Particle Size on Methylene Blue Adsorption Process in Textile Wastewater," *Indonesian Journal of Chemistry*, vol. 23, no. 2, pp. 461–474, 2023.

[46] C. Rodríguez Correa, M. Stollovsky, T. Hehr, Y. Rauscher, B. Rolli, and A. Kruse, "Influence of the Carbonization Process on Activated Carbon Properties from Lignin and Lignin-Rich Biomasses," *ACS Sustain Chem Eng*, vol. 5, no. 9, pp. 8222–8233, Sep. 2017, doi: 10.1021/acssuschemeng. 7b01895.

[47] L. S. Blankenship, J. Jagiello, and R. Mokaya, "Confirmation of pore formation mechanisms in biochars and activated carbons by dual isotherm analysis," *Mater Adv*, Mar. 2022.

[48] Y. Wang *et al.*, "Preparation of Microporous Molding Activated Carbon Derived from Bamboo Pyrolysis Gasification Byproducts for Toluene Gas Adsorption," *Materials*, vol. 16, no. 15, Aug. 2023.

[49] B. G. H. Briton, L. Duclaux, Y. Richardson, K. B. Yao, L. Reinert, and Y. Soneda, "Effectiveness of the dispersion of iron nanoparticles within micropores and mesopores of activated carbon for Rhodamine B removal in wastewater by the heterogeneous Fenton process," *Appl Water Sci*, vol. 9, no. 7, Oct. 2019.

[50] D. A. Khuong, T. Tsubota, and H. N. Nguyen, "Comprehensive Understanding of the Impact of Alkaline-Activated Bamboo-Derived Carbon for Enhancing Supercapacitor Performance," *Journal of Physical Chemistry C*, vol. 128, no. 41, pp. 17313–17327, Oct. 2024.

[51] C. Qiu, L. Jiang, Y. Gao, and L. Sheng, "Effects of oxygen-containing functional groups on carbon materials in supercapacitors: A review," Jun. 01, 2023, *Elsevier Ltd*.

[52] B. M. J. Kalpana Balasooriya, J. Rajapakse, and C. Gallage, "Local agricultural waste as low-cost adsorbents for the removal of iron and 2 manganese in drinking water filters in remote Australia," 2024. [Online]. Available: https://ssrn.com/abstract=4865139