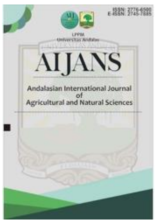
Andalasian International Journal of Agricultural and Natural Sciences (AIJANS)

ISSN: 2715-601X (Online)

Available at: http://aijans.lppm.unand.ac.id/index.php/aijans/index

DOI: https://doi.org/10.25077/aijans.v4.i02.84-98.2023



Article

Effect of Activator Types on the Production of Activated Carbon from Cocoa (Theobroma cacao, L.) Pod Husk as Metal Adsorbent

Aisman[1*], Sahadi Didi Ismanto[1], Nadila Aprilianda[1]

[1] Department of Food Technology and Agricultural Products, Universitas Andalas

Article Information

Received : 2023-09-05
Revised : 2023-09-15
Accepted : 2023-09-28
Published: 2023-10-11

Keywords

Keyword; Adsorption, Activated Carbon, Cocoa Pod Husk, Heavy Metal Iron

*Corresponding Author

aisman@ae.unand.ac.id

Abstract

The objective of this study is to investigate the distinctive properties of activated carbon derived from cocoa pod husks that have been activated using various activators. The study seeks to assess the absorption capacity of the resulting activated carbon for the heavy metal Fe, and to identify the most effective activator for this purpose. The activators used were ZnCl2, H3PO4, KOH, and MgCl2 each at a concentration of 10%. The characteristics of the activated carbon produced include; yield 70.18–82.24%, water content 0.75–2.25%, ash content 3.50–11.00%, part lost on heating 950°C or volatile matter 9.38–15.61 %, pure activated carbon of 76.94–79.16%, and absorption of iodine of 574.36–628.30 mg/g. The utilization of activated carbon derived from cocoa pod husks has demonstrated its efficacy in the adsorption of the heavy metal iron (Fe) present in well water. This adsorption process exhibits a notable absorption capacity within the range of 0.0967–0.0991 mg/g, accompanied by a high absorption efficiency ranging from 96.62% to 99.02%. The most effective activator, as determined by its iodine number, was found to be potassium hydroxide (KOH), which exhibited an impressive absorption capacity of 628.30 mg/g of iodine. On the other hand, magnesium chloride (MgCl2) emerged as the most economically viable activator, with a price of Rp. 30,00 per gram.

INTRODUCTION

Activated carbon is widely recognized as the predominant adsorbent due to its exceptional capability to eliminate contaminants from both water and wastewater. Activated carbon exhibits a significant level of porosity and surface area. There exist three distinct categories of porosity, which are delineated by the dimensions of the pores: micropores, mesoporous, and macropores. In order to effectively adsorb molecules of varying sizes, it is important for activated carbon to possess a substantial micropore volume and a suitable distribution of pore diameters [1]. In the context of pore structure, it is important to note that the combined volume of mesopores and macropores primarily functions as a means of entry to micropores.

The cost of commercial activated carbon is relatively high, thus prompting the need to identify a more cost-effective alternative adsorbent. Numerous scholars engage in the production of activated carbon utilizing agricultural or wood waste materials, including but not limited to cocoa pod husks, macadamia nut husks, almond husks, coconut husks, rice husks, and sago waste.

The weight of the cocoa pod husk accounts for approximately 70-75% of the overall weight of the fruit. Based on statistical data provided by the Central Bureau of Statistics for West Sumatra Province, it is projected that the cocoa output in West Sumatra in the year 2020 will amount to 53,070 tons. The aggregate cocoa output has the capacity to generate around 37,149–39,803 tons of cocoa pod trash. Several different methods have been employed to utilize cocoa pod husks, including their conversion into adsorbents, food antioxidants, dietary fiber, and animal feed [2]. The utilization of cocoa pod skin as an adsorbent offers several advantages. Firstly, it adds value to agricultural waste, so contributing to waste management practices. Additionally, cocoa pod skin serves as a renewable natural resource, ensuring its availability in the long term.

Activated carbon is often derived from two main sources: synthetic carbon precursors, particularly polymer types like polyamide, polyvinyl chloride, and resins, and conventional precursors such as lignocellulosic materials including cellulose, hemicellulose, and lignin [1]. The cacao pod husk possesses favorable attributes as a precursor for activated carbon due to its composition of cellulose, hemicellulose, and lignin [3].

In order to enhance the microporosity of lignocellulosic materials, it is necessary to activate their carbon component. There exist two distinct methods of activation, specifically thermal/physical activation and chemical activation. The process of physical activation encompasses the utilization of heat, steam, and carbon dioxide (CO2). Nevertheless, it has been observed that certain factors, such as temperature, pressure, and heating rate, do not exhibit a substantial influence on the dispersion of micropores [1]. Chemical activation involves the utilization of many chemical substances, including ZnCl2, H3PO4, KOH, MgCl2, NaOH, and AlCl3, as activators. Chemical activation has several advantages over physical activation. These include the utilization of lower temperatures, resulting in increased yield, improved microporous distribution, a significantly higher surface area, and reduced mineral content [2].

The utilization of H3PO4 as an activator for producing activated carbon from citrus peels has been found to yield the highest porosity, particularly in terms of micropore size [4]. The utilization of cocoa pod husks as a source of activated carbon, when activated with ZnCl2, has been found to have superior absorption properties. Specifically, this activated carbon demonstrates the maximum efficiency in absorbing metal ions of As (V), with an absorption rate of 80% [2]. The utilization of olive waste-derived activated carbon, activated by the use of potassium hydroxide (KOH), has been identified as the most effective adsorbent for the removal of Fe (II) metal ions, with an absorption efficiency of 99.39% [5]. The activation process of activated carbon derived from teak wood saws involved the utilization of various activators, including H3PO4, NaOH, H2SO4, and NaCl, each at a concentration of 10%. The effectiveness of these activators in facilitating the absorption of heavy metals was afterwards evaluated [6].

Activation using ZnCl2 generates a high yield by forming an aromatic graphite structure [7]. Activation with H3PO4 induces depolymerization and dehydration of biopolymer components, resulting in the decomposition of lignocellulosic material [8]. Activation with KOH yields activated carbon with the best pore structure and the greatest specific surface area, but the yield is lower than with other activators [9]. According to some research findings, MgCl2 has a potent dehydrating effect on polymers and is also beneficial for forming porous structures in activated carbon [10].

Activated carbon exhibits promising potential as an adsorbent for the heavy metal Fe present in well water surrounding final waste disposal sites, such as the Final Disposal Site (TPA) located in Air Dingin area in Padang. The accumulation of waste materials generates leachate, a significant contributor to the contamination of well water sources. There exist three primary sources of leachate, specifically the water content derived from waste, the water resulting from biological activities, and the introduction of water through rainfall. The leachate will infiltrate the soil until it reaches the wells belonging to the local inhabitants. The leachate has the potential to contain various hazardous substances, including inorganic compounds such as ammonium, calcium, potassium, sulfate, chloride, and heavy metals. It may also contain organic compounds like dissolved and particulate organic matter, volatile fatty acids, humic substances, fulvic substances, and xenobiotic substances. Additionally, there is a possibility of the presence of pathogenic microorganisms within the leachate [11]. The presence of these substances will result in water pollution.

Iron (Fe) is classified as a heavy element that has the potential to contaminate groundwater sources such as well water. The presence of an excessive amount of iron (Fe) can have detrimental effects on both the environment and human health. Biological processes are incapable of decomposing heavy metals, rendering them non-biodegradable. However, these metals have a tendency to accumulate within the food chain. The well water in the vicinity of the Air Cold TPA Padang City has a range of Fe concentrations between 0.407 and 1.0 mg/L, as reported by reference [12]. In accordance with established guidelines, the permissible limit for iron content in drinking water quality standards is restricted to a maximum concentration of 0.3 mg/L [13].

Based on the aforementioned rationale, a study was undertaken to investigate the utilization of activated carbon derived from cocoa pod husks. The activation process involved the use of different activators, namely ZnCl2, H3PO4, KOH, and MgCl2 , each at a concentration of 10%. ZnCl2 is a salt derived from a strong acid and a weak base, while H3PO4 is a weak acid. KOH, on the other hand, is a strong base, and MgCl2 is a salt formed from a strong acid and a strong base.

EXPERIMENTAL SECTION

Materials

The primary source utilized in this study is the cocoa pod husks, sourced specifically from the Pauh region in Kamang Mudik, Agam Regency. The well water of residents residing in the vicinity of the Final Disposal Site (TPA) located in Air Dingin Padang is identified as the primary origin of heavy metal contamination. The solution employed consists of ZnCl2, H3PO4, KOH, MgCl2, distilled water, and additional substances required for the purpose of analysis.

Instrumentation

The equipment employed in this study comprises several instruments such as glassware, an analytical balance, an oven, a pyrolysator, a desiccator, a stainless-steel knife, a mortar, a 100 mesh sieve, pH indicator paper, an atomic absorption spectrophotometer (AAS), and other necessary tools for conducting the analysis.

Procedure

Research Design

The present study involved conducting an experiment to investigate the efficacy of various activators in activating carbon derived from cocoa pod husks. The study employed a descriptive research strategy, focusing on examining the link between the features of the activator and the outcomes of the activated carbon tests. The conducted experiments involved the utilization of activators in the following manner.

A = ZnCl2 10%

B = H3PO4 10%

C = KOH 10%

D = MgCl2 10%

Research Stages

Preparation of cocoa pod husks

The outer layer of the cocoa pod is subjected to a cleaning process, followed by fragmentation into smaller segments, and afterwards subjected to a drying procedure within an oven set at a temperature of 100 ℃ for a duration of 24 hours.

The production of activated carbon

The carbonization process involves subjecting dried cocoa pod husks to pyrolysis in a pyrolysator for a duration of three hours. The carbon material underwent grinding and subsequent sieving using a 100 mesh screen. It was then subjected to activation using activators consisting of ZnCl2 10%, H3PO4 10%, KOH 10%, dan MgCl2 10% for a duration of 24 hours. The carbon substance and activator are present at a ratio of 1:2. Following the completion of the process, the activated carbon undergoes a thorough washing procedure using distilled water until it reaches a state of neutrality, characterized by a pH value of 7. The activated carbon undergoes a drying process in which it is subjected to an oven at a temperature of 100℃ for a duration of 24 hours.

Observation

The research commences by conducting observations on the raw materials, examining the properties of activated carbon, and investigating the adsorption capabilities of activated carbon in relation to the heavy metal Fe. The process of examining raw materials encompasses the assessment of alterations in both the mass and water content of cocoa pod husks. The observed parameters pertaining to the properties of activated carbon encompass the yield (%), water content (%), ash content (%), parts lost during heating to 950℃ (%), pure activated carbon (%), and iodine absorption capacity (mg/g). The capacity of activated carbon to adsorb Fe metal ions was assessed by the utilization of an atomic absorption spectrophotometer (AAS).

RESULT AND DISCUSSION

The examination of raw materials and the subsequent carbonization process.

The cocoa pod husk is used as the primary raw material due to its composition rich in lignocellulosic material, which possesses the potential to undergo conversion into carbon atoms. The study involved the examination of raw materials, namely the water content of the husk before to and following the drying process. Table 1 displays the water content of cocoa pod husks.

Table 1. Water content of the cocoa pod husk

Sample	Water content (%)
Fresh cocoa husk	80,04
Dried cocoa husk	19,60

The carbonization process induces the decomposition of the organic materials present in the cocoa husk, leading to the liberation of volatile compounds. The majority of non-carbon components are emitted into the air. A pore will be formed as a result of the void created by the volatile matter. The resultant carbon has a limited pore capacity and surface area. The emission of volatile compounds leads to a reduction in size, resulting in a drop in the overall mass of the material as shown in Table 2.

Table 2. The reduction in mass of cocoa husk during the carbonization process

Description	Mass and Unit
Initial mass	980 g
Final mass	560 g
Mass loss	420 g
Reduction in size	42,86%

The carbonization process yields charcoal with a black-gray appearance, but certain portions may remain uncarbonized due to the imperfect nature of the process. The carbonization process involves initiating heating from the lower section of the pyrolysator tube, hence facilitating faster charring of the material located at the bottom. In addition to carbonized material, the process of carbonization also yields byproducts such as tar and liquid smoke.

Characteristics of Activated Carbon

Yield

The objective of the yield calculation is to ascertain the proportion of charcoal that undergoes conversion into activated carbon subsequent to the activation procedure. Table 3 displays the outcomes of the examination conducted on the yield of activated carbon derived from cocoa husk, which were activated using various activators.

Table 3. Activated Carbon Yield

Treatment	Yield (%)
KOH	70,18
H3PO4	73,82
MgCl2	77,32
ZnCl2	82,24

The obtained yield of activated carbon ranged from 70.18% to 82.24%. The activation method involving KOH resulted in the lowest yield, with a percentage of 70.18%. Conversely, the activation method with ZnCl2 yielded the highest percentage, reaching 82.24%. The water content of activated carbon has an impact on its production. An increase in water content leads to a corresponding rise in yield. This observation is supported by the fact that the activation of ZnCl2 results in the maximum water content, while the activation of KOH leads to a comparatively lower water content.

In general, the utilization of ZnCl2 as an activator leads to an enhancement in yield by facilitating the creation of an aromatic graphite structure [7]. Zinc chloride (ZnCl2) functions as a Lewis acid, a type of chemical species that accepts free electron pairs. Consequently, its presence enhances the aromatic condensation polymerization reaction. Condensation polymerization refers to the chemical process in which polymers are synthesized through the combination of small molecules containing functional groups, either with or without the concurrent liberation of small molecules. To clarify, this phenomenon exclusively takes place inside monomers possessing functional groups.

The utilization of KOH as an activator results in the development of a favorable pore structure and the attainment of the highest specific surface area for activated carbon. However, it is important to note that the yield obtained through KOH activation is comparatively lower when compared to other activators. The reason for this phenomenon is that the activation of KOH expedites the elimination of carbon by means of intercalation or insertion of potassium metal ions into the carbon network [9]. The process of intercalation gives rise to the formation of micropores, mesopores, and even macropores.

Water content

The water content refers to the quantity of water that is chemically attached to activated carbon. The process of carbonization results in the release of water content and the subsequent opening of carbon pores. The activator is a chemical compound that acts as a desiccant, facilitating the removal of water molecules from carbon compounds. Table 4 displays the outcomes of the examination conducted on the water content of activated carbon derived from cocoa pod husks that were activated using various activators.

Table 4. Average Water Content of Activated Carbon

Treatment	Water content (%) ±SD
MgCl2	0,75 ±0,25
KOH	1,00 ± 0,50
H3PO4	1,75 ± 0,25
ZnCl2	2,25 ± 0,25

The average water content of the activated carbon obtained ranges from 0.75–2.25%. The lowest water content (0.75%) was produced by MgCl2 activation and the highest water content (2.25%) was produced by ZnCl2 activation. The data in Table 4 shows that all products have met the quality requirements for activated carbon water content according to the Indonesian National Standard (SNI) 06-3730-1995. Specifically, the water content does not exceed 15% [14].

A higher surface area of activated carbon can be inferred from a lower water content, leading to enhanced adsorption capacity and efficiency. According to some research findings, it has been shown that MgCl2 exhibits a significant capacity for dehydrating polymers and can also be effectively utilized in the creation of porous structures in activated carbon [10].

The presence of a significant amount of water content results in the infiltration of water molecules into the pores of activated carbon, leading to a competitive effect during the adsorption process. Consequently, this competition diminishes both the adsorption capacity and efficiency of the activated carbon. The augmentation in water content can be attributed to the presence of many polar functional groups on the surface of activated carbon, facilitating enhanced interaction with water molecules owing to their shared polarity. This phenomenon can be attributed to the quantity of distilled water incorporated into the laundering procedure. Furthermore, it should be noted that activated carbon has hygroscopic properties, resulting in its water content being influenced by the absorption of moisture from the surrounding air at various stages such as cooling, weighing, and packaging.

Ash Content

Ash is an element that lacks carbon and exists as a mineral residue found within the pores of activated carbon. The carbonization process results in the generation of ash as a byproduct of the remaining combustion. The process of activation results in the concentration of ash content, which is contingent upon the type of raw material employed. Silica is a prominent constituent of ash. An increase in silica content leads to a corresponding rise in ash content. Table 5 displays the outcomes of the examination conducted on the ash content of activated carbon derived from cocoa pod husks, which were activated using various activators.

Table 5. Average Activated Carbon Ash Content

Treatment	Ash Content (%) ±SD
H3PO4	3,50 ± 1,50
MgCl2	5,50 ± 0,50
KOH	6,50 ± 0,50
ZnCl2	11,00 ± 0,00

The activated carbon obtained has an average ash concentration ranging from 3.50% to 11.00%. The activation method including H3PO4 resulted in the lowest ash level, measuring at 3.50%. Conversely, the activation method with ZnCl2 yielded the greatest ash content, measuring at 11.00%. The data shown in Table 5 indicates that the activated carbon product activated with ZnCl2 fails to meet the quality standards for ash level. According to the Indonesian National Standard (SNI) 06-3730-1995, the maximum allowable ash percentage is 10% [14].

The reduced ash concentration is attributed to the diffusion reaction of carbon during the activation process, which facilitates the displacement of the pore-blocking activator. On the other hand, the elevated ash content might be attributed to the continued oxidation processes of activated carbon, particularly in particles of smaller size, as the activator remains entrapped within the pores. The ash level of activated carbon can be correlated with the mineral elements present in the raw materials and activators utilized, including zinc (Zn), potassium (K), phosphorus (P), and magnesium (Mg).

The activation of ZnCl2 led to the attainment of the greatest ash content. The inability of ZnCl2 to dissolve and eliminate minerals in carbon can be attributed to this phenomenon. The presence of a high ash percentage is not anticipated due to its propensity to obstruct pores and diminish the mechanical integrity of activated carbon. As the ash concentration increases, there will be a corresponding drop in both the adsorption capacity and efficiency.

Volatile Substances in 950 °C Heat Treatment

Volatile substances is the non-carbon elements H2, CO, and CO2 that result from interactions between carbon elements and water vapor. Pores will form in the space left by volatile substances during the carbonization process. In addition, the activator helps to sanitize and expand the surface of the activated carbon. The activator is capable of degrading non-carbon elements, thereby weakening the surface structure of activated carbon and releasing non-carbon elements, namely hydrogen, oxygen, and nitrogen, in the form of liquid tar and gas. Table 6 displays the results of an analysis of activated carbon volatile substances from cocoa pod hulls activated with various activators.

Table 6. Average Volatile Substances of Activated Carbon

Treatment	Volatile Substances (%) ±SD
ZnCl2	9,38 ± 0,78
KOH	15,56 ± 0,61
H3PO4	15,59 ± 0,48
MgCl2	15,61 ± 0,36

The average levels of volatiles extracted from activated carbon varied between 9.38 and 15.61%. ZnCl2 activation generated the least amount of volatile matter (9.38%), while MgCl2. activation produced the highest amount of volatile matter (15.61%). The data in Table 6 demonstrates that all products meet the quality requirements for activated carbon volatile matter as specified by the Indonesian National Standard (SNI) 06-3730-1995, as it is less than 25% [14].

Essentially, the level of volatile matter is affected by the carbonization duration and temperature. If the carbonization process is prolonged at high temperatures, numerous volatile substances are released, resulting in an increase in the number of pores in the activated carbon. In contrast, large levels of volatile matter are the result of non-carbon elements that have not fully decomposed during the carbonization and activation processes. The greater the volatile matter content, the lower the adsorption capacity and efficacy.

Fixed Carbon

Fixed carbon is carbon bound to activated carbon after water, charcoal, and volatile substances have been removed [15]. The amount of cellulose, hemicellulose, and lignin that can be converted into carbon atoms affects the amount of purified activated carbon extracted from cocoa pod husks. Table 7 displays the results of an analysis of purified activated carbon extracted from cocoa pod husks and activated with various activators.

Table 7. Average Fixed Carbon

Treatment	Fixed carbon (%) ±SD
KOH	76,94 ±0,61
ZnCl2	77,37 ± 0,53
MgCl2	78,14±0,61
H3PO4	79,16 ±1,27

The obtained average fixed carbon content ranges from 76.94 to 79.16%. KOH activation generated the least pure activated carbon (76.94%) and H3PO4 activation produced the most fixed carbon (79.16%). The data in Table 7 demonstrates that all products satisfy the quality requirements for fixed carbon according to the Indonesian National Standard (SNI) 06-3730-1995, as the value is greater than 65 % [14].

High concentrations of fixed carbon indicate that there are a greater number of bonded carbon elements, thereby increasing the number of cavities and surface area of activated carbon. The greater the fixed carbon content, the greater the adsorption capacity and efficacy. Moisture content, ash content, and levels of volatile substances influence fixed carbon. If the sum of these three variables is high, the amount of fixed carbon will decline.

The utilization of H3PO4 as an activator led to the attainment of the lowest ash content, albeit accompanied by rather high levels of water and volatile matter content. In contrast, the utilization of potassium hydroxide (KOH) for activation results in a reduced water content, while concurrently leading to elevated levels of ash and volatile matter content. Furthermore, the utilization of potassium hydroxide (KOH) for activation results in the least amount of product obtained, leading to the production of purified activated carbon. Nevertheless, the utilization of potassium hydroxide (KOH) resulted in the most elevated iodine value. This phenomenon can be attributed to the superior production of micropores and the more favorable distribution of pore sizes compared to alternative activators.

Iodine Absorption Number

The measurement of iodine absorption serves as a straightforward and often employed metric for the characterization of activated carbon. The assessment of iodine absorption provides insight into the pore dimensions of activated carbon. This test can serve as an indicator of the activation of carbon. Iodine molecules possess a diminutive size, hence enabling them to effectively demonstrate the adsorption capacity of activated carbon towards molecules of comparable dimensions. The determination of iodine number involves the titration of iodine and sodium thiosulphate solution. Table 8 displays the outcomes of the analysis conducted on the iodine number of activated carbon derived from cocoa pod husks, which were activated using various activators.

Table 8. Average Iodine Number of Activated Carbon

Treatment	Iodine number (mg/g) ±SD
ZnCl2	574,36 ±3,17
MgCl2	590,22 ±6,35
H3PO4	609,26 ±12,69
KOH	628,30 ±6,35

The obtained range of the average iodine number of activated carbon was 574.36–628.30 mg/g. The activation process using ZnCl2 resulted in the lowest iodine number, measuring at 574.36 mg/g. Conversely, the activation process including KOH yielded the greatest iodine number, measuring at 628.30 mg/g. According to the information presented in Table 8, it can be observed that none of the goods meet the quality standards for iodine absorption as specified by the Indonesian National Standard (SNI) 06-3730-1995, as their iodine absorption values fall below the threshold of 750 mg/g [14].

The lowest iodine number is seen with activation using ZnCl2, which can be attributed to the generation of fewer microporous structures and the degradation of certain pore walls. Furthermore, the introduction of ZnCl2 led to an increase in both water content and ash content, consequently impeding the adsorption mechanism of iodine (I2).

The reason why KOH activation yields the largest iodine number is due to its substantial microporous structure, which arises from the chemissorption (chemical adsorption) of potassium metal ions within the carbon pores. The utilization of ZnCl2, H3PO4, KOH, and MgCl2 as activators in chemisorption experiments led to varying levels of reactivity and expansion of the pore structure [16]. As the iodine number increases, there is a corresponding increase in the absorption capacity of activated carbon.

Analysis of Activated Carbon Absorption of Heavy Metal

The efficacy of activated carbon in adsorbing heavy metal Fe in well water is determined by comparing the concentration of Fe before and after the addition of activated carbon. The present observation employs the atomic absorption spectrophotometry (AAS) technique as outlined in the SNI 6989.4:2009 standard [17]. Table 9 displays the outcomes obtained from the assessment of the initial concentration of iron (Fe) in well water.

Table 9. Initial Fe Concentration in Well Water

Test no.	Fe concentration (mg/L)
1	0,4728
2	0,5281

The initial concentration of Fe was determined to be 0.50045 mg/L on average. This suggests that the intake of well water may not be advisable due to the fact that it exceeds the established drinking water quality standards, which specify a maximum iron concentration of 0.3 mg/L [13].

This examination represents a practical implementation of activated carbon as a means of purifying or cleansing water contaminated with heavy metals. The well water utilized exhibits characteristics of turbidity, displaying a brown hue and emitting an unpleasant odor, attributable to the presence of organic substances and iron content. When well water is allowed to sit in a container for an extended period, it undergoes a process that leads to the formation of a brown sludge. Upon the addition of 0.25 grams of activated carbon to a 50 milliliter sample of well water, a noticeable reduction in both the brown coloration and odor was observed. The observed phenomenon can be attributed to the presence of organic materials and iron that have been effectively adsorbed within the pores of the activated carbon. Table 10 displays the outcomes obtained from the assessment of the ultimate concentration of iron in well water subsequent to the introduction of activated carbon.

Table 10. Average Final Concentration of Fe in Well Water

Treatment	Fe concentration (mg/L)
ZnCl2	< 0,0049
H3PO4	< 0,0049
MgCl2	< 0,0113
KOH	< 0,0169

The data presented in Table 10 demonstrates the ability of all products to decrease the concentration of Fe in well water. However, it is important to note that the exact values obtained cannot be determined with precision due to the utilization of parts per million (mg/L) units, which results in the occurrence of the Limit of Detection (LoD). The minimum value that can be generated by the SSA (Substance Specific Activity) is 0.0049 milligrams per liter (mg/L). Hence, employing parts per billion (ppb) units, specifically µg/L or 0.001 mg/L, for quantifying the ultimate Fe content is recommended in order to attain enhanced precision in the collected data. Table 11 provides a comprehensive overview of the capacity and efficiency of activated carbon adsorption in relation to the heavy metal Fe.

Table 11. Absorption Capacity and Efficiency of Activated Carbon Absorption

Treatment	Absorption Capacity (mg/L) ± SD	Absorption Efficiency (%) SD
KOH	0,0967 ± 0,00	96,6230 ± 2,28
MgCl2	0,0978 ± 0,00	97,7354 ± 2,23
ZnCl2	0,0991 ± 0,00	99,0209 ± 0,00
H3PO4	0,0991 ± 0,00	99,0209 ± 0,00

According to the results presented in Table 11, the absorption capacity is categorized as being of a significantly low magnitude, while the absorption efficiency is observed to be notably high. The observed phenomenon is contingent upon the starting concentration of the adsorbate (Fe) and the concentration of the adsorbent (activated carbon). The initial concentration of iron (Fe) was quite low, measuring 0.50045 mg/L, and was not in equilibrium with the concentration of activated carbon supplied, which was 0.25 g. At the point of maximal Fe adsorption, there remain unoccupied spots on the surface of the adsorbent, resulting in a decrease in the overall absorption capacity. On the other hand, the presence of a significant concentration of activated carbon leads to a notable enhancement in absorption efficiency. Hence, acquiring knowledge about the appropriate adsorption conditions is crucial in order to achieve maximum adsorption capacity and efficiency. The utilization of unactivated cocoa pod carbon has been found to effectively decrease the levels of iron (Fe2+) and manganese (Mn2+). The extent of reduction in iron and manganese concentrations is dependent on the quantity of carbon employed [18].

CONCLUSION

The cocoa pod husk activated carbon obtained exhibits a yield ranging from 70.18% to 82.24%. The moisture content falls within the range of 0.75% to 2.25%, while the ash content ranges from 3.50% to 11.00%. The portion lost on heating at 950 ℃ or volatile compounds is found to be between 9.38% and 15.61%. The pure activated carbon content ranges from 76.94% to 79.16%. Additionally, the absorption capacity of iodine is measured to be between 574.36 mg/g and 628.30 mg/g. The activated carbon that is generated exhibits the ability to adsorb the heavy metal iron (Fe) present in well water. It possesses an absorption capacity ranging from 0.0967 to 0.0991 mg/g, along with an absorption efficiency ranging from 96.62% to 99.02%. Based on the iodine number, it has been determined that KOH is the most effective activator for manufacturing activated carbon from cocoa pod husks, with a value of 628.30 mg/g. In terms of cost, MgCl2 is the most economical activator, priced at Rp. 30/g. Other activators such as H3PO4, KOH, and ZnCl2 are priced at Rp. 60/ml, Rp. 160/g, and Rp. 320/g, respectively. Ongoing experimentation with the scanning electron microscope (SEM) remains imperative in order to enhance our understanding of the precise structural characteristics of the activated carbon that is produced.

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