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Design of water purification polluted by heavy metal Fe with active charcoal media of palm oil and bamboo

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Abstract. The design of a water purifier contaminated with heavy metal Fe has been made using activated charcoal media from palm oil shell and bamboo. The best oil palm shell activated charcoal with the following conditions: yield; 78.79%, water content; 0.50%, ash content; 10%, volatile matter content; 59.13%, bound carbon content; 41%, while the best activated bamboo charcoal with conditions: yield; 68.64%, water content; 0.50%, ash content; 8%, volatile matter content; 61.80%, bound carbon content; 38%. The experiment was started by making a sample of Kahayan river water according to data from the environmental service of Central Kalimantan province with a Fe content of 5.59 mg / L. The sample was tested using an Atomic Absorption Spectrophotometer (AAS). From the data, it can be concluded that the absorption of heavy metal Fe with a length of 5 cm of activated charcoal can reduce all levels of Fe in the sample so that variations in the length of activated charcoal filling exceeding 5 cm are more effective

Keywords: activated charcoal, heavy metal, water purifier.

1. Introduction

One of the important factors in the use of water in daily life is to meet drinking water needs. Clean water is water that is free from disease-causing microorganisms and chemicals that are detrimental to human health and other living things [1]. Water with poor quality in the long term can lead to bone loss, tooth corrosion, anemia, and kidney damage. This occurs due to the presence of heavy metals dissolved in the water, which are toxic (poison) [2].

The Kahayan River is an example of a river polluted with heavy metals in Central Kalimantan. The heavy metal content in the Kahayan River shows that the heavy metal content of Fe in water samples taken for the last five years has exceeded the threshold, which is shown in Table 1.

Table 1. Data on Monitoring of Kahayan River Water Quality for 2015-2018[3]

Sampling point name	Distance from estuary (kilometers)	Heavy metal content of Fe (mg/L)								Maximum limit of class I parameters (mg/L)
		2015		2016		2017		2018		
		Feb	Agu	Feb	Agu	Mar	Nov	Feb	Jul	
Hanua	345,12	0,01	0,61	1,99	*	0,63	*	2,65	1,64	0,3
Pelabuhan Tumbang Rungan	241,42	0,02	0,51	2,4	7,52	0,36	3,53	2,9	2,41	0,3

Sampling point name	Distance from estuary (kilometers)	Heavy metal content of Fe (mg/L)								Maximum limit of class I parameters (mg/L)
		2015		2016		2017		2018		
		Feb	Agu	Feb	Agu	Mar	Nov	Feb	Jul	
Pelabuhan Pesawat MAF Palangka Raya	233,21	2,22	0,38	1,97	6,34	0,56	3,50	3,02	2,44	0,3
Pelabuhan Rambang	229,59	2,86	0,45	1,86	6,77	0,66	2,79	2,86	2,15	0,3
Pelabuhan PT.Pelindo Pulang Pisau	77,82 Km	*	*	*	5,59	*	*	*	*	0,3

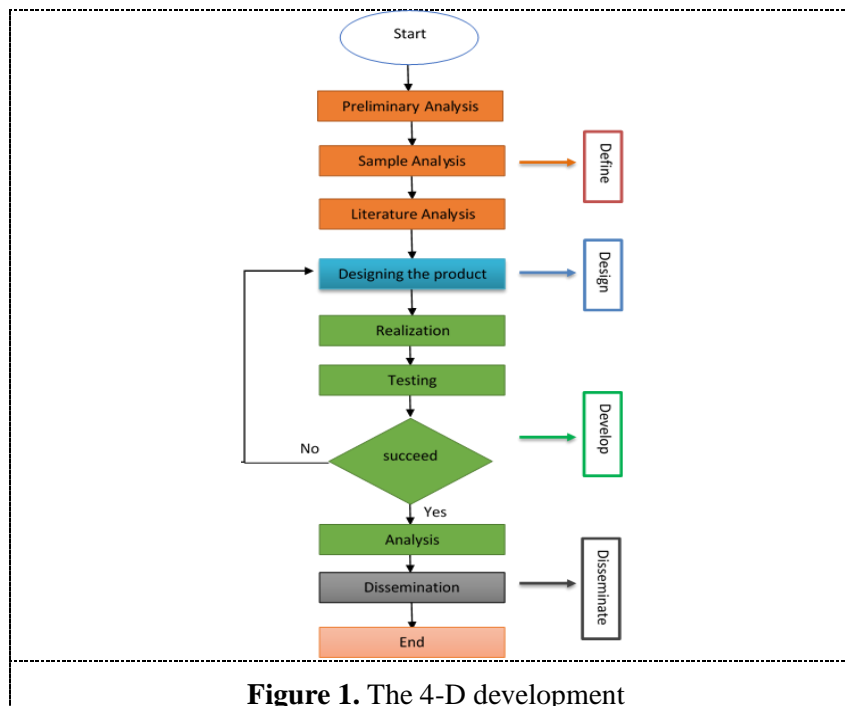
The first-class parameter is the water parameter, which is designated for drinking water raw water and or other designation requiring the same water quality.

Heavy metals are harmful to life in organisms if their presence exceeds threshold levels. These heavy metals also threaten human health because they can become toxic compounds when present in the human body and exceed the threshold [4]. According to the Government Regulation of the Republic of Indonesia Number 82 of 2001 concerning Management of Water Quality and Water Pollution, it states that the need for drinking water based on chemical parameters for the maximum permissible iron (Fe) content does not exceed 0.3 mg / L. Iron (Fe) is needed by the body in small amounts to form red blood cells, namely 7-35 mg / day, mostly obtained from water. Fe substance that exceeds the dose causes health problems for the body.

Fe in large doses can damage the intestinal wall. Death is often caused by damage to the intestinal wall. Fe levels exceeding 1 mg / L cause irritation to the eyes and skin. The solubility of iron in the water that exceeds 10 mg / L causes the water to smell like rotten eggs [5]. To reduce levels of heavy metal Fe, a water purifier is needed in which there are amorphous carbon compounds produced from materials containing carbon that can adsorb these chemical compounds, namely activated charcoal. Activated charcoal can be used to adsorb certain compounds, including reducing heavy metal levels Fe [6]. Based on the design of a water purifier which uses coagulation, flocculation, activated sand filtration, and activated carbon adsorption methods and a combination of activated sand filtration and activated carbon adsorption in laundry liquid wastewater, it can reduce turbidity to the maximum limit of clean water. The water produced is not clean water but is safe to dispose of in the environment [7]. Researchers are interested in developing designs for water purification devices that can reduce the concentration of heavy metals in river water so that it becomes clean water. Efforts to reduce levels of heavy metal Fe in the Kahayan River require the development of designs for water purification devices using activated charcoal media from palm oil and bamboo shell waste. Activated carbon is known as an adsorbent that promises to be applied in a wide variety of applications because of its low cost, well-developed pore structure, and high adsorption capacity [8].

2. Method

The method used in this research is the 4-D Model Research and Development method developed by S. Thiagarajan, Dorothy S. Semmel, and Melvyn I. Semmel. The 4-D development model consists of 4 main stages, namely, Define, Design, Develop, and Disseminate [9]. The 4-D development stage used in this research was shown in figure 1.



The purifier developed in this study consists of two parts in the manufacture of this water purifier, namely the buffer and the purifier itself. The support is made of angle iron with a length of 12 meters. The water purifier consists of a tube for activated charcoal media made of glass syrup bottles and a container for contaminated water made from 20 liters of drinking water gallons. The process of making and testing tools was carried out from July 2019 to January 2020.

2.1 Activated Charcoal Making

Making activated charcoal uses a procedure developed by which consists of several stages, namely the carbonization stage, the refining stage, and the activation stage [10]. The materials used for activated charcoal are palm oil waste and bamboo. The two ingredients are first cleaned and dried. a) The carbonization stage, oil palm, and bamboo shells are carbonized at 700°C for 1 hour. After one hour, the temperature is lowered and cooled overnight. b) In the refining stage, the coconut shell charcoal and bamboo are mashed using a blender. The powder of oil palm shell charcoal is filtered at a pass size of 60 mesh and retained at 80 mesh. The bamboo charcoal powder is filtered and passes at 80 mesh size c) Activation Stage, the filtered powder is physically activated. The powder is soaked in distilled water for 24 hours to enlarge the pores. After soaking the charcoal, then filtering and drying, the charcoal powder is then heated into a thermocone furnace at 900°C for 1 hour. The surface area increases with increasing activation temperature [11]. The activated charcoal powder is cooled. The charcoal was analyzed for yield, moisture content, ash content, volatile matter content, and bound carbon content.

2.2 Water Sample Making and Testing of Heavy Metal Content

Making a sample of water contaminated with heavy metal Fe with the highest metal content, namely 5.59 mg / L, according to data from the Central Kalimantan Province Environmental Service. The author made a sample of water contaminated with heavy metal Fe with a Fe content of 5.59 mg / L by diluting the standard 1000 ppm Fe solution, using the following dilution formula:

$$M_1 \times V_1 = M_2 \times V_2 \quad (1)$$

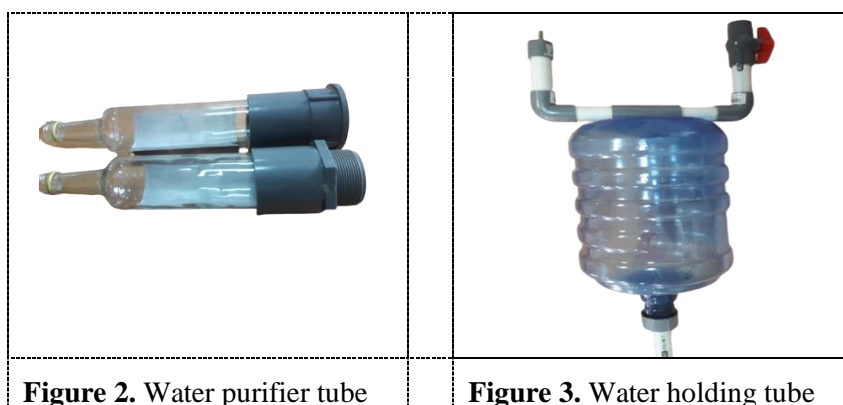
Where M_1 the concentration of the diluted solution is, M_2 is the concentration of the diluent solution, V_1 is the volume of the standard solution that is diluted, and V_2 is the volume of the diluted solution.

Samples that have been made based on the dilution formula are then tested at the Central Kalimantan Provincial Health Laboratory Center. Tests were carried out to ensure that the water sample contaminated with heavy metal Fe that has been prepared is exactly 5.59 mg / L.

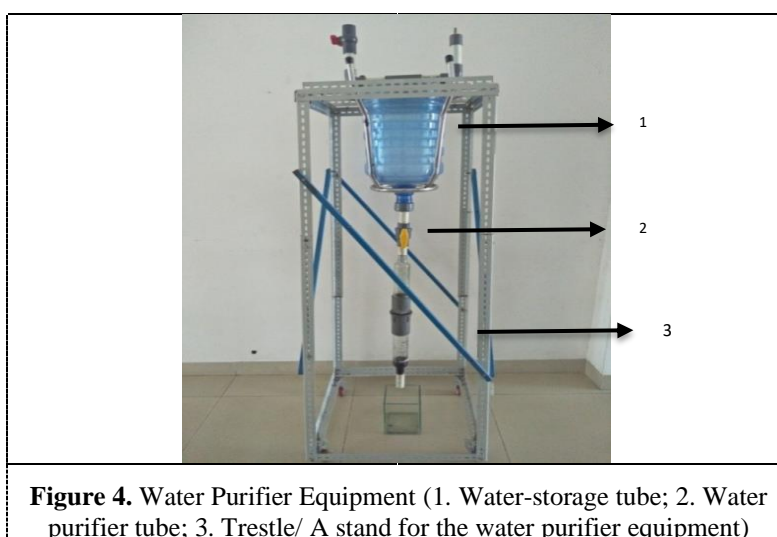
3. Result and Discussion

3.1 The process of making a water purifier

The design of the water purifier that has been made is divided into two parts, namely the buffer part and the purifier part. The support section is made of an iron frame with a length of 61 cm, a width 61 cm, and a height of 150 cm. The water purifier tube is made of two glass bottles, connecting the outer and inner pipes with a size of 2 inches. The two glass bottles were perforated using a drill bit with a drill bit size of 40 mm. Glass bottles that have been perforated are connected to a 2-inch pipe and glued using resin, as shown in figure 2. The water reservoir is made of 20 liters of drinking water gallons. The bottom of the gallon of water is drilled and connected to the U pipe; both ends of the U pipe are used to enter the water and provide air pressure, as shown in figure 3.



The complete design of a water purifier is shown in Figure 4. The process of making a water purifier in this study uses three types of activated charcoal as a water purification medium (oil palm shell activated charcoal, bamboo activated charcoal, and oil palm-bamboo mixed activated charcoal) as needed. And the common test conditions. Similar research has produced a water purifier that can improve water quality by reducing water acidity and heavy metal content with just one tube and different absorbent materials [12,13].



3.1 Testing of activated charcoal

Testing of activated charcoal-based on quality standards Indonesian national standards 06-3730-1995, regarding activated charcoal, the maximum moisture content contained in the charcoal is 15%, the maximum ash content is 10%, the maximum volatile substance content is 25%, and the bound carbon content is at least 65%.

Table 2. Results of the Activated Charcoal Quality Test

Treatment	Water content	Ash content	Volatile Substance Levels	Bounded carbon content
A ₁	0.50%	18%	62.44%	38%
A ₂	0.50%	10%	59.13%	41%
A ₃	0.50%	7%	62.60%	37%
B ₁	1.17%	8%	62.76%	37%
B ₂	1.17%	9%	67.96%	32%
B ₃	0.50%	8%	61.80%	38%
(SNI) 06-3730-1995	Max. 15%	Max. 10%	Max. 25%	Min. 65%

Notes:

- A₁ = Oil palm shell activated charcoal, the size of the charcoal powder passes 40 meshes and is retained at 60 mesh
- A₂ = Oil palm shell activated charcoal, the size of the charcoal powder passes 60 mesh and is retained at 80 mesh
- A₃ = Oil palm shell activated charcoal, the size of the charcoal powder passes 80 mesh
- B₁ = Bamboo activated charcoal, the size of the charcoal powder passes at 40 mesh and is retained at 60 mesh
- B₂ = Bamboo activated charcoal, the size of the charcoal powder passes at 60 mesh and is retained at 80 mesh
- B₃ = Bamboo activated charcoal, the size of the charcoal powder passes at 80 mesh

Research that has been carried out the highest amount of moisture content is found in activated charcoal derived from bamboo, while charcoal from palm oil has relatively the same moisture content. There is no effect of size variation (40 mesh, 60 mesh, and 80 mesh) of activated charcoal on the water content contained. This water content is determined in order to determine the hygroscopic properties of activated charcoal. In line with this study, there is a tendency that the activation temperature is inversely related to moisture content. Thus, the heating that is carried out on charcoal is successful in reducing the moisture content until it reaches the required quality standard[14]. Water content is related to hygroscopic properties, moisture content, porosity properties, and is influenced by the time the charcoal is placed in the open during the cooling process. The water content in this study is classified as low, which means that the carbonization process that has been carried out in the previous stage has gone very well.

The ash content of activated charcoal from palm oil and bamboo does not have a significant difference. However, in general, it can be observed that the ash content in palms reaches a percentage of 18% (size 40 mesh). The percentage does not meet the SNI quality standard for ash content, which is a maximum of 10%. However, apart from palm charcoal measuring 40 mesh, all other activated charcoal is below the standard or exactly meets the SNI quality standard. Another research showed that the ash content of activated charcoal activation is in the range of 2.96 - 9% [15]. This result is quite consistent with the results obtained by researchers where the ash content obtained is around 9%. It seems like the water content, the variation in the size of activated charcoal, has no significant effect on the ash content. Measuring the ash content of activated charcoal has the aim of knowing the metal oxide content in activated charcoal. Two factors influence the ash content, namely the activation temperature factor, the activation time, and also the combination of temperature and activation time.

The content of volatile substances required by the SNI quality standard is a maximum of 25%. In this study, the average level of volatile substances obtained was 63.6%. The volatile content that meets the standard means that a reaction between carbon atoms and water vapor will form volatile non-carbon

compounds such as CO, CO₂, and H₂ during the activation process [16]. The high percentage of volatile substances in activated charcoal should not be avoided because the compounds that stick to the surface of activated charcoal can reduce the absorption of charcoal in both solution and gas [14].

In general, the percentage of bound carbon in this study was 36.44%. Between the two types of activated charcoal, the highest content of bound carbon is found in oil palm, although the difference between the two is not very significant. As before in the moisture content, ash content, and volatile matter content, the bonded carbon content was not affected by variations in the size of the char (40, 60, and 80 mesh). The high and low levels of carbon produced in the study are determined by various factors, namely the content of volatile substances and the content of activated charcoal ash. Ash content and substance content are easily reversed with the protected carbon content. The greater the value of volatile content, the lower the carbon stored in charcoal. The lower the value of the volatile substance and the ash content of activated charcoal, the higher the value of the carbon content; Besides, it is also supported by the content of cellulose and lignin, which can be carbon atoms [17].

The next test was carried out to determine the levels of heavy metal Fe in the filter inlet and outlet, which was carried out at the Physics Laboratory of IAIN Palangkaraya. Testing of water purification equipment by inserting activated charcoal into a glass tube with a filling length of 5 cm. The activated charcoal used is palm shell activated charcoal with a powder size of 40 mesh and held at 60 mesh and bamboo activated charcoal with a powder size of 80 mesh. In the next step, the researchers entered the water sample that was contaminated with heavy metal Fe 5.59 mg / L into the tube on the water tap located on the U pipe. The tap on the U pipe was then closed, and it was ensured that no air could enter. The tube is pressurized 3 bars to help speed up the purification process.

The results of purification are collected with a 500 mL measuring cup. 500 mL of purified water is then put into a sterile plastic bottle and tested at the Central Kalimantan Provincial Health Laboratory Center. The researcher repeated the previous process by varying the length of the activated charcoal filling with a length variation of 5 cm, 10 cm, and 15 cm. Types of activated charcoal are palm shell activated charcoal, bamboo activated charcoal, and oil palm shell activated charcoal. The test result data is shown in table 3.

Table 3. Data Comparison of Heavy Metal Fe in the Inlet and Outlet Filters

Treatment	Heavy Metal Content of Fe in the filter inlet (mg / L)	The heavy metal content of Fe at the filter outlet (mg / L)
A ₁	5,59	<0,014
A ₂	5,59	<0,014
A ₃	5,59	<0,014
B ₁	5,59	<0,014
B ₂	5,59	<0,014
B ₃	5,59	<0,014
A ₁ B ₁	5,59	<0,014
A ₂ B ₂	5,59	<0,014
A ₃ B ₃	5,59	<0,014

Notes; A = oil palm shell activated charcoal, B = bamboo activated charcoal, AB = oil palm-bamboo shell activated charcoal; 1 = length of activated charcoal filling 5 cm, 2 = length of activated charcoal filling 10 cm, 3 = length of activated charcoal filling 15 cm.

The purification results obtained were all variations in the length of the filling and the variations in the type of activated charcoal were able to reduce heavy metal Fe content by more than 70%. From the data, it can be seen that the variation in the length of the filling does not significantly affect the decrease in the heavy metal Fe content. The factor that affects the adsorption of activated charcoal is the surface area. The more the surface area of the adsorbent, the more substance is adsorbed. This adsorbent is

determined by the particle size and the number of adsorbents [18]. The length of the activated charcoal content used in this study is 5 cm, 10 cm, and 15 cm, meaning that the length of the 15 cm content has a larger surface area than the 10 cm length of the activated charcoal content, which is bigger than the 5 cm content length. The difference in the surface area of the adsorption power of 15 cm must be greater than 10 cm, and the adsorption capacity of the 10 cm fill length is greater than 5 cm.

This is supported by other studies that vary the heap height of activated carbon, and the flow rate shows that the higher the activated carbon heap and the flow rate, the adsorption capacity and Thomas ion constant Pb^{2+} increases [19]. A similar study by varying the thickness of coconut shell activated charcoal in absorbing the heavy metal content of Pb in a pesticide solution containing lead showed that the thicker the activated charcoal is, the more effective it is [20].

The results obtained in this study did not have a large effect on the adsorption results with variations in the length of the fill. The length of 5 cm of charcoal filling has been able to reduce almost all heavy metal Fe, meaning that with a filling length of more than 5 cm, the adsorption capacity of activated charcoal is more effective.

The testing tools and methods used in the testing of heavy metal Fe can also affect the reduction in heavy metal content. The test equipment used has a detection limit of 0.014 mg/L. The test results of all samples are below the detection limit of the tool so that to see the effect of the duration of filling activated charcoal on the reduction of heavy metal Fe content cannot be observed. This research is only able to show that the design of a water purifier with activated charcoal media is successful in reducing levels of heavy metal Fe without seeing the effect of differences in the length of activated charcoal. Activated carbon has great potential for removing heavy metals from water due to its large surface area, nanoscale size, and availability of various functions. It is easier to modify and recycle chemically [21].

The results of this study indicate that the purifier can be used to reduce levels of heavy metal Fe. The procedure used in the study was one repetition for each variation. Of course, the data obtained is not as accurate as repeated data. The same repetition procedure was carried out and aimed to determine the decrease in Hg (II) levels using white gravel adsorbent coated with chitosan in determining the effectiveness of the adsorption using only one repetition [22].

4. Conclusion

The design of a water purifier contaminated with heavy metal Fe with activated charcoal as media of palm oil and bamboo shell waste consists of 2 parts, namely the buffer, and the purifier. The supporting part is made of an iron frame with 61 cm length, 61 cm width, and 150 cm height. Water purifying tube made of two glass bottles, 2 inch inner and outer pipe connectors. The two glass bottles were perforated using a drill bit with a drill bit size of 40 mm. The water reservoir is made of drinking water, measuring 20 liters. The activated charcoal media used consists of oil palm shell activated charcoal, bamboo, and a mixture of both activated charcoal. The purification results obtained were all variations in the length of the filling and the variations in the type of activated charcoal were able to reduce the heavy metal Fe content by more than 70%. From the data, it can be seen that the variation in the length of the filling does not have a significant effect on the decrease in heavy metal Fe content. The factor that affects the adsorption of activated charcoal is the surface area. The more the surface area of the adsorbent, the more substance is adsorbed. This adsorbent is determined by the particle size and the amount of adsorbent.

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