Characterization of activated charcoal from sugar palm bunches (Arenga pinnata (Wurmb) Merr) and the application as adsorbent lead (Pb), copper (Cu) and chrome (Cr) in solution

N Adrianto1,*, V H R Mongkito1, S Fayanto2, M Anas1 and R Eso1

1Physics Education, Universitas Halu Oleo, Jl. H.E.A. Mokodompit, Kendari 93231, Indonesia
2Physics Education, Universitas Ahmad Dahlan, Jl. Pramuka, No.42 Umbulharjo, Yogyakarta 55161, Indonesia

*Corresponding author: adriantnanang97@gmail.com

Abstract. This study proposes to determine the ability of activated charcoal from sugar palm bunches (Arenga Pinnata MERR) as lead adsorbent (Pb), copper (Cu) and chromium (Cr). The sample was carbonated with a temperature of 200-400ºC, then mashed by using mortal and sieved using a size of 100 mesh. Samples were activated with activation temperature variations of 600ºC, 700ºC, and 800ºC and characterized using Scanning Electron Microscope (SEM) with 2500x magnification and Atomic Absorption Spectroscopy (AAS). The SEM results indicate surface morphology of the best-activated charcoal of at a temperature of 700ºC with uniformly distributed pore size. In the AAS analysis results obtained for Pb absorption capacity of 0.0082 mg/g and absorption efficiency of 86.86%, the Cu absorption capacity of 0.0203 mg/g and absorption efficiency of 94.37% and Cr adsorption capacity of 0.0243 mg/g and efficiency absorption 96.39%. The value of absorption capacity obtained the result of AAS characterization, and the best adsorption efficiency was at 700ºC.

1. Introduction
Industrial processes and urbanization play an essential role in enhancing heavy metal contamination in the environment and producing various problems, one of them is the contamination of hazardous metals such as lead (Pb), copper (Cu) and chrome (Cr) [1]. Concentrations of copper (Cu) and chromium (Cr) elements that exceed the maximum standards set in drinking water can cause skin cancer and respiratory devices [2]. Accumulation of lead metal in the body causes symptoms of poisoning in everyone, among other things the respiratory system, blood and nervous system [3]. So we need an appropriate method to reduce heavy metals in the ecosystem.

In conventional technologies, heavy metal removal is provided expensively because of non-regenerable materials used and high costs [4]. Today the adsorption method has been developed using various low-cost adsorbent materials including Fito-filtration [5]. Bio-adsorbents, clays, activated carbons, zeolites, it has significant advantages [4]. The rationale of Fito-filtration is to use plant biomass that has died as a binder for metal ions [6]. Activated charcoal can be preparedly from agricultural waste such as cashew nut shell, rice husk, durian shell, and corncob [7-10]. However, it is sporadic that literature concern on the potential of sugar palm bunches as a raw material of activated
charcoal anywhere as sugar palm can grow in Southeast Sulawesi. The area of sugar palm plant in this region is 3,477 ha which widely spread in Bombana, Muna and Kolaka Regencies [11]. However, most of the people especially in Muna Regency only used liquid of sugar palm for making brown sugar or as raw material for a traditional beverage is called “tuak“ (wine) and the most popular term in Muna Language is named “Kameko." The empty bunches can also become firewood, and most of them grow trash in the local environment. This sugar palm bunch contain 27.74% lignin, 68.11% hemicellulose, 33.79% α-cellulose, 11.10% moisture content and 1.80% extractive so that the sugar palm bunches has very high potential to be activated charcoal as an adsorbent [12].

This research aims to prepare activated charcoal from sugar palm with a variation of activation temperature and its application to remove lead (Pb), copper (Cu) and chrome (Cr) in solution. The maximize its function as activated charcoal, several things need to be considered, including the arrangement of pores and the composition of activated charcoal [13]. The proportion of the pores considerably affects the quality of activated charcoal because the pores contained in activated charcoal have the most relevant benefits in the adsorption process [14]. Through the analysis of surface structure, it can provide information on the size of the pore diameter which will later be used in the adsorption process [15]. The number of pores arranged influence by the heating temperature, the higher the heating temperature, the more pores are formed so that, the more carbon produced [16].

2. Methods

2.1. Raw material
Materials in this research are waste sugar palm bunches obtained from Muna Regency of Southeast Sulawesi. The solution of lead (Pb), copper (Cu), chromium (Cr) and distilled water.

2.2. Preparation and characterization of waste sugar palm bunches.
Waste sugar palm bunches is initially ashed and dried on the sunlight for 24 hours. The dried sugar palm bunch then carbonize with temperature 250 ºC - 400 ºC. The sugar palm bunches char is crushed using a mortar and sieved of 100 mesh. The sample activated by using a furnace with activation temperature ranging from 600 ºC to 800 ºC. The activated charcoal of sugar palm bunches is characterized using Scanning Electron Microscope (SEM) and Atomic Absorption Spectroscopy (AAS).

2.3. Determination of The adsorption of Pb (II), Cu (II) and Cr(III) ions
Amount of 25 ml of a solution containing lead (Pb), copper (Cu), and chromium (Cr) were analyzed using Atomic Absorption Spectrophotometry (AAS) to obtain the initial concentration of expositions ions. The activated charcoal of sugar palm bunches (activation temperature of 600ºC) of 3-gram added into 25 ml of lead solution (Pb) in a 50 ml Erlenmeyer. This compound is shaken using magnetic stirrer for 60 minutes with the rate of 150 rpm. The sample is then filtered using a filter paper; the residual lead concentration is determined using AAS. The same procedure for activated charcoal of sugar palm with of 700 ºC and 800 ºC. The same method treated for Copper (Cu) and Chromium (Cr).

3. Results and Discussion

3.1. Effect the activation temperature on the surface morphology
The activated charcoal of sugar palm that activated with temperature variations of 600ºC, 700ºC, and 800ºC, were analyzed using Scanning Electron Microscope (SEM) with magnification 2500x as displayed in Figure 1.
Figure 1. SEM image of activated charcoal of sugar palm bunch (a) No activation, (b) activation 600°C, (c) activation 700°C, (d) activation 800°C
Figure 1 explains that the produced pore is cylindrical and has a different surface structure with rough and irregular surface features with various cavities that are randomly distributed the pore surface transversely [17], as the results of the Image-J analysis shown in Table 1.

Table 1. The average pore diameter size of activated charcoal of sugar palm bunch determined by Image-J analysis

| No | Activation temperature | Average size (nm) |
|----|------------------------|-------------------|
| 1  | No activation          | 23.2              |
| 2  | 600°C                  | 33.6              |
| 3  | 700°C                  | 37.4              |
| 4  | 800°C                  | 35.6              |

The SEM results show that a better pore diameter found at an activation temperature of 700 °C (Fig.1c ) with the diameter pore size of 37.4 nm. The formation of pores was due to the evaporation process of flying substances from raw materials during the carbonization process. Carbonization has caused degraded material components to produce gas (CO, CO$_2$, hydrogen, and methane) and liquid (tar, hydrocarbons, wood vinegar, water) [18]. The pores will evaporate and cause the surface area to increase, but higher temperatures can cause the pores degraded as a result of excess temperature pressure [19]. Meanwhile, at a temperature of 800 °C, there is a decrease in pore diameter. Aforementioned is a character with the increase in heat pressure which damages a portion of the charcoal crystal structure so that the size of the pore diameter decreases [20]. The conclusion is that with the activation temperature of charcoal pores from the sugar palm bunches produced the size varies from 23-35.6 nm and is classified as mesoporous.

3.2. Effect of activation temperature on adsorption ability

AAS analysis results with initial concentrations for Pb 0.0293 mg/L, Cu of 0.0668 mg/L and Cr of 0.0781 mg/L. The results of the analysis showed that there was a reduction in the concentration of the solution using activated charcoal made from sugar palm bunches as shown in Table 2.

Table 2. Results of absorption ability analysis of sugar palm bunches using atomic absorption spectroscopy (AAS).

| Activation temperature variations | Absorption concentration (mg/L) | Adsorption capacity (mg/g) | Absorption efficiency (%) |
|----------------------------------|---------------------------------|-----------------------------|---------------------------|
|                                  | Pb | Cu | Cr | Pb | Cu | Cr | Pb | Cu | Cr | Pb | Cu | Cr |
| No activation                    | 0.0246 | 0.0564 | 0.0659 | 0.0015 | 0.0034 | 0.0040 | 16.04 | 15.56 | 15.60 |
| 600°C                            | 0.0092 | 0.0056 | 0.0075 | 0.0064 | 0.0196 | 0.0226 | 68.47 | 91.55 | 90.39 |
| 700°C                            | 0.0038 | 0.0038 | 0.0028 | 0.0082 | 0.0203 | 0.0243 | 86.86 | 94.37 | 96.39 |
| 800°C                            | 0.0077 | 0.0075 | 0.0066 | 0.0072 | 0.0197 | 0.0237 | 73.73 | 88.73 | 91.57 |

Characterization identifies that the activation temperature affects the adsorption ability. The is data by the measure of adsorption capacity produced in each activation temperature in Pb, Cu and Cr metals. Table 2 presents a process in which the variation of activation temperature from 600-800°C shows various adsorption abilities which at a temperature of 700 °C there is an increase in absorption of 0.0082 mg/g for Pb, 0.0203 mg/g in Cu and 0.0243 for Cr. For each temperature, the change in absorption does not show significant variations. The is because the temperature of 600°C, 700°C, and 800°C has a pore diameter size that is not much different as shown in Table 1.

Table 1 identifies that activated charcoal from sugar palm bunches is in the mesoporous category. Chandra et al. argue that the presence of mesoporous in activated charcoal can increase adsorption ability and adsorption capacity, especially larger molecules [21]. This result sees from the SEM and AAS characterization tests that are showing the structure of sugar palm biomass waste a temperature of
700 °C has an excellent structure to determine the quality of metal adsorbent for the lead, mercury, and chromium.

**Figure 2.** Graph of activation temperature variation relation with adsorption capacity

Figure 2 explains that increasing the activation temperature 700 °C to results in high absorption of Pb, Cu, and Cr metals. Aforementioned is possible because the increase in activation results in quite large pores (see Table 1). Similar results obtained by other researchers Haimour and Emeish explained that the increase in activation temperature from 700 °C increases the adsorption ability of active charcoal[22]. But at 800 °C temperatures, there is a decrease in adsorption ability, this is most likely due to the change in the composition of the micropore and convert it into larger pores which reduce the ability of adsorption [23][24]. The explains that the reduction in surface activity affects the adsorption ability of sugar palm activated charcoal with more exothermic Pb, Cu, and Cr metals. So it can be concluded that the activation temperature affects the pore surface structure and adsorption ability in solution.

4. Conclusion
The influence of effects activation temperature adsorption ability of Pb, Cu, and Cr metals as well as an activated charcoal surface structure. Optimal adsorption results accomplished at a temperature of 700 °C with an adsorption capacity of 0.0082 mg/L for Pb, 0.0203 mg/L for Cu and 0.0243 mg/L for Cr with a pore size of 37.4 nm and activated charcoal from sugar palm bunches is in the mesoporous category.

Acknowledgments
Our thanks to the Ministry of Research, Technology and Higher Education Indonesia who has funded the research in the schema student creativity program. Likewise, the author thanks also to Vivi Hastuti Rufa Mongkito for becoming a supervisor.

References
[1] T Shanti and V M Selvarajan 2013 Hindawi. J. Chemistry. 10 1155
[2] Maldhure A V and Ekhe J D 2011 Chemical. Eng. J. 91 168
[3] Thajuank S, Insuk N, Udeye U and Trontakoon J 2009 Int. J. Physic. Sci. 4 8
[4] Ince M and Ince O K 2017 Int. J. Pure. Appl. Sci. 3 2
[5] Ablish P C, Pandey V C, Srivastava P, Rakesh P S, Chandran S, Singh N and Thomas A P 2009 J. Hazardous. Materials. 35 170
[6] Anawar H M, Sanchez A G, Alam M T K and Rahman M M 2009 *Int. J. Envi. Polution*. 33 2
[7] Anas M, Jahiding M, Ratna. Hasanah A and Kurniadi D 2014 *Prosiding. Pertemuan. Ilmiah XXVII. DIY*. 0385 0823
[8] Yahaya N K E M, Latif N F P M and Abustan I 2010 *Int. J. Eng. Tech*. 10 6
[9] Jun T Y, Arumugam S D, Latip N H A, Abdullah A M and Latiff P A *Int. J. Envi. Asia*. 3 143
[10] Jadhav A S, Salwe S, Tambe M and Shinde N H 2011 *Int. J. Advanced. Eng. Tech*. 2 2
[11] BPS 2014 *Sulawesi Tenggara dalam Angka 2014* (Sulawesi Tenggara: Badan Pusat Statistik)
[12] Sumatyah, Wirjosentono B and Karsono 2016 *Int. J. PharmTech. Research*. 9 7
[13] Tan Y H, Davis D A, Fujikawa K, Ganesh N V, Dhemcenkoand A V and Stine K J 2012 *J. Materials. Chemistry*. 22 6733
[14] Phul R, Kaur C, Farooq U and Ahmad T 2018 *Materials. Sci. Eng. Int. J.* 2 4
[15] Wu Y S, Vliet L J V, Frijlink H W and Maarschalk K V D V 2007 *Int. J. Pharmaceutics*. 11 342
[16] Anovits L M and Cole D R 2015 *Reviews. In. Mineralogy. Geochemistry*. 80 1259
[17] Jawad A H, Rashid R A, Ishak M A M and Wilson L D 2016 *J. Desalination. Water. Treatment*. 57 25194
[18] Juejun T, Sapunnee J and Chaiyot T 2013 *Suranaree. J. Sci. Tech*. 4 269
[19] Gao Y, Yue Q, Gao B, Sun Y, Wang W, Li Q and Wang Y 2013 *Chemical. Eng. J.* 38 217
[20] Soltani S M, Yazdi S K and Hosseini S 2015 *J. Appl. Nanosci*. 4 13
[21] Chandra T C, Mirna M M, Sudaryanto Y and Imsadji S 2007 *Chemical. Eng. J.* 11 127
[22] Haimour N M and Emeish S 2016 *J. Waste. Manag*. 6 26
[23] Budinova T, Petrov N, Parra J and Bloutzov V 2008 *J. Environ. Management*. 1 88
[24] Lua A C, Lau F C and Guo J 2006 *J. Anal. Appl. Pyrolysis*. 76 96