

# Characteristic and Adsorption Capacity of Activated Carbon and Bentonite to Heavy Metal

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**Abstract:** Laboratory waste can take the form of organic and inorganic materials if it accumulates, it can be harm the surrounding environment such as soil, water and plants. Some heavy metals are discharged without prior processing so it is feared that they can cause environmental pollution. The purpose of this research was to identify heavy metals from the laboratory activities waste and reduce that heavy metals using activated carbon and bentonite. The adsorption method using adsorbents such as activated carbon and bentonite is widely used to reduce metal contamination in waste and for analysis of heavy metal content in this research we used an atomic absorption spectrophotometer. The results of the analysis show the presence of several heavy metals such as Pb, Cu, Ag, Co, Cd, Cr and Hg. Identified laboratory waste results are quite high at 35 g/L for Cu, 1200 ppm for Pb metal and 220 ppm Ag. Adsorption using carbon and bentonite showed a reduction of Cu in the laboratory waste of 90.8 and 83.9% respectively with 2gram adsorbents. This shows that carbon and bentonite can be used as adsorbents to reduce metals in laboratory waste.

**Keywords:** Adsorption, Bentonite, Carbon, Laboratory, Waste, Heavy Metal.

## INTRODUCTION

Waste is a residual that produced from a production process both industrial and domestic (household) whose presence at a certain time and place is not desired by the environment because it has no economic value. Laboratory waste is waste from a laboratory, in this case specifically a chemical laboratory. This waste can come from chemicals, equipment for laboratory activities and others. In a certain amount with a certain level, that waste can damage health and even kill other humans or lives so it is necessary to set limits that are permitted in the environment at a certain time. Laboratory waste in the form of organic and inorganic materials can produce sufficiently hazardous waste. Reagents or heavy metals also used in a laboratory activities and when it accumulated it can be harm the environment<sup>[1]</sup>. The presence of heavy metal ions is of major concern due to their toxicity to many life forms. Humans can become exposed to heavy metals in dust through several routes which include ingestion, inhalation, and dermal absorption<sup>[2]</sup>. Mainly related to the heavy metals lead, mercury and cadmium but covering other heavy metals like chromium as well extensive documentation of the potential harmful effects to humans and the environment is available.

Waste is a waste of chemicals that have been used, raw materials expire, or process products in the laboratory such as the remaining specimens. Organic or inorganic wastes with certain concentrations and qualities can have a negative impact on the environment, especially for human health, so it is necessary to handle waste. As it is known that metals such as chromium, copper, lead, manganese, mercury, cadmium are very dangerous to human health and also the environment because they are toxic<sup>[3, 4, 5]</sup>.

The laboratory is mentioned as one of the sources of producing solid, gas or liquid waste. Laboratory waste is a waste that produced from the laboratory, in this case specifically a chemical laboratory. Laboratory in general is a place where the process of experiments or chemical analysis carried out involving human resources, hazardous chemicals and by-products of the reactions that occurred.

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Laboratories are very unique because all the harmful chemicals in them are small but can produce potential waste against environmental damage<sup>[6]</sup>.

This waste can come from chemicals, equipment for laboratory work and others. This laboratory waste has a dangerous risk to the environment and living things. When viewed chemically, this waste consists of chemicals of organic compounds and inorganic compounds. The level of danger of poisoning caused by waste depends on the type and characteristics of the waste. Waste characteristics are influenced by particle size (micro), are dynamic, spread widely and have a long or long impact. While the quality of waste is influenced by the volume of waste, waste content, pollutant content and frequency of waste<sup>[7]</sup>.

As a waste, its presence is quite alarming, especially those sourced from chemical laboratories due to the toxic and dangerous materials used in many chemical laboratories. The disposal of a number of hazardous materials into the environment can cause problems for the environment because the presence of these materials is difficult to biodegrade. In a certain amount with a certain level, its presence can damage the food chain that exists in the environment and endanger health and even kill other humans or lives so it is necessary to set permitted limits in the environment at a certain time<sup>[8]</sup>. Heavy metal is a global issue for the environment and human health due to its toxicity, causing bioaccumulation in the human body and food chain, carcinogenic and can cause mutations in some organisms<sup>[9]</sup>.

## MATERIAL AND METHODS

- Adsorbates : laboratory activities waste
- Adsorbent : activated carbon and bentonite

### Sampling of the Laboratory Waste

Samples from the waste of practical activities in each laboratory are accommodated in a container for one activity. The sample was added with concentrated nitric acid and filtered by filter paper, and then the filtrate that obtained ready for analysis.

### Metal Adsorption

20 grams of adsorbent soaked in aquademin with a volume ratio of 1: 50 and stirred for 2 hours using a magnetic stirrer at a speed of 100 rpm. The mixture was deposited and left for 2 days then filtered and the residue dried in an oven at 105°C for 24 hours. The adsorbent was mashed up until it size 100 mesh. For the adsorption process 5 beakers are prepared and added by 0.4; 0.8; 1.2 ; 1.6 and 2 grams adsorbents and 25 mL of laboratory waste are added to each beaker. The mixture is stirred using a shaker for 12, 20, 30, 45 and 60 minutes at a speed of 200 rpm. The mixture is filtered by filter paper to separate the filtrate from the adsorbent. The filtrate then added by a few drops of HNO<sub>3</sub> and analyzed the content of Cu and Pb ions using AAS.

### Adsorbent Characterization

Characterization of the adsorbent before and after adsorption was carried out by determining the functional group using FT-IR (Fourier Transform InfraRed Spectroscopy), morphology using SEM (Scanning Electron Microscopy), and pore size using SAA (Surface Area Analyzer) with BET method.

## RESULTS AND DISCUSSION

The presence of heavy metals such as Cu, Cr, Co, Cd, Ag, Mg and Pb was found in a large number of results in laboratory activities, which were around 0.25 - 212.87 ppm and Cu metal was found in the largest amount as shown in Figure 1.

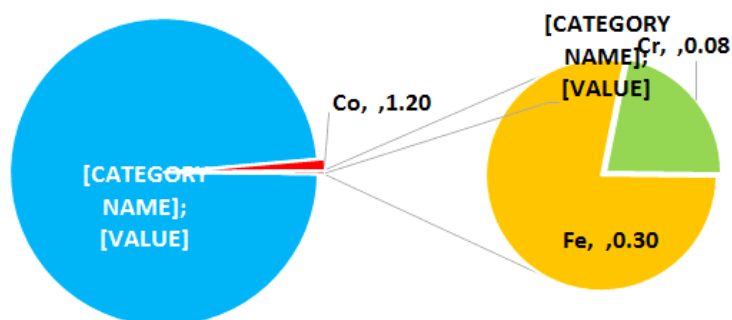


Figure 1: Types of metal waste in analytical chemistry laboratories

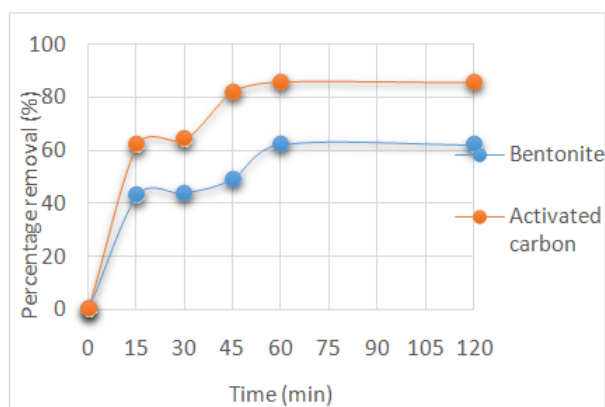
Some of these metal wastes are produced from experiments activities in the laboratory using reagents from compound compositions in the composition and a sufficiently high amount so that the waste that is wasted is of sufficiently high concentration (Figure 1). Cu metals are found in very high amounts, which is more than 90% of total waste in the laboratory by using reagents from compounds in concentrations and amounts that are quite high so that the waste that is wasted is still quite high in concentration (Figure 1). Cu metals are found in very high amounts, which is more than 90% of total waste in the laboratory.

Copper is an indispensable element in carbohydrate and fat metabolism and maintaining heart and blood vessel activity. According to WHO the maximum concentration of copper that allowed in drinking water is 1.5 mg / L and in adults the body contains 100 - 150 mg Cu<sup>2+</sup>. If it exceeds the concentration, it will be toxic to the body and cause health problems such as nausea, headache, respiratory problems, anemia, bleeding in the gastrointestinal, liver, kidney failure and death<sup>[10]</sup>.

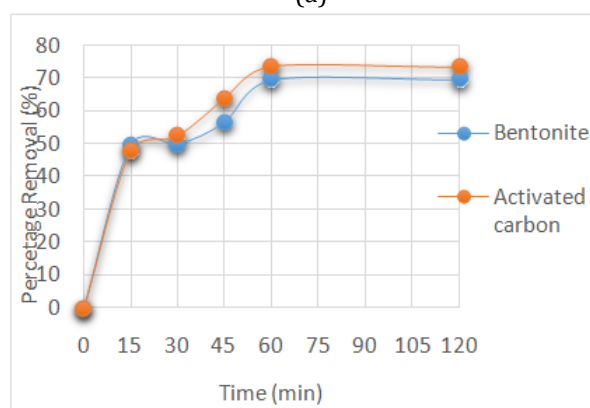
Research from Lou and Chang<sup>[11]</sup> related to the development of procedures for handling wastes containing a lot of heavy metals, states that ten metals such as Pb, Cd, Cu, Cr, Zn, Ag, Hg, Sn, Mn and Ni are categorized as heavy metals so that its existence must be reduced. These heavy metals can be adsorbed using carbon or bentonite. Bentonite in mineralogy belongs to a large group of clay soils, is a rock formed from volcanic ash and contains montmorillonite minerals. There are two types of bentonite stones, namely Bentonite Na and Bentonite Ca, each of which has a different function. Bentonite is used as the main alternative in the adsorption process due to the content of montmorillonite compounds which have a measure of inter-layer space which has a large capacity in adsorption so that it can be used as an adsorbent.

Likewise with carbon or often referred to as activated charcoal with the configuration of carbon atoms freed from bonding with other elements, and pores cleared from other compounds so that the surface and center become active which can cause adsorption of liquids or gases will increase.

The results of optimization of the interaction time of the adsorbent against Cu metal (Figure 2) show that the optimum time that used to perform optimum adsorption for bentonite or activated carbon is 60 minutes. In Figure 2 shows that the adsorbent can reduce metals in waste by 60 - 85%.



(a)



(b)

Figure 2: Effect of contact time on the adsorption of lead (a) and copper ion (b) using activated carbon and bentonite

Teker *et al.*<sup>[12]</sup> conducted an optimization of the contact time of activated carbon from rice husk against  $\text{Cu}^{2+}$  and obtained an optimum contact time of 60 minutes with an effectiveness of 58%. Activated charcoal has a structure in the form of twisted tissue from imperfect carbon layers which are interconnected by an aliphatic bridge. The surface area, dimensions and distribution of carbon atoms making up the structure of activated charcoal are highly dependent on raw materials, carbonation conditions and their activation processes<sup>[13]</sup>.

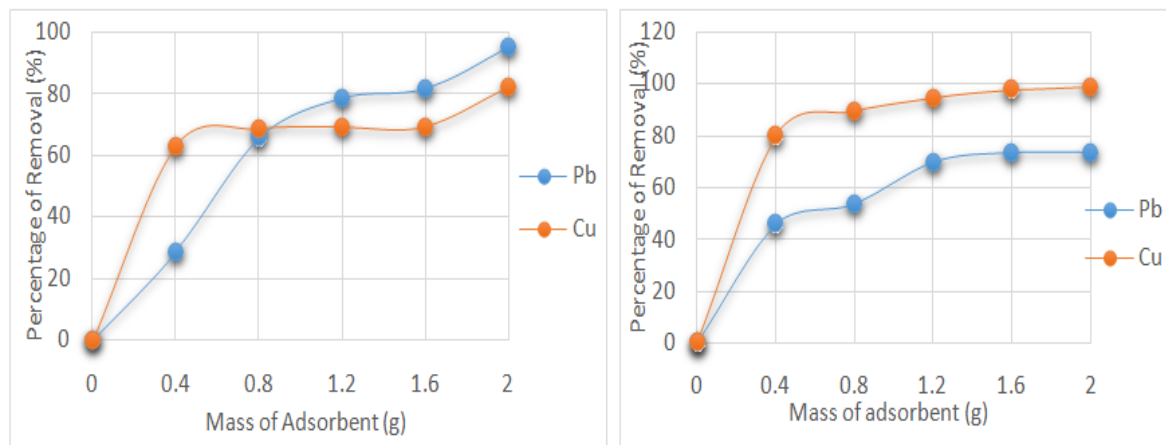


Figure 3: Effect of mass adsorbent using activated carbon and bentonite on the adsorption of lead (a) and copper ion (b)

On the mass of 2 gram adsorbent all metals showed an optimal reduction in concentration with a reduction in metal ions of 73.7 - 99.2%. Carbon has greater effectiveness when compared to bentonite in both copper and lead metal ions. Karnib<sup>[14]</sup> made a reduction in waste containing Pb by 83%, using 20 mg activated carbon in 20 ml of metal-containing waste. In another research, it was stated that activated carbon was successfully used to remove Fe (III) and Mn (II) ions from El-General drainage water in the coast of Alexandria, Egypt<sup>[15]</sup>.

The Langmuir equation is based on the maximum adsorption correlation of the adsorbates molecule to the surface of the adsorbent, where the adsorption energy is constant and there is no displacement of the adsorbates in the surface field<sup>[16]</sup>. The plot between  $C_e$  and  $C_e/n$  obtained a graph of the Langmuir equation with the values of constants, K and b in the system as in Table 1.

Table 1: Correlation of The adsorbates molecule to the surface of the adsorbent

Adsorbent	Adsorbates	K	b (mol g <sup>-1</sup> )	R <sup>2</sup>
Activated carbon	Copper	58,14	0,408	99,3
	Lead	163,93	0,489	99,6
Bentonite	Copper	188,68	0,392	99,8
	Lead	384,62	0,608	99,9

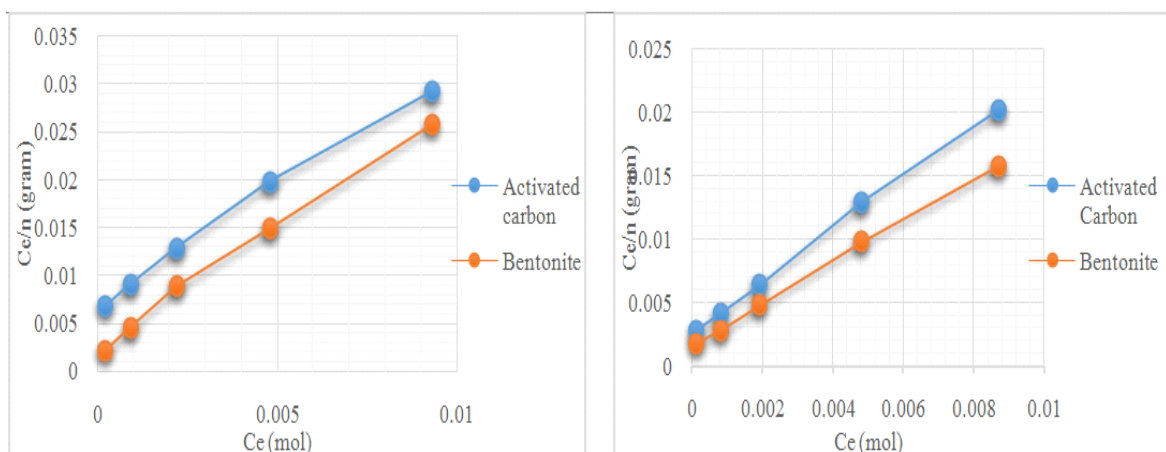
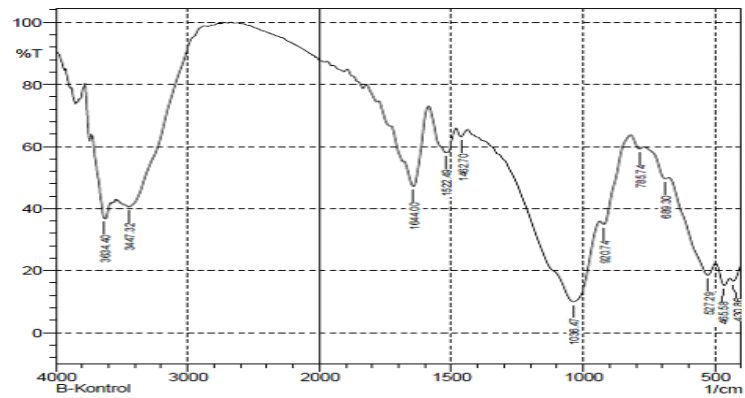
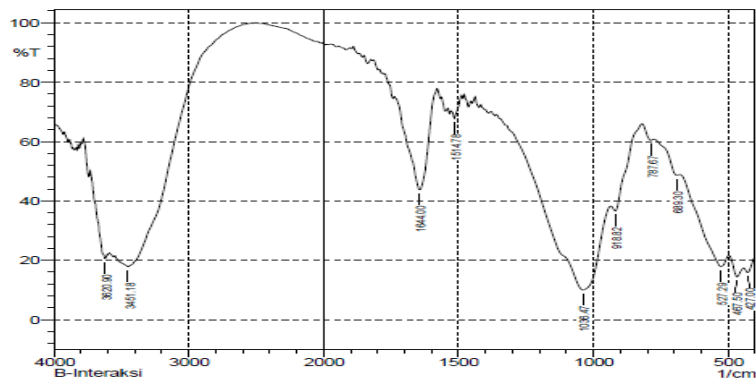


Figure 4: Langmuir Isotherm for lead and copper ions adsorption



(a)



(b)

Figure 5. FT-IR spectra bentonite (a) before adsorption and (b) after adsorption

The peak at wave number  $3634\text{ cm}^{-1}$  shows stretching vibrations of the hydroxyl groups and peaks at  $3347.3\text{ cm}^{-1}$  indicating the presence of stretching O-H vibrations caused by adsorption of water molecules absorbed on the interlayer and having weak hydrogen bonds with Si-O surfaces. The presence of wave number  $1644\text{ cm}^{-1}$  indicates Montmorillonite. The absorption band at wave number  $1036.5\text{ cm}^{-1}$  is caused by stretching vibrations of Si-O from Si-O-Si which are observed as wide absorption peaks with sharp intensity. The presence of a wave number  $689.3\text{ cm}^{-1}$  indicates the presence of Si / Mg-O symmetry range vibrations<sup>[17]</sup>.

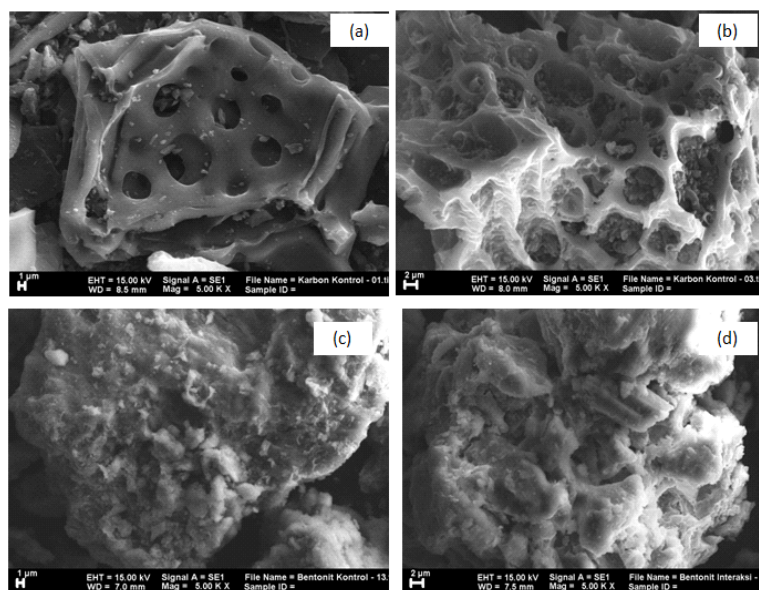


Figure 6: Scanning electron microscope of activated carbon (a) before adsorption, (b) after adsorption and bentonite (c) before adsorption, (d) after adsorption

Functional groups can be formed on activated carbon when activated, which is caused by the interaction of free radicals on the carbon surface with atoms such as oxygen and nitrogen, which come

from processing or atmosphere. This functional group causes the surface of the activated carbon to be chemically reactive and affects its adsorption properties. The activation process aims to enlarge the pore by breaking the hydrocarbon bonds or oxidizing surface molecules so that the carbon changes, the surface area increases and affects the adsorption power<sup>[18]</sup>. Activated carbon morphology supports the above statement which shows a wide enough pore as shown in Figure 6. These results are supported by pore measurements of carbon and bentonite as in Table 5.5 where the active carbon pore area is almost 6 times that of bentonite while the carbon pore volume almost 10 times the volume of pore bentonite.

Table 2: Pore area and pore volume activated carbon and bentonite

No.	Adsorbent	Pore area (m <sup>2</sup> /g)	Pore volume (cc/g)
1.	Activated Carbon	756,34	263,49
2.	Bentonite	142,74	21,05

Based on the data obtained in Figure 5, it shows that there is a reduction in metal concentration in waste when compared to the control (without the addition of adsorbents). With increasing concentrations of adsorbents both bentonite and carbon have almost the same effect, namely a decrease in metal concentration. The decrease was 90.8% using activated carbon and 83.9% with bentonite at 2 gram adsorbent concentration respectively. This shows that the presence of these two adsorbents can reduce the presence of metal waste in laboratory waste effluents. At 30 ppm of heavy metals, the percentages were 90, 86, 83.6, 83 & 50.6,% for Ni, Cd, Zn, Pb & Cr respectively<sup>[14]</sup>. Activated carbon and rice husks were successfully removed from Fe (III) and Mn (II) ions from El-General drain water, Alexandria coast, Egypt<sup>[15]</sup>. The maximum removal of natural zeolite was 91% at copper concentration 10 mg / l, and the maximum removal of zinc using natural zeolite was 96% at a metal concentration of 10 mg / l<sup>[16]</sup>.

## CONCLUSION

Laboratory activities can produce residual waste that contained some dangerous heavy metals with a high enough concentration. The highest concentration of metal waste found is Cu with a concentration of 7123 ppm, Pb 291.3 ppm and Ag 44.7 ppm. With the addition of bentonite adsorbent and activated carbon can reduce copper metal in laboratory waste by 80 - 90%.

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## REFERENCES

- [1] Egorova, K. S., & Ananikov, V. P. (2017). Toxicity of metal compounds: knowledge and myths. *Organometallics*, 36(21), 4071-4090.
- [2] Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K., & Sutton, D. J. (2012). Heavy metal toxicity and the environment. In *Molecular, clinical and environmental toxicology*, 133-164.
- [3] Ong, S. A., Toorisaka, E., Hirata, M., & Hano, T. (2010). Adsorption and toxicity of heavy metals on activated sludge. *ScienceAsia*, 36(3), 204-209.
- [4] Raja, C. E., Selvam, G. S., & Omine, K. I. Y. O. S. H. I. (2009). Isolation, identification and characterization of heavy metal resistant bacteria from sewage. In *Int Joint Symp on Geodisaster Prevention and Geoenvironment in Asia*, 205-211.
- [5] Bulut, Y. (2007). Removal of heavy metals from aqueous solution by sawdust adsorption. *Journal of Environmental Sciences*, 19(2), 160-166.
- [6] National Research Council. (2011). *Prudent practices in the laboratory: handling and management of chemical hazards, updated version*. National Academies Press.
- [7] Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary toxicology*, 7(2), 60-72.
- [8] Lakherwal, D. (2014). Adsorption of heavy metals: a review. *International journal of environmental research and development*, 4(1), 41-48.
- [9] Rahman, M., & Sathasivam, K. V. (2015). Heavy metal adsorption onto Kappaphycus sp. from aqueous solutions: the use of error functions for validation of isotherm and kinetics models. *BioMed research international*, 2015.



- [10] Ahamed, A. J., & Begum, A. S. (2012). Adsorption of copper from aqueous solution using low-cost adsorbent. *Archives of Applied Science Research*, 4(3), 1532-1539.
- [11] Lou, J. C., & Chang, C. K. (2007). Completely treating heavy metal laboratory waste liquid by an improved ferrite process. *Separation and Purification Technology*, 57(3), 513-518.
- [12] Teker, M., İMAMOĞLU, M., & SALTABAŞ, Ö. (1999). Adsorption of copper and cadmium ions by activated carbon from rice hulls. *Turkish Journal of Chemistry*, 23(2), 185-192.
- [13] Kyotani, T. (2000). Control of pore structure in carbon. *Carbon*, 38(2), 269-286.
- [14] Karnib, M., Kabbani, A., Holail, H., & Olama, Z. (2014). Heavy metals removal using activated carbon, silica and silica activated carbon composite. *Energy Procedia*, 50, 113-120.
- [15] Masoud, M. S., El-Saraf, W. M., Abdel-Halim, A. M., Ali, A. E., Mohamed, E. A., & Hasan, H. M. (2016). Rice husk and activated carbon for waste water treatment of El-Mex Bay, Alexandria Coast, Egypt. *Arabian Journal of Chemistry*, 9, S1590-S1596.
- [16] Salam, O. E. A., Reiad, N. A., & ElShafei, M. M. (2011). A study of the removal characteristics of heavy metals from wastewater by low-cost adsorbents. *Journal of Advanced Research*, 2(4), 297-303.
- [17] Webb, S.W., Stanley, D.A., & Scheiner, B.J. (1986). *An Infrared Examination of Ion-Exchanged Montmorillonite Treated with Polyethylene Oxide*. Report of Investigation 9038, Bureau of Mines.
- [18] Doloksaribu, M., Bambang, P., Kuwat, T., & Harsojo. (2017). Preparation and Characterization of Activated Carbon Based on Coconut Shell for Supercapacitor. *International Journal of Science: Basic and Applied Research*, 35(3): 430-437.