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# THE EFFECT OF ADSORBENT AGENTS: SILICA, ANDISOL, LECA, ANTHRACITE, AND ACTIVATED CARBON ON POLLUTANT UPTAKE IN THE CITARUM RIVER

(*Pengaruh agen penjerap silika, andisol, LECA, antrasit, dan karbon aktif terhadap penjerapan polutan di Sungai Citarum*)

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## *ABSTRACT*

*Citarum is the longest and largest river in West Java-Indonesia which plays a critical role in the water supply. Water treatment is needed to process the Citarum water due to its pollutants have been over standard for human consumption. Nowadays, the adsorption process is still popular in water treatment process because of its effectiveness. In this study, the effectivity of five adsorbents on Citarum water treatment: silica, andisol, LECA (Light Expanded Clay Aggregate), anthracite, and activated carbon has been evaluated with variable contact time and solid loading. After treatment, turbidity and heavy metal of filtrate were analyzed. Surface characteristics, functional group, and surface area of five adsorbents were done by FE-SEM (Field Emission - Scanning Electron Microscopes), FTIR (Fourier Transform Infrared Spectroscopy), and BET (Brunauer-Emmett-Teller) surface area analysis, respectively. The result showed that andisol and LECA decreased turbidity of Citarum water from 21.30 NTU (Nephelometric Turbidity Unit) to 1.23 and 2.52 NTU after 10 min contact time. Activated carbon was taking another 10 min longer to decrease turbidity to 2.26 NTU yet it has the highest surface area, 548.31 ($m^2/g$). Surface area was in correlation with FE-SEM result where activated carbon has a more regular and larger pore size compared to others adsorbent. In general, andisol, LECA, activated carbon were successful to decrease turbidity of Citarum water which correlated to their paricles' surface area.*

***Keywords: adsorption; Citarum water river; adsorbents; pore size***

## ABSTRAK

Sungai Citarum merupakan sungai terpanjang dan terbesar di Jawa Barat, Indonesia yang mempunyai fungsi vital sebagai sumber air. Pengolahan air sungai Citarum sebelum disalurkan ke masyarakat diperlukan untuk menghilangkan pengotor karena kandungan pengotor pada air sungai Citarum melebihi batas ambang yang dipersyaratkan untuk air konsumsi. Saat ini proses penjerapan atau adsorpsi merupakan proses yang umum digunakan pada perusahaan pegolahan air karena efektifitasnya. Pada penelitian ini, efektifitas lima agen penjerap yaitu silika, andisol, hidroton, antrasit, karbon aktif telah dievaluasi dengan perbedaan rasio padatan dan larutan, dan waktu kontak. Setelah pengolahan, kekeruhan dan logam berat dalam air dianalisa. Karakteristik permukaan, gugus fungsi, dan luas permukaan dari kelima agen penjerap dianalisa masing-masing menggunakan FE-SEM (*Field Emission - Scanning Electron Microscopes*), FTIR (*Fourier Transform Infrared Spectroscopy*), dan analisa luas permukaan BET (*Brunauer-Emmett-Teller*). Hasil analisa menunjukan bahwa masing-masing andisol dan LECA menurunkan kekeruhan dari air Citarum dari 21.30 NTU (*Nephelometric Turbidity Unit*) menjadi 1.23 dan 2.52 NTU setelah waktu kontak 10 menit. Karbon aktif membutuhkan waktu 10 menit lebih lama untuk menurunkan kekeruhan menjadi 2.26 NTU akan tetapi karbon aktif memiliki luas permukaan yang paling tinggi yaitu 548.31 ($m^2/g$). Luas permukaan berkaitan dengan hasil FE-SEM dimana karbon aktif memiliki pori yang teratur dan berukuran besar. Pada umumnya, andisol, LECA, dan karbon aktif telah berhasil menurunkan kekeruhan air Sungai Citarum yang berkaitan dengan luas permukaan partikelnya.

**Kata kunci: agen penjerap; air sungai Citarum; penjerapan; luas permukaan**

## I. INTRODUCTION

One of the goals of watershed management is to ensure the availability of clean water for living things. Water is one of the crucial needs for all living things to survive and for socio-economic activities. The high population and economic growth in Indonesia make human and industrial activities expanding rapidly. As a result, the environment is increasingly being threatened by inevitable waste water production. Pollution of water resources can be caused not only by synthetic and natural chemicals but also heavy metals as toxic and dangerous pollutants. The pollutans are considered being a hazard for human beings (Piccin, Cadaval, De Pinto, & Dotto, 2017; Belinawati, Soesilo, Asteria, & Harmain, 2018; Seliem et al., 2020).

Citarum River is one of the natural water supply which has a flow length of about 300 km and the downstream located in Karawang Regency, West Java, Indonesia (Shara, Moersidik, & Soesilo, 2021). In Karawang, Citarum River has vital functions to supply water for irrigation, electricity generation, fisheries, reservoir water, and drinking water where the water river was treated by Perusahaan Daerah Air Minum (PDAM) Karawang (Sholeh, Pranoto, Budiastuti, & Sutarno, 2018). Despite the important role of Citarum River, the accumulation rate of solid and liquid waste in the Citarum River and its tributaries has caused an intolerable impact in environmental feasibility and human health. In 2019, more than 1,600 industries dominated by the textile, pulp and paper, and electroplanting industries have operated along the Citarum River. Only about 400 industries carry out wastewater treatment and the rest are discharged directly into wastewater without proper treatment into the Citarum River (Widyawati, Notodarmojo, Hidayat, & Helmy, 2019; Sholeh, Pranoto, Budiastuti, & Sutarno, 2018). Therefore, the water quality of Citarum River such as watercolor, heavy metal (commonly Fe and Mn), biological oxygen demand (BOD), chemical oxygen demand (COD), and high turbidity are the main obstacles at PDAM water plant treatment Energy Dispersive X-Ray.

Different technologies and methods for wastewater treatment have been extensively reported and developed. In general, the technologies and methods used to remove contaminants from wastewater include anaerobic treatment, coagulation, flocculation, flotation, filtration, ion exchange, membrane separation, and advanced oxidation (Da'na, 2017). Nevertheless, they have their restrictions and are still considered a challenge. The adsorption process is considered the most effective and affordable method for wastewater treatment (Piccin, Cadaval, De Pinto, & Dotto, 2017). It is affected by temperature, adsorbate and adsorbent properties, the presence of other pollutants, and atmospheric and experimental conditions such as pH, concentration of pollutants, dosage, contact time, and particle size of the adsorbent (Ali & Gupta, 2007). Currently, PDAM Karawang treats Citarum water through coagulation, flocculation, sedimentation, filtration, and desinfection (Suhartono, 2020). Filtration is one of the crucial steps in this process due to the adsorption of light particles and heavy metals that can not precipitated until the sedimentation step (Barakat, 2011). Therefore, selecting the best adsorbent during the filtration process is crucial, as well.

The essential criteria for adsorbent are its abundance and sustainability because it impacts the treatment budget and environment. Recently, natural adsorbents are popular in Water Treatment Plants (WTP), such as activated carbon from biomass and clay or soil-based adsorbent. Activated carbon has been recognized as the most widely used adsorbent due to its immense ability to remove various pollutants such as heavy metals, metalloids, halogens, dyes, pharmaceuticals, organic pollutants, toxins, etc (Bonilla-Petriciolet, Mendoza-Castillo, & Reynel-Ávila, 2017).

One of clay-based adsorbent which has extensively been used is Light Expanded Clay Aggregate (LECA). LECA is a highly porous material that has a low density, natural pH, and thermal resistance up to 1000 °C. It has a uniform pore structure so it can adsorb environmental pollutants and not lost significantly during the backwash process (Mohammadi, Yetilmezsoy, & Uygur, 2013; Sepehr et al., 2014). Andisol is a kind of soil that has a large amount of non-crystalline materials such as imogolite, allophane, Al/Fe-humus and ferrihydrite complexes, and the accumulation of organic carbon. This material is highly porous and have large specific surface areas (Babel & Opiso, 2010). As well as other adsorbents, silica also a porous material that potential for adsorbents to remove pollutants (Cashin, Eldridge, Yu, & Zhao, 2018). Mesoporous silica can adsorb n-pentane (Gor et al., 2013) and heavy metals with modification (Da'na, 2017). Anthracite is a type of coal that is compact, hard, has a high luster, and high carbon content (Rahman, Azam, & Alam, 2012). Some studies reported that anthracite is an effective adsorbent to remove pollutant such as Mn (VII) and Cr (VI) (Seliem et al., 2020), quinoline (Xu et al., 2019), and phosphate ion (Rahman, Azam, & Alam, 2012).

Anthracite and silica are common adsorbents in water plant treatment. Nevertheless, these adsorbents have not optimal to adsorb pollutants and heavy metals. The concentration of Fe and Mn, also turbidity are relatively high even after complete treatment (Analysis Report PDAM (unpublished data), 2020). In this study, we compared anthracite and silica with other potential adsorbents such as andisol, activated carbon, and LECA. The purpose of this study was to investigate the effect of activated carbon, LECA, andisol, silica, and anthracite to remove pollutants from Citarum River. The influence of adsorbent properties such as functional groups, surface area, and morphological features on the water treatment was also investigated.

## II. MATERIALS AND METHODS

### A. Time and Location

This research was conducted in Karawang Regency. The water sample was taken from the main canal of North Tarum (west branch) during the rainy season. Figure 1 shows water sampling location.

### B. Materials

Andisol, LECA, silica, and anthracite were purchased from local companies in Karawang, West Java, Indonesia. Meanwhile, activated carbon from OPEFB (Oil Palm Empty Fruit Bunches) was prepared by one-step process of carbonization and continued by activation according to Sari, Yanto, & Pari (2019). Andisol, silica, and anthracite were ground into small particles then sieved into particles size of 10-14 mesh while activated carbon into 180 mesh. The LECA sample was selected with a particle size up to 10 mm. All adsorbent materials were presented in Figure 2.

### C. Methods

1. Batch experiment

The batch study was conducted to determine the adsorption capacity of each adsorbent materials. 100 ml of Citarum water samples was put into 250 ml erlenmeyer flasks and stirred at 250 rpm for 10, 20, and 30 minutes with solid loading 1: 10 (gr/ml) for antracite, silica, andisol, and LECA, and 1:100 (gr/ml) for activated carbon. After that, it was filtered using 0.45 um filter paper.Prior to that turbidity (HACH 2100Q, USA), and AAS analysis (XplorAA, GBC USA) were performed to determine Fe and Mn concentration. This experiment was arried out three replications for each adsorbent.


Figure 1. The location of water sample at main canal of North Tarum (West Branch), Karawang Regency
Source: Google Maps (2021)


Figure 2. The visual appearance of the adsorbents: anthracite (a), andisol (b), LECA (c), silica (d), and activated carbon (e)
Source: Visualization of materials (2020)

2. Adsorbent Characterization and Analysis

a. FTIR analysis

Attenuated Total Reflectance -Fourier Transform Infra-Red (ATR-FTIR) analysis (Spectrum two-Perkin Elmer, USA) was used to characterize the functional groups of adsorbent materials. About 1 gr of adsorbents were placed on a diamond plate and then IR spectra were recorded in absorption mode with a scan count of 4 per sample and a resolution of 4.0 cm in the wave number range of 4000 to 400 $cm^{-1}$ at room temperature using spectrum two Perkin Elmer software.

b. SEM and BET analysis

The micrograph of the adsorbents was obtained by Field Emission Scanning Electron Microscopy (FE-SEM) using FE-SEM Thermo Scientific - Quattro S (USA). The samples were fixed on a specimen holder with tape and each sample was examined at 500-fold magnification. The specific surface area and pore structure characteristic of the adsorbents were determined by adsorption-desorption isotherms of nitrogen at 196 °C using automated gas adsorption analyzer namely AUTOSORB-1 (Quantachrome Instruments, USA). Before analysis, degassing of samples was conducted at 300 ºC for 3 hours. Brunauer-Emmet-Teller (BET) method was used to calculate the surface area of samples. The average pore diameter and pore volume of the adsorbents were determined by Barret-Joymer-Halenda (BJH) model.

## III. RESULTS AND DISCUSSION

1. Influence of adsorbents on turbidity

The causes of high levels of turbidity are the accumulation of sedimentation over the years and the impact of household waste disposal. The level of pollution can be vary depending on the source of the pollutant, seasonal turbidity during rainy season, and the river flow itself (Sholeh, Pranoto, Budiastuti, & Sutarno, 2018). According to Babur & Kara (2017), water treatment is one of the important step in integrated watershed management to produce clean water. One of the effective water treatment is adsorption process.

In this study, the turbidity of the Citarum river is 21.30 NTU (Figure 3) while according to Indonesian Minister of Health Regulation no. 492 the quality standard of turbidity for water supply is less than 5 NTU. In Figure 3, it clearly showed that after the treatment process the best adsorbent to decrease turbidity is Andisol which can decrease significantly to 1.23 NTU and then LECA to 2.52 in 10 minutes. Nevertheless, turbidity increased after 20 minutes of stirring for LECA and andisol and 30 minutes for silica. The use of LECA and silica as adsorbent significantly increased the turbidity from 2.52 to 23.40 NTU and 8.98 to 33.10 NTU, respectively. Activated carbon consistently decreases the turbidity until 2.26 NTU for 30 minutes. However, it needs more time than LECA and andisol in absorbing the pollutant. The partial dissolution of adsorbent in the solution can have an impact on the decreasing adsorption capacity. Adsorbent hardness is one of the factors to determine the suitable adsorbent material (Mohammadi, Yetilmezsoy, & Uygur, 2013; Sepehr et al., 2014).

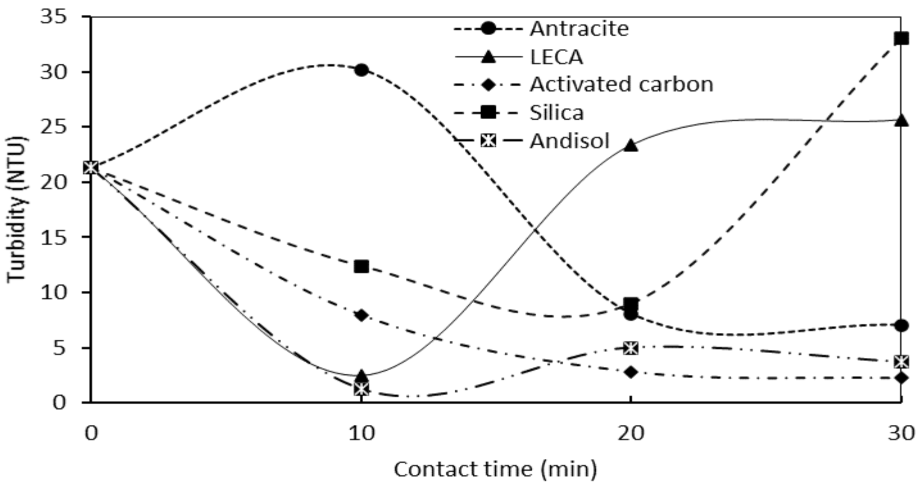


Figure 3. Influence of adsorbent and contact time on the water turbidity of Citarum River
Source: Analysis Result (2021)

 

Table 1. The concentration of Fe and Mn before and after treatment using different adsorbents

| Adsorbents | Fe (mg/kg) | Mn (mg/kg) |
|---|---|---|
| (before treatment) | Nd* | Nd* |
| Anthracite | 625.94 | 5.31 |
| Andisol | Nd* | Nd* |
| LECA | Nd* | Nd* |
| Silica | Nd* | Nd* |
| Activated Carbon | Nd* | Nd* |

*not detected
Source: Analysis Result (2021)

2. Influence of adsorbents on heavy metals adsorption

Table 1 shows the concentration of Fe and Mn before and after treatment. Before treatment, the sample did not contain Fe or Mn. This finding is different with previous report by Sholeh, Pranoto, Budiastuti, & Sutarno (2020b) The raw water quality depends on the domestic waste, sedimentation, and industry's effluent, as well as the current season (Hasbiah & Kurniasih, 2019). The experiment from Sholeh, Pranoto, Budiastuti, & Sutarno (2020b) with the same water resources showed that the concentration of Mn and Fe in the water before treatment was 0.005-0.02 ppm and 0.015-0.03 ppm, respectively. The concentration of Mn and Fe have been below the threshold recommended by Permenker RI number 32 of 2017 of 0.5 and 1 ppm, respectively. Because of sampling in the rainy season, Mn and Fe's concentration in this research became very low or not detected.

Furthermore, after 30 minutes of treatment using andisol, LECA, silica, and activated carbon were also not detected. Meanwhile, Fe and Mn were detected using anthracite after 30 minute of treatment. Fe concentration was very high up to 625.94 mg/kg, while Mn concentration was 5.31 mg/kg. This condition affected the filtrate color after treatment. The yellowish color observed in the filtrate after treatment with anthracite can be attributed to the release of Fe and Mn ions which were loaded during the stirring process. Hence it shows that anthracite is not an effective adsorbent. This condition is caused by the presence of iron which is one of the metal components in anthracite (Ribeiro, DaBoit, Flores, Kronbauer, & Silva, 2013). Further study is needed to investigate the elemental composition of adsorbents.

3. Adsorbents Characterization

a. Functional groups of adsorbents by FTIR

FTIR spectra is available in Figure 4 while the interpretation of data can be seen in Table 2. Figure 4 shows that silica, andisol, and LECA have the same strong bands at 1081 $cm^{-1}$ (3), 800 $cm^{-1}$ (5), and 462 $cm^{-1}$ (7) which can be interpreted as asymmetric vibration of siloxane (Si-O-Si), deformation of Si-O peak in $SiO_4$, and Si-O from amorphous silica (Noverliana & Asmi, 2015; Shokri, 2020).

Table 2. Interpretation of the FTIR bands of silica, andisol, LECA, anthracite, and activated carbon

| No | Bands ($cm^{-1}$) | Interpretation |
|---|---|---|
| **1** | 2928 | aliphatic (-$CH_2$) (He, Liu, Nie, & Song, 2017; Zhang et al., 2015) |
| **2** | 1611 | carbonyl (C=O) (He, Liu, Nie, & Song, 2017; Zhang et al., 2015) |
| **3** | 1031 | siloxane (Si-O-Si) |
| **4** | 1010 | Si-O-C (Noverliana & Asmi, 2015; Shokri, 2020) |
| **5** | 800 | Deformation Si-O in $SiO_4$ (Noverliana & Asmi, 2015; Shokri, 2020) |
| **6** | 687 | C-H in aromatic ring (Zhang et al., 2015) |
| **7** | 462 | Amorphous silica (Si-O) (Zhang et al., 2015) |

Source: Analysis Result (2020)

However, shapes of these peaks are sharper in Silica than the peak of andisol and LECA which may relate to silica content in the adsorbent. The observed functional group of silica in this study was slightly different from Adam, Chew, & Andas' (2011) study. The band around 3440 $cm^{-1}$ which corresponds to hydroxyl stretching in silanol (Si-OH), was not detected in this study. Andisol soil is formed from volcanic rocks, and it usually is found at altitude 700-1500 m above sea level. Due to the main compound of andisol that is amorphous silica or aluminum (Park, Hyun, & Koo, 2020), many research reported utilization of andisol as an adsorbent for the drinking water process (Pranoto, Inayati, & Firmansyah, 2018). Besides vibration of siloxane, FTIR spectra of andisol at 1081 $cm^{-1}$ also corresponds to alumina (Al-O-Al). However, stretching vibration both Al-OH and Si-OH at the range of 3400-3500 $cm^{-1}$ is not detected in this research (Pranoto, Martini, & Maharditya, 2020). It may be because the different locations of andisol soil have the different chemical composition (Zebua, Guchi, & Sembiring, 2020). Unlike andisol, $SiO_2$ is the main mineral in LECA, and all the functional groups correspond to $SiO_2$, which was detected in the FTIR spectra (Sohrabi & Akhlaghian, 2016).

Anthracite is a type of coal that consists of fixed carbon and organic matter. The appearance of stretching vibration at 2928 $cm^{-1}$ (1) represents the existence of an aliphatic structure that commonly presents in anthracite (He, Liu, Nie, & Song, 2017). Stretching of carbonyl group appeared at 1611 $cm^{-1}$ band (2) while C-H stretching in aromatic rings appears at 687 $cm^{-1}$ band (6). According to FTIR spectra in Figure 3, the use of anthracite in this study consists of mineral silica that exists at bands of 1031 $cm^{-1}$ (3), 1010 $cm^{-1}$ (4), 800 $cm^{-1}$(5), 462 $cm^{-1}$ (7) (Zhang et al., 2015). Unlike others adsorbents, activated carbon has no observed peak due to vaporized volatile material during the thermal process in activated carbon production (Sari, Yanto, & Pari, 2019). Therefore, functional groups of lignocellulose as the raw material disappeares and remains 99% carbon.

b. Morphology of Adsorbents

The micrographs from SEM at the magnification 500 times of adsorbents anthracite, silica, andisol, activated carbon, and LECA is available in Figure 5. Morphology of anthracite in Figure 5a

 

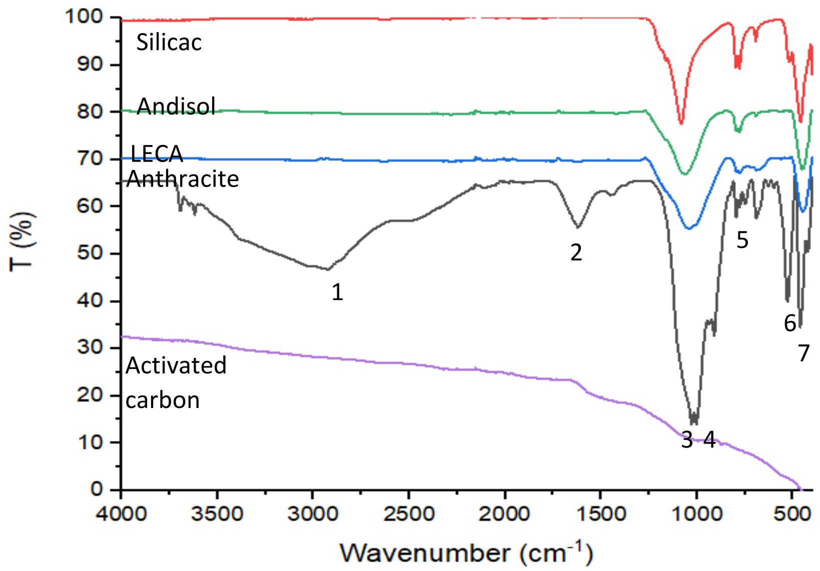


Figure 4. FTIR spectra of silica, andisol, LECA, anthracite, and activated carbon
Source: Analysis Result (2020)

shows inhomogeneous pore distribution with wedge-shaped and ruptures because of the impact process of coalification where the surface of anthracite contains some crystalline and amorphous phases (Liu, Zhang, Choi, & Lu, 2018). According to EDS report, anthracite contains 85% carbon 8% titanium and iron, and 7% amorphous phase (Ribeiro, DaBoit, Flores, Kronbauer, & Silva, 2013). However, silica has smooth morphological surface with seldom pore (Figure 5b). Rosalia, Asmi, & Ginting (2016) investigated effect of calcination on silica's surface that increasing temperature of calcination decreased pore size of morphological silica. Besides that silica, zinc and silver were also included as mineral component in silica by EDX (Energy Dispersive X-Ray) analysis (Colboc et al., 2016).

Rupture and irregular pore are identified in surface graph of andisol (Figure 5c). SEM image shows the existence of micro-and mesoporous particle that can retain particles and minerals such as Fe. Pranoto, Martini, & Maharditya (2020) investigated the adsorption of Fe on andisol trapped on the pore of andisol. After Fe adsorption, the pore size of andisol was smaller compared to the pore size before adsorption which indicated that Fe embedding on the pore. The EDX result showed that Fe entrenched on the pore (Pranoto, Martini, & Maharditya, 2020). Others results showed that the pore can entrap bacterial such as Coliform total dan *E. Coli* (Sholeh, Pranoto, Budiastuti, & Sutarno, 2020a) and also decreased BOD and COD (Sholeh, Pranoto, Budiastuti, & Sutarno, 2020b).

The activated carbon micrograph in Figure 5d showed regular and larger pores (macro size) compared to others adsorbents which are typically observed in activated carbon. The macro-pore (size ~50 nm) was a result of diffusion and reaction of steam with carbon as a treatment for the synthesis of activated carbon (Sari, Yanto, & Pari, 2019). The

 

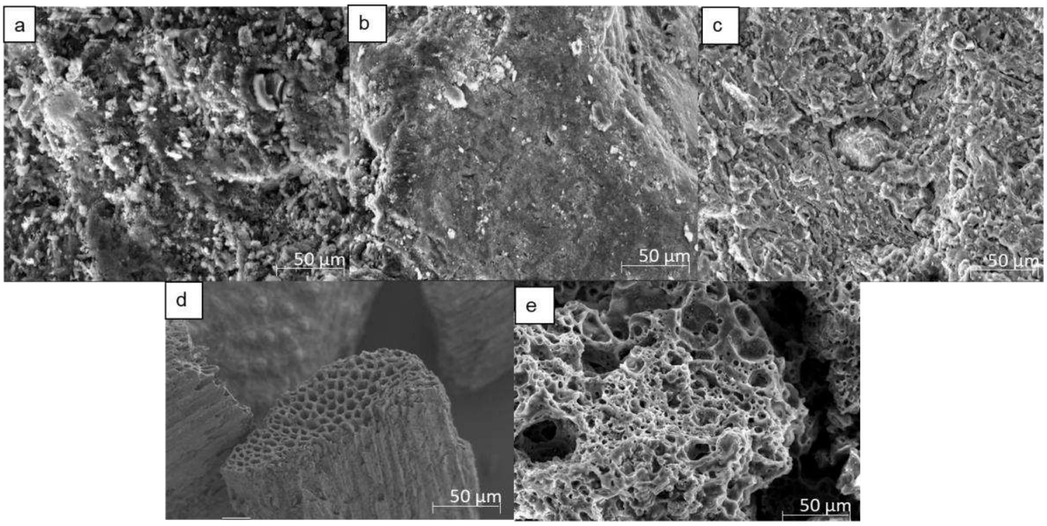


Figure 5. The micrographs from SEM at the magnification 500 times of adsorbents: anthracite (a), silica (b), andisol (c), active carbon (d), and LECA (e)
Source: Analysis Result (2020)

Table 3. The pore characteristics of the adsorbents

| Adsorbents | BET surface area ($m^2/g$) | Pore volume (cc/g) | Average pore diameter (Å) |
|---|---|---|---|
| Silica | 114.405 | 0.183 | 17.082 |
| Andisol | 172.204 | 0.303 | 17.126 |
| LECA | 119.574 | 0.209 | 17.151 |
| Anthracite | 229.523 | 0.393 | 17.057 |
| Activated carbon | 548.310 | 0.948 | 17.034 |

Source: Analysis Result (2021)

pores size of the activated carbon can force adsorption of impurities which have been widely used in water the treatment plant (Jiang et al., 2019; Jin, Jin, Wang, Feng, & Wang, 2013). According to EDS report by Sari, Yanto, & Pari (2019), activated carbon contained 100% carbon without others element.

Surface of LECA in Figure 5e presented the irregular porous surfaces. Even though the chemical component by FTIR of LECA was similar to the chemical component of andisol, the pores are typically different. These pores are able to trap contaminant in water such as phosphor (Mlih et al., 2020). In addition, the detail of the surface pore of each adsorbent is available in the BET section.

Nitrogen adsorption is a procedure to determine the porosity of the adsorbents. The surface area, pore-volume, and average pore diameter of silica, andisol, LECA, anthracite, and activated carbon are in Table 3. According to The International Union of Pure and Applied Chemistry (IUPAC) classification, the average pores diameter of the adsorbents indicate that the pores are classified into micro-porous (less than 20 Å). The higher surface area and porosity of the adsorbents may be attributed to the high sorption efficiency (Rout, Bhunia, & Dash, 2015). Table 3 shows that activated carbon has the highest surface area and pore volume, while silica has the lowest. The results of these pore characteristics are related to the turbidity of the solution where silica is only able to reduce the turbidity up to 8.98 NTU. Even though activated carbon has the highest surface area, the adsorption rate based on turbidity is lower than the adsorption rate of LECA and andisol. It occured because the solid loading of the activated carbon is only 1:100 (w/v) while the others are 1:10 (w/v). Therefore, the activated carbon needs more time to adsorb the pollutant.

This research findings are essential and in line with one of the goals in watershed management, that is to ensure the availability of clean water for human life. The availibity of clean water can be obtained through some water treatments as explained above; however, the prevention of river water from pollution is better than preserving nature. .

## IV. CONCLUSION

Before the adsorption process, the turbidity of Citarum water was 21.30 NTU which was not eligible for human consumption. The turbidity was successfully decreased to below 5 NTU after the treatment using andisol and LECA for 10 minutes with a solid loading of 1:10 (gr/mL). Activated carbon took 10 minutes longer than the time of andisol and LECA to decrease turbidity due to its lower solid loading ratio. Silica has the lowest adsorption rate that may correlate to its pore size. The adsorption rate of the absorbents was greater for the higher pore size. According to BET analysis, the order of surface area was activated carbon>anthracite>andisol>LECA>silica.
The pore size by BET corresponds to the surface image by FE-SEM analysis where activated carbon has regular and larger pores compares to others pores. In general, all the used adsorbents, except active carbon, have similar functional groups such as siloxane and amorphous silica at the band of 1031 $cm^{-1}$ and 462 $cm^{-1}$. We concluded that active carbon, LECA, and andisol are suitable to purify water due to their large surface area. However, the effectiveness of the combination of five adsorbents in water treatment need to evaluated further.

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## AUTHORS CONTRIBUTION

Fahriya Puspita Sari: Conceptualization, methodology, data analysis, data curation, writing – original draft preparation, review and editing. Nissa Nurfajrin Solihat: Conceptualization, methodology, data analysis, data curation, writing – original draft preparation, review and editing. Muhammad Sholeh: Methodology, validation, supervision. Lucky Risanto: Methodology, data curation. Fitria: Methodology, editing, validation. Faizatul Falah: Methodology, data curation. Widya Fatriasari: Methodology, validation, reviewing, editing, supervision.

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