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# PHOSPHATE REDUCTION IN LAUNDRY WASTEWATER USING ACTIVATED COFFEE GROUNDS AND FLY ASH AS ADSORBENTS

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**ABSTRACT**

The growth and development of the population have significantly accelerated economic progress within society. Consequently, many new businesses have emerged, including commercial laundry services. One of the substances found in laundry wastewater, phosphate can cause eutrophication, which disrupts the balance of aquatic ecosystems. One method that can be developed to address this issue is adsorption technology. The aim of this research was to lower the phosphat content and to meet the Regulation of the Minister of Environment of the Republic of Indonesia No. 5 of 2014. The increasing number of coffee shops generates coffee grounds that have the potential to be processed into activated carbon. Additionally, fly ash a by-product of coal combustion contains silica and can be used as an adsorbent. The activated carbon is activated using 0.1 N NaOH and combined with fly ash in various compositions: 2:8, 4:6, 5:5, 6:4, and 8:2. Besides the variation in composition, contact time is also varied 30 minutes, 60 minutes, 90 minutes, 120 minutes, and 150 minutes. The observed parameters include pH and phosphate concentration at each contact time. The research results show that the optimal composition is 0.2AC:0.8FA with the highest phosphate removal efficiency of 60.3% at 150 minutes contact time and a pH of 7.1. However, the final phosphate concentration has not yet met the quality standard of 2 mg/L set by the Regulation of the Minister of Environment of the Republic of Indonesia No. 5 of 2014.

***Keyword:*** *Adsorption, Coffee grounds, Fly ash, Laundry wastewater, Phosphate removal.*

## 1. INTRODUCTION

The growth and development of the population have significantly accelerated economic progress within society. As a result, many new businesses have emerged, including commercial laundry services, which have become increasingly common. Laundry wastewater has become a potential source of environmental pollution with serious negative impacts. This wastewater is categorized as grey water a type of domestic wastewater and contains various detergent components such as surfactants, builders, bleaching agents, and additives [1]. One of the primary pollutants in laundry wastewater is phosphate, which is responsible for eutrophication (nutrient enrichment) in water bodies [2]. Therefore, a simple treatment method is required to address this issue.

One potential method for treating laundry wastewater is adsorption. Adsorption is a process in which one or more components in a fluid solution are concentrated on the surface of a solid material known as an adsorbent. This technique can effectively separate components from a gas or liquid solution [3], [4]. The adsorbent used is activated carbon a porous solid derived from carbon-rich materials and produced through high-temperature processing. The larger the surface area of the activated carbon, the greater its adsorption capacity [5]. Organic waste materials containing carbon are suitable as raw materials for activated carbon production.

Coffee grounds are one such organic waste that can be converted into activated carbon for use as an adsorbent in the adsorption process [6], [7]. However, the utilization of coffee grounds remains limited [8]. When disposed of improperly, coffee waste can be toxic to the environment due to the presence of caffeine, tannins, and polyphenols. Coffee grounds contain 47.8–58.9% total carbon, making them

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suitable for activated carbon production due to their high hydrocarbon content and large surface area and pore structure [4].

In addition to coffee grounds, fly ash containing a high concentration of silica ($SiO_2$) can also be used as an adsorbent. Fly ash is composed of several chemical compounds, including $SiO_2$ (52.0%), $Al_2O_3$ (31.9%), and $Fe_2O_3$ (5%) [9]. The high silica content of fly ash makes it a promising material for adsorbing contaminants in laundry wastewater [10], [11]. The effectiveness of coffee grounds and fly ash as adsorbents in reducing ammonia ($NH_3$) concentrations in urea wastewater [12].

Sodium hydroxide (NaOH) has been found to be a more effective activating agent than hydrochloric acid (HCl) for producing activated carbon, as it results in a larger specific surface area, enhancing adsorption performance. This study focuses on the novelty of optimizing adsorption conditions for contaminant removal in laundry wastewater by determining the most effective activation parameters for the adsorbent. Therefore, this research offers significant potential for advancing more efficient wastewater treatment technologies.

## 2. RESEARCH METHODOLOGY

### 2.1 Equipment and Materials

To support the success of this research, the required tools and materials are listed in **Table 1** below.

**Table 1.** Equipment and Materials Used

| No. | Equipment Name | No. | Equipment Name | No. | Material Name |
|---|---|---|---|---|---|
| 1 | 100-mesh sieve | 10 | Furnace | 1 | Coffee grounds |
| 2 | Porcelain crucible | 11 | UV-Vis Spectrophotometer | 2 | 0.1 M NaOH solution |
| 3 | Desiccator | 12 | Filter paper | 3 | Fly ash |
| 4 | Oven | 13 | Sample bottle | 4 | Sulfate reagent |
| 5 | Furnace | 14 | pH meter | 5 | Distilled water |
| 6 | Beaker glass | 15 | Glass funnel | 6 | Laundry wastewater |
| 7 | Analytical balance | 16 | Volumetric pipette | | |
| 8 | Spatula | 17 | 100 mL beaker glass | | |
| 9 | 100 mL graduated cyl. | 18 | Aluminum foil | | |

### 2.2 Research Variables

The research variables used in this study are presented in **Table 2.**

**Table 2.** Research Variables

| Independent Variables | Dependent Variables | Controlled Variables |
|---|---|---|
| Mass ratio of coffee grounds:fly ash (20:80; 40:60; 50:50; 60:40; 80:20) and contact time (30, 60, 90, 120, 150 minutes) | Adsorption efficiency, pH, % rejection | Initial concentration, stirring speed, NaOH concentration |

### 2.3 Research Procedure

Research Procedure was shown in Figure 1.

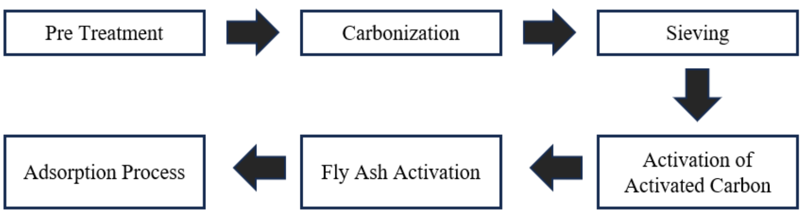


**Figure 1.** Research Procedure

**1) Pretreatment**

The coffee grounds were first washed and sun-dried for 24 hours, followed by oven drying at 105–110 °C for 30 minutes. The dried grounds were then stored in a desiccator to prevent moisture absorption and weighed using an analytical balance.

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**2) Carbonization**

The pretreated coffee grounds were placed in a porcelain crucible and heated in a furnace at 600 °C for 75 minutes to convert them into activated carbon. The carbonized coffee grounds were then cooled to room temperature (±25 °C).

**3) Sieving**

The carbonized coffee grounds were sieved using a 100-mesh sieve to obtain a uniform particle size. Smaller particles passed through the sieve while larger ones remained on top.

**4) Activation of Activated Carbon**

The coffee ground carbon was activated by soaking in 0.1 M NaOH solution (150 mL) for 48 hours. This chemical activation increased the porosity of the material. After soaking, the carbon was washed with distilled water until neutral pH was achieved and then oven-dried at 110 °C for 30 minutes.

**5) Fly Ash Activation**

The fly ash was physically activated by heating in a furnace at 600 °C for 2 hours. This process removed trapped water and impurities from the pores, thereby enhancing its adsorption capacity.

**6) Adsorption Process**

The adsorption process began by mixing 50 mL of laundry wastewater with adsorbents (coffee grounds and fly ash) in Erlenmeyer flasks. A total of 10 samples were prepared. The mixture was stirred at 150 rpm for 60 minutes, and the resulting filtrate was analyzed using UV-Vis spectrophotometry. Effectiveness was tested for various mass ratios of coffee grounds to fly ash: 20:80, 40:60, 50:50, 60:40, and 80:20. Additionally, optimum contact time was evaluated at 30, 60, 90, 120, and 150 minutes.

## 3. ANALYSIS AND RESULT

### 3.1 Moisture and Ash Content Characteristics of Coffee Grounds

**1) Moisture Content Test**

According to Indonesian National Standard (SNI) 06-3730-1995 for activated carbon requirements and testing, the moisture content is used to determine the hygroscopicity of carbon and calculated using the following formula:

$$\text{Moisture Content (\%)} = \frac{(Mo-M)}{Mo} \times 100\% \quad (1)$$

The measured moisture content is 2.65%, where:

Mo = mass of coffee grounds/carbon before drying (grams)

M = mass after drying (grams)

**2) Ash Content Test**

Ash content is also based on SNI 06-3730-1995. It is calculated as:

$$\text{Ash Content (\%)} = \frac{F-G}{B-G} \times 100\% \qquad (2)$$

The measured ash content is 7.45%, where:

B = mass of crucible with sample

F = mass of crucible with ash

G = mass of empty crucible

The results show that the activated carbon derived from coffee grounds has a moisture content of 2.65% and an ash content of 7.45%, both of which fall below the maximum thresholds set by the standard (15% moisture and 10% ash), as summarized below:

**Table 3.** Activated Carbon Quality from Coffee Grounds

| Parameter | SNI Limit | Measured Value |
|---|---|---|
| Moisture (%) | Max 15% | 2.65% |
| Ash (%) | Max 10% | 7.45% |

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### 3.2 FTIR Characterization

Fourier Transform Infrared (FTIR) spectroscopy was used to identify functional groups in coffee grounds and fly ash before and after activation. Spectra were obtained in the range of 400–4000 cm⁻¹, as shown in **Figure 2.**

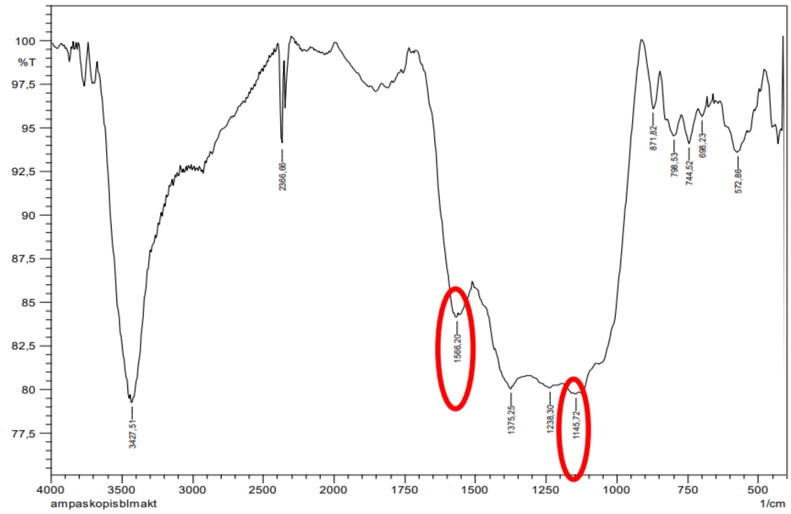


**Figure 2.1** (a) Coffee Grounds (Before Activation)

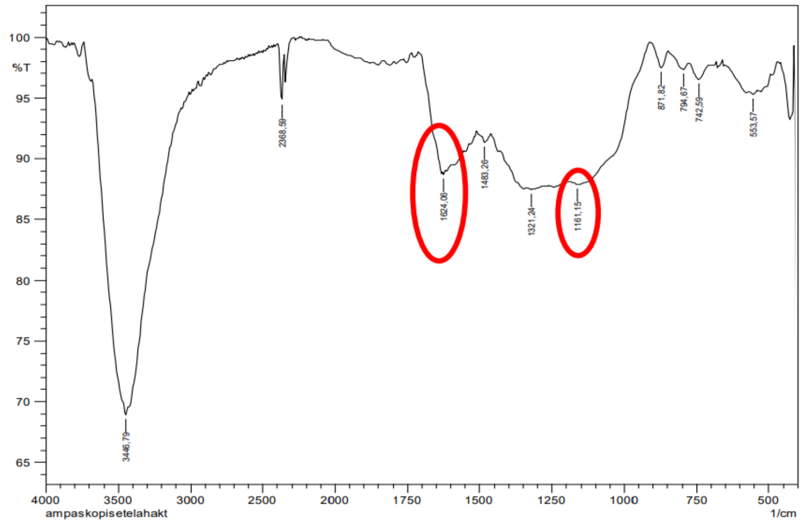


**Figure 2.2** (b) Coffee Grounds (After Activation)

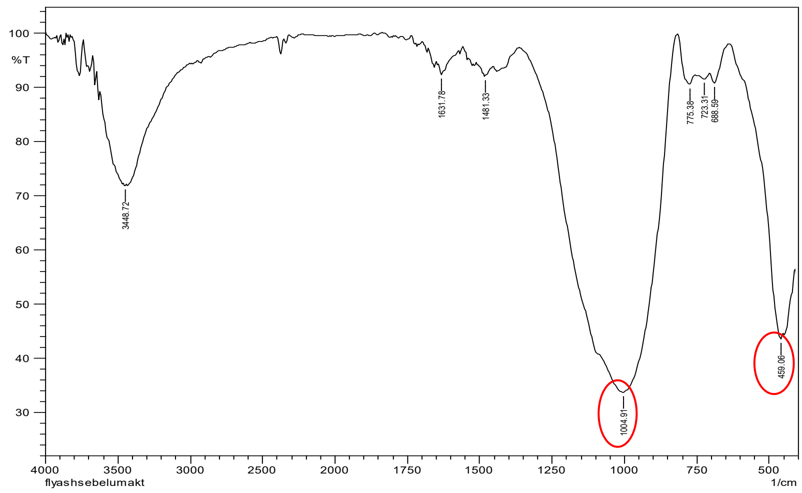


**Figure 2.3** (c) Fly Ash (Before Activation)

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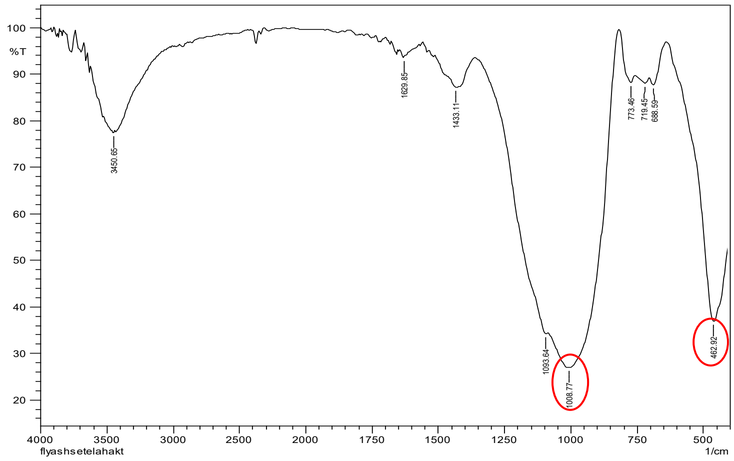


**Figure 2.4** (d) Fly Ash (After Activation)

**Table 4.** FTIR Peak Data

| Sample | Peak Before ($cm^{-1}$) | Peak After ($cm^{-1}$) | Wavelength Range ($cm^{-1}$) | Functional Group |
|---|---|---|---|---|
| Coffee Grounds | 1566.20 | 1624.06 | 1500–1600 | C=C Aromatic |
| | 1145.72 | 1161.15 | 1000–1300 | C–O |
| Fly Ash | 1004.91 | 1010.70 | ~1000 | Si–O–Si |
| | 459.06 | 462.92 | ~460 | Si–O |

FTIR spectral analysis revealed significant changes in coffee grounds before and after activation. Prior to activation, a peak at 1556.20 $cm^{-1}$ was observed, which corresponds to the stretching vibration of aromatic C=C groups, indicating the presence of moderate carbon content. After activation, this peak shifted to 1624.06 $cm^{-1}$, signifying an increase in aromatic carbon content. This shift suggests an enhancement in the carbon bonding structure. Additionally, the peak at 1145.72 $cm^{-1}$, associated with C–O stretching, indicates the presence of ester or ether groups containing carbon. The wavenumber range of 1500–1600 $cm^{-1}$ corresponds to the vibration of C=C functional groups in lignin rings, implying that the activation process enhances the aromatic carbon content of the coffee grounds.

The FTIR spectra of fly ash also exhibited notable peak shifts before and after activation. The shift from 1004.91 $cm^{-1}$ to 1010.70 $cm^{-1}$ indicates asymmetric stretching of Si–O–Si bonds, confirming the presence of silica functional groups. Furthermore, the shift from 459.06 $cm^{-1}$ to 462.92 $cm^{-1}$ corresponds to Si–O stretching vibrations, further affirming the silica content in the fly ash. These changes demonstrate that the activation process helps maintain the structural stability of silica in the fly ash.

## 3.3 SEM Characterization

Scanning Electron Microscopy (SEM) was used to observe the pore structure of coffee grounds and fly ash, both before and after activation, at 3000× magnification (**Figure 3**).

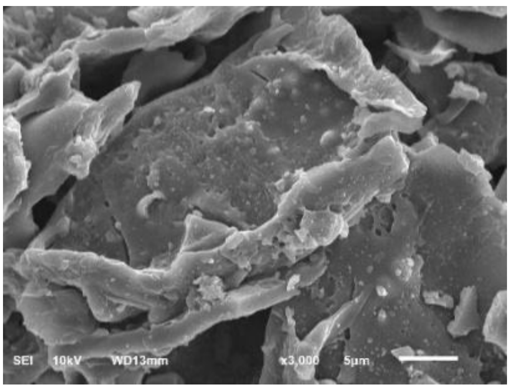


**Figure 3.1** (a) Coffee Grounds (Before Activation)

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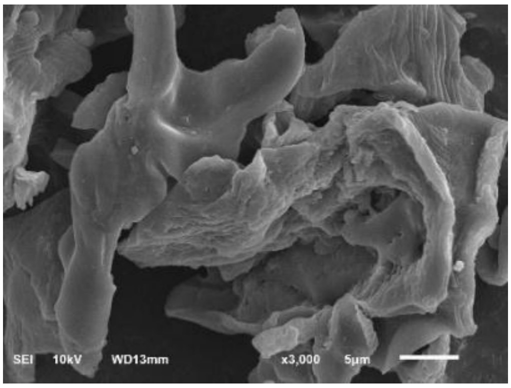


**Figure 3.2** (b) Coffee Grounds (After Activation)

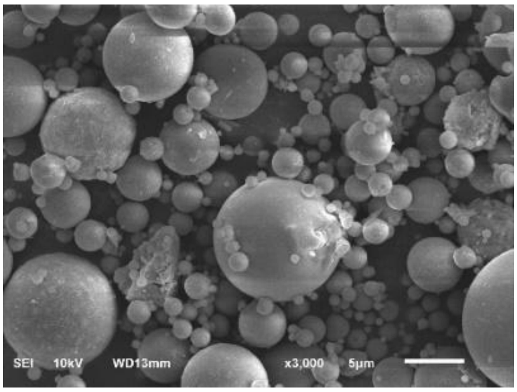


**Figure 3.3** (c) Fly Ash (Before Activation)

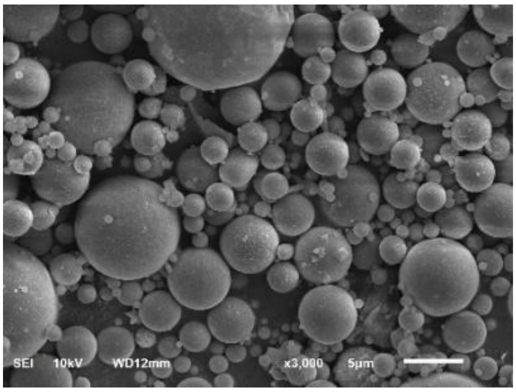


**Figure 3.4** (d) Fly Ash (After Activation)

Based on **Figure 3**, morphological changes in pore structure can be observed on the surface of coffee grounds before and after activation. In image (b), the activated coffee grounds exhibit larger pores compared to image (a), which depicts the unactivated sample. The increase in pore size is attributed to the chemical activation process using NaOH, which promotes a more open and orderly pore morphology. In image (d), the activated fly ash also displays notable differences, showing a greater number of pores and smaller particles compared to the unactivated fly ash in image (c). This is due to the NaOH activation process, which more effectively decomposes the silicate structure, creating more open pores and resulting in a cleaner surface morphology.

### 3.4 Adsorbent pH Measurement

The pH of laundry wastewater is a crucial parameter indicating its acidity or alkalinity, which directly affects environmental compatibility and treatment effectiveness. In this study, pH measurements were conducted before and after the adsorption process using various ratios of coffee grounds (AK) and fly ash (FA) as composite adsorbents.

Before treatment, the wastewater exhibited an acidic character with an initial pH of 5.8. After undergoing adsorption, a consistent increase in pH was observed across all adsorbent variations, with

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values shifting toward neutral or slightly alkaline conditions. This indicates that the adsorption process significantly influenced the neutralization of acidity in the wastewater.

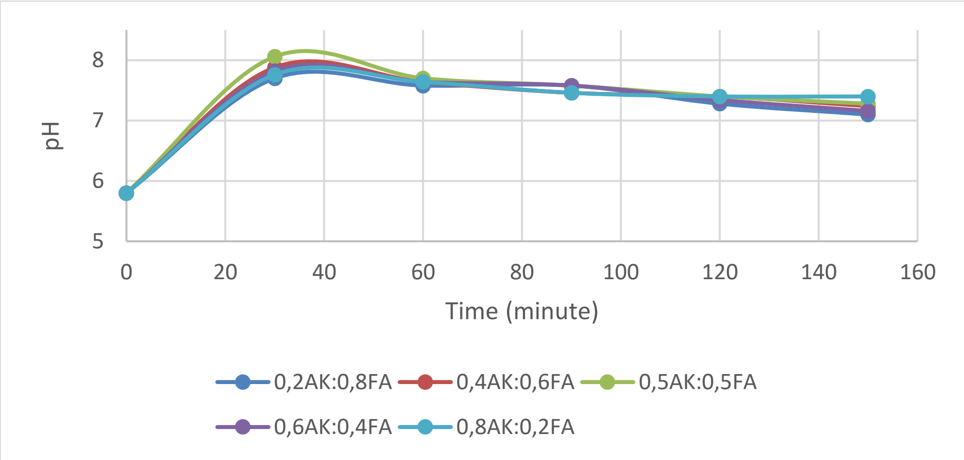


**Figure 4.** Effect of Contact Time on pH

As illustrated in **Figure 4**, different adsorbent compositions affected the final pH values. The combination of 0.2AK:0.8FA resulted in the lowest final pH value of 7.1, which is closest to neutral. This trend demonstrates that adsorbents with a higher proportion of fly ash were more effective at increasing pH. The basic nature of fly ash, which can neutralize hydrogen ions ($H^+$) in the solution, played a dominant role in elevating the pH toward neutral values.
Additionally, the duration of contact time had a noticeable impact on pH. The highest pH values were observed at 150 minutes of adsorption, the longest exposure time tested. This trend suggests that extended contact time allows more $H^+$ ions to be adsorbed, gradually increasing the pH until equilibrium is reached. At equilibrium, the rate of $H^+$ ion adsorption equals the rate of desorption, resulting in a stable pH.
Importantly, the treated wastewater's final pH falls within the permissible limits set by the Indonesian Minister of Environment Regulation No. 5 of 2014, which requires effluent pH values between 6 and 9. Therefore, the combination of coffee grounds and fly ash, particularly with higher fly ash content, proved effective in adjusting wastewater pH to environmentally acceptable levels.

### 3.5 Phosphate Concentration Analysis

Phosphate concentration in laundry wastewater was measured using a UV-Vis spectrophotometer. Phosphate was detected at various concentrations with a correlation coefficient (r) of 0.982 at a wavelength of 887.55 nm. The reduction of phosphate concentration was analyzed by varying the contact time and the composition ratio of the adsorbent. The initial phosphate concentration was 6.906 mg/L.

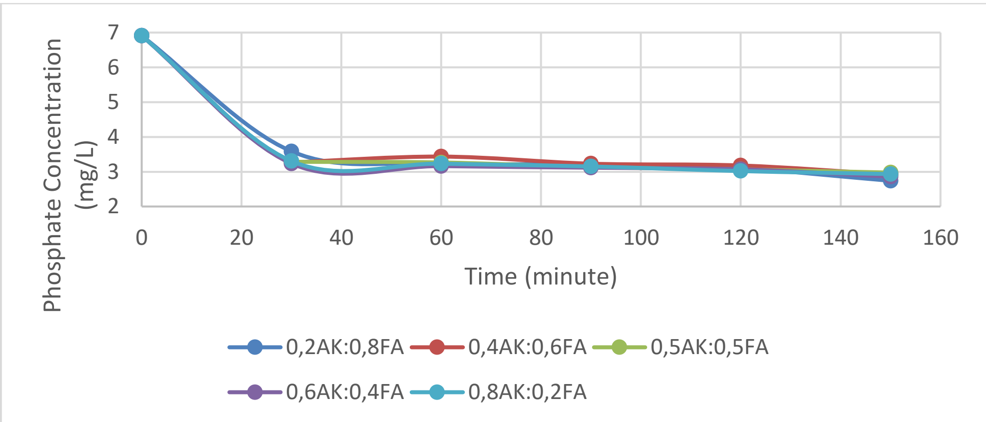


**Figure 5.** Effect of contact time on phosphate concentration in laundry wastewater.

**Figure 5** shows the relationship between contact time and phosphate concentration. All variations demonstrated that the longer the contact time between the adsorbent and the laundry wastewater, the

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greater the reduction in phosphate concentration. This is due to the adsorption rate being influenced by the duration of contact, allowing more phosphate ions to be absorbed by the adsorbent over time, thereby decreasing the concentration of phosphate in the wastewater.

The most effective adsorbent composition was observed at a 0.2AK:0.8FA ratio, yielding the lowest final phosphate concentration of 2.74 mg/L after 150 minutes of contact time. Fly ash exhibited a well-developed porous structure, offering more active sites for phosphate adsorption. However, the final phosphate concentration did not meet the Indonesian environmental quality standard (2 mg/L) as regulated in the Ministry of Environment Regulation No. 5 of 2014. Although the study successfully reduced phosphate levels, the adsorption capacity was not sufficiently optimal to meet the regulatory standard.

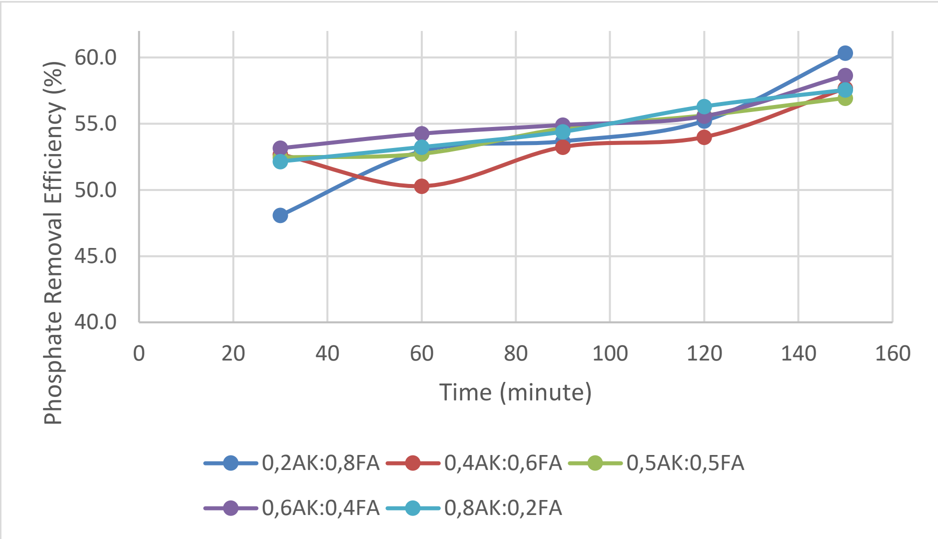


**Figure 6**. Effect of contact time on phosphate removal efficiency using activated coffee grounds and fly ash

**Figure 6** illustrates the relationship between contact time and phosphate removal efficiency. All tested variations showed an increase in removal efficiency over time. The highest efficiency was achieved with the 0.2AK:0.8FA ratio, reaching 60.3% at 150 minutes. A higher proportion of fly ash proved to be more effective in phosphate reduction due to its larger number of active sites and greater porosity, which enhanced the adsorption process. The longer the contact time, the more opportunity phosphate had to interact with the adsorbent, increasing the amount adsorbed. Consequently, the lower the final phosphate concentration, the higher the removal efficiency achieved.

## 4. CONCLUSION

This study demonstrates that coffee grounds and fly ash activated with NaOH are effective in reducing phosphate concentrations in laundry wastewater. Coffee grounds enhance adsorption capacity through increased aromatic carbon content, while fly ash contributes with its high porosity, silica content, and ability to raise pH. The optimal adsorbent composition was found to be 0.2 parts activated coffee grounds and 0.8 parts fly ash (0.2AK:0.8FA). The highest phosphate reduction occurred at 150 minutes. The maximum phosphate removal efficiency was 60.3%, achieved at 150 minutes using the 0.2AK:0.8FA composition.

## REFERENCES

[1] N. Apriyani, "Penurunan Kadar Surfaktan dan Sulfat dalam Limbah Laundry," 2017.
[2] Y. Politeknik *et al.*, "Analisis Pengelolaan Limbah Cair Usaha Laundry."
[3] P. Baryatik *et al.*, "Pemanfaatan Arang Aktif Ampas Kopi sebagai Adsorben Kadmium pada Air Sumur," 2019.
[4] A. D. Moelyaningrum, "Pemanfaatan Arang Aktif Ampas Kopi Sebagai Adsorben Kadmium Pada Air Sumur (The Usage of Coffee Waste Actived Charcoal as Adsorbent of Cadmium in

 P-ISSN : 2598-1277
E-ISSN : 2621-3966

Well Water),” *Jurnal Teknologi Lingkungan Lahan Basah*, vol. 7, no. 1, p. 011, Jan. 2019, doi: 10.26418/jtllb.v7i1.31115.

[5] R. Dewi, A. Dan, and I. Nofriadi, “AKTIVASI KARBON DARI KULIT PINANG DENGAN MENGGUNAKAN AKTIVATOR KIMIA KOH,” 2020. [Online]. Available: www.ft.unimal.ac.id/jurnal_teknik_kimia

[6] “Pemanfaatan Arang Aktif dari Ampas Kopi dan Sekam Padi Sebagai Adsorben Logam Timbal”.

[7] Mariana, M. Marwan, F. Mulana, Y. Yunardi, T. A. Ismail, and M. F. Hafdiansyah, “Activation and characterization of waste coffee grounds as bio-sorbent,” in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Apr. 2018. doi: 10.1088/1757-899X/334/1/012029.

[8] A. Ita Juwita, A. Mustafa, R. Tamrin, P. Studi Agroindustri, and P. Pertanian Negeri Pangkep, “Studi Pemanfaatan Kulit Kopi Arabika (Coffee Arabica L.) Sebagai Mikro Organisme Lokal (MOL).”

[9] A. F. Samosir, B. Yulianto, and C. A. Suryono, “Arang Aktif dari Ampas Kopi sebagai Absorben Logam Cu Terlarut dalam Skala Laboratorium,” 2019.

[10] H. Suseno, “Kombinasi Biosorben Sargassum Dan Arang Sekam Padi Untuk Limbah Cair Industri Batik: Efisiensi Penggunaan Air Pada Industri Batik Dengan Strategi Regenerasi Air Limbah,” *jurnl TPL*, vol. 14, no. 284, 2011.

[11] D. Novianti and A. Tuhu, “Penurunan Tss Dan Warna Limbah Industri Batik Secara Elektro Koagulasi,” *Envirotek : Jurnal Ilmiah Teknik Lingkungan*, vol. 6, no. 1, pp. 37–44, 2014.

[12] M. Septiani, Z. Darajat, I. Pasinda, and D. Kurniawan, “Kajian Perbandingan Efektivitas Adsorben Ampas Kopi Dan Fly Ash Pada Penurunan Konsentrasi Amonia (Nh3) Dalam Limbah Cair Urea,” *JST (Jurnal Sains Terapan)*, vol. 7, no. 2, pp. 52–59, Dec. 2021, doi: 10.32487/jst.v7i2.1171.