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COD REMOVAL PERFORMANCE USING COMBINATION OF SPENT COFFEE GROUNDS ACTIVATED CARBON AND RIVER SAND AS FILTRATION MEDIA IN TOFU INDUSTRIAL WASTEWATER

Arief Rahman[1*], Mulyadi Abdul Wahid [1], Sapriyadi[1]

[1]*Department of Environmental Engineering, Faculty of Science and Technology, Ar-Raniry State Islamic University, Banda Aceh, Indonesia*

**Email Correspondence: arief.rahman@ar-raniry.ac.id*

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ABSTRACT

Tofu industrial wastewater contains a high level of chemical oxygen demand (COD), which may cause negative impacts if not treated before being discharged into the environment. Filtration is one of the simple and effective methods for COD removal in tofu industrial wastewater, utilizing filtration media such as sand and activated carbon. The objective of this research is to evaluate the performance of spent coffee grounds (SCG) activated carbon and river sand as filtration media in COD removal from tofu industrial wastewater. The research was carried out using a dual media filtration unit composed of SCG activated carbon and river sand, with media thicknesses of 15 cm and 30 cm, respectively. The results show that the combination of SCG activated carbon and river sand as filtration media can reduce the COD level in tofu industrial wastewater from 928 mg/L to 307 mg/L (66.92%), although it still does not meet the quality standard (300 mg/L). Based on the findings, it can be concluded that the combination of SCG activated carbon and river sand has the potential to lower COD levels in tofu industrial wastewater, but further improvement is required to enhance its effectiveness.

Keywords: *Spent Coffee Grounds Activated Carbon; River Sand; Filtration; COD Removal; Tofu Industrial Wastewater*

ABSTRAK

Air limbah industri tahu mengandung kadar COD (*chemical oxygen demand*) tinggi yang dapat memberikan dampak negatif jika tidak diolah sebelum dialirkan ke lingkungan. Filtrasi merupakan salah satu metode penyisihan COD yang sederhana dan efektif, memanfaatkan media filtrasi seperti pasir dan arang aktif. Tujuan dari penelitian ini adalah untuk mendapatkan kemampuan arang aktif ampas kopi dan pasir kali sebagai media filtrasi dalam menyisihkan kadar COD dalam air limbah industri tahu. Penelitian ini dilakukan dengan menggunakan unit filtrasi dual media dengan arang aktif ampas kopi dan pasir kali sebagai media filter, dengan ketebalan masing-masingnya 15 cm dan 30 cm. Hasil penelitian menunjukkan bahwa kombinasi arang aktif ampas kopi dan pasir kali dapat menyisihkan kadar COD pada air limbah industri tahu dari 928 mg/L menjadi 307 mg/L (66.92%), namun masih belum memenuhi standar kualitas (300 mg/L). Berdasarkan penelitian ini, dapat disimpulkan bahwa kombinasi arang aktif ampas kopi dan pasir kali dapat menurunkan kadar COD pada air limbah industri tahu, namun masih memerlukan pengembangan agar dapat lebih efektif.

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Kata Kunci: *arang aktif ampas kopi; pasir kali; filtrasi; penyisihan COD; air limbah industri tahu*

Introduction

The organic matter in tofu industrial wastewater may cause negative environmental impacts if not treated before being discharged. In addition to causing unpleasant odors (Andira, et al., 2024), tofu industrial wastewater that contains organic matter may increase COD levels in water, leading to a decline in dissolved oxygen (DO) levels, which can trigger hypoxic (low DO concentration) or anoxic (virtually no DO) conditions. Water with hypoxic or anoxic conditions cannot support fish or macroinvertebrate populations (U.S. EPA, 2021). Therefore, tofu industrial wastewater should be treated through proper treatment processes to meet the required quality standards. According to the Regulation of the Minister of Environment of the Republic of Indonesia No. 5 of 2014, the allowable COD concentration in tofu industrial wastewater before discharge is 300 mg/L.

One of the methods that can be used to treat COD in tofu industrial wastewater is filtration, which utilizes filtration media (e.g., sand, activated carbon) to remove particles. In the filtration method, the treatment process occurs as water flows through the filtration media (Masduqi & Assomadi, 2010). The principal mechanisms and phenomena contributing to the removal of materials in filtration include straining, sedimentation, impaction, interception, adhesion, flocculation, chemical adsorption, physical adsorption, and biological growth (Tchobanoglous, et al., 2004).

Filtration media such as sand can trap particles larger than its pore size while allowing smaller particles to pass through. Due to its abundance and ease of preparation, sand is considered a simple and practical filtration material. The preparation of sand before use includes cleaning, drying, and sieving.

Coffee grounds are derived from coffee beans that have undergone several processes, including roasting. Already carbonized through the roasting process and containing more than 50% carbon (Jenicek, 2022), spent coffee grounds (SCG) have great potential to be used as activated carbon after undergoing cleaning, drying, and activation. Since SCG might cause negative impact if being disposed to the environment (Priena & Handajani, 2023), the utilization of SCG also prevent environmental pollution. As an activated carbon material, SCG has been shown to reduce COD levels by up to 86.15% in batik industrial wastewater (Febrianti, et al., 2023), and up to 96.25% in coffee wastewater treatment (Zainuddin, et al., 2022).

This research aims to assess the performance of SCG activated carbon and river sand in removing COD from tofu industrial wastewater. The results can be used to support future development of SCG activated carbon and river sand as effective filtration media.

Methods

In this research, 30 liters of wastewater were collected from X Tofu Industry located on Krueng Neng Street, Jaya Baru Subdistrict, Banda Aceh City. The COD level of the tofu industrial wastewater from X Tofu Industry is shown in Table 1.

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Table 1. COD level of X Tofu Industry

COD value (mg/L)	Standard Discharge (mg/L)*
928	300

*Regulation of the Indonesian Minister of Environment No. 5, 2014

As shown in Table 1, the COD level of the tofu industrial wastewater exceeds the quality standard, indicating the need for appropriate treatment.

The SCG used in this research was obtained from robusta coffee grounds collected from a coffee shop. Robusta coffee beans were roasted at a typical temperature of 232°C using an oven (Yusibani, et al., 2023). Since SCG is already carbonized through the roasting process, the carbonization step was omitted in this study. The preparation steps for the SCG activated carbon were as follows:

1. 4 kg of SCG was dried in an oven for 2 hours at 105°C.
2. The dried SCG was sieved using a No. 10 mesh.
3. The sieved SCG was chemically activated using 0.1 M HCl for 48 hours.
4. The activated SCG was filtered using Whatman Grade 42 filter paper.
5. It was then rinsed three times with distilled water until the rinsed water reached a neutral pH of 7.
6. The SCG was dried again in an oven for 2 hours at 105°C.
7. The SCG activated carbon was then ready for use.

The experiment used a filtration method. The filtration unit was constructed from a 4″ PVC pipe with a length of 90 cm and filled with pebbles, river sand, and SCG activated carbon. The pebbles (20 cm thick) functioned as a buffer for the river sand. The river sand and SCG activated carbon were used as the filtration media with respective thicknesses of 30 cm and 15 cm. The design of the filtration unit is shown in Figure 1.

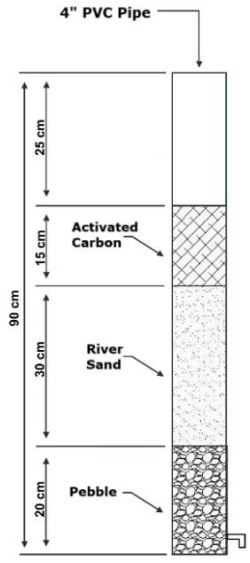

Figure 1. Filtration Unit Design

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The experiment was carried out by discharging 10 liters of tofu industrial wastewater into the filtration unit, allowing it to flow through the media at a flow rate of 0.0507 m/s. The filtered water exiting from the outlet was collected in a bucket.

The treated water was tested in the laboratory to determine the post-treatment COD level, referring to SNI 6989.15-2019, the Indonesian National Standard for COD testing in water and wastewater.

After being tested, the percentage of removal was calculated by comparing post-treatment COD level and pre-treatment COD level using the following formula:

$$R(\%) = \frac{C_0 - C_e}{C_0} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

With R is removal percentage, C_0 is the pre-treatment COD level, and C_e is the post-treatment COD level. R value indicates the performance of SCG activated carbon and river sand in reducing the COD level of tofu industrial wastewater.

Results and Discussion

The experimental results show that the filtration unit utilizing SCG activated carbon and river sand was able to reduce the COD level in tofu industrial wastewater from an initial concentration of 928 mg/L to 307 mg/L. The summary of the experimental results is presented in Table 2.

Table 2. The Experimental Results

C_0 (mg/L)	C_e (mg/L)	R (%)	Quality Standard (mg/L)
928	307	66.92	300*

* Regulation of the Indonesian Minister of Environment No. 5, 2014

As shown in Table 2, the filtration unit achieved a COD removal efficiency of 66.92%. This indicates that SCG activated carbon and river sand performed well in reducing COD levels in tofu industrial wastewater. As the wastewater slowly flows through the filtration media, organic particles are trapped in the pores of the river sand, which are smaller than the particle size. Meanwhile, the SCG activated carbon functions as an adsorbent that retains organic matter within its porous structure. The retention provided by the sand allows sufficient contact time for the SCG activated carbon to adsorb the organic contaminants. These results provide evidence that a filtration unit using sand and activated carbon can be utilized to treat COD in tofu industrial wastewater. This finding is consistent with other studies using similar filtration methods and media, as shown in Table 3.

Table 3. Results of the Experiments Using Filtration with Sand and Activated Carbon for COD removal

No.	Wastewater	Activated Carbon	R (%)	Reference
1	Tofu Industrial Wastewater	SCG	66.92	Output of This Study
2	Tofu Industrial Wastewater	Cacao fruit rind	32.8	Ramazana (2024)

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No.	Wastewater	Activated Carbon	R (%)	Reference
3	Abattoir Wastewater	Nipa Fruit Rind	58.82	Darmawan (2023)
4	Abattoir Wastewater	Candlenut Shell	69	Rizqi (2023)
5	Abattoir Wastewater	Cacao Fruit Rind	74	Alief (2024)
6	Abattoir Wastewater	Jengkol Fruit Rind	70.5	Nurdina (2023)

Based on Table 3, the COD removal efficiency achieved using SCG activated carbon is comparable to other activated carbon sources, some of which show higher percentages. Nevertheless, SCG shows good potential as an alternative filtration media for wastewater treatment. However, since the final COD concentration still exceeds the quality standard of 300 mg/L, further improvement of the filtration media is necessary.

Possible improvements for SCG activated carbon include using stronger acid or alkali solutions during activation, conducting recarbonization processes, or using smaller particle sizes to increase the surface area. For river sand, improvements may involve determining the effective size and uniformity coefficient to optimize its filtration properties. In addition to improving the filtration media, the overall treatment system for tofu industrial wastewater could be enhanced by integrating pre-treatment and post-treatment processes. For example, sedimentation units can be used in pre-treatment to reduce organic particle loads on filtration unit, while aeration units can be used in post-treatment to further lower COD concentrations.

Conclusion

The results of this study show that SCG activated carbon and river sand, when used as filtration media, perform well in reducing COD levels in tofu industrial wastewater. The combination successfully reduced COD concentrations from 928 mg/L to 307 mg/L, achieving a removal efficiency of 66.92%. From the result, it is also concluded that the SCG activated carbon and river sand that being utilized in this research still does not meet the quality standard, which is 300 mg/L, hence both SCG activated carbon and river sand needs further improvement to perform better.

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References

Alief, M. S., “Kemampuan Arang Aktif Kulit Buah Kakao (*Theobrema cacao L.*) Sebagai Media Filtrasi Pada Penyisihan Kadar COD dan TSS Pada Limbah Cair UPTD RPH Kota Banda Aceh”, Universitas Islam Negeri Banda Aceh, 2024.

Andira, M. H. M., Fajri, R., Rahmadhani, S. E., Rosyida, S. H., & Matin H. H. A. (2024). Evaluation of Water Pollution Due to Tofu Industrial Waste: Studies Case and Strategy Countermeasures. Waste Technology (WasTech). Vol. 12(1), April 2024.

DOI: 10.22373/ijes.v3i1.7663
ISSN 3046-885

Darmawan, D. P., "Efektivitas arang aktif Dari Kulit Buah Nipah (*Nypa fruticans*) sebagai Media Filter Dalam Pengolahan Limbah Cair Tahu", Universitas Islam Negeri Banda Aceh, 2023.

Febrianti, C., Ulfah, M., Kusumastuti. (2023). Pemanfaatan Ampas Kopi sebagai Bahan Karbon Aktif untuk Pengolahan Air Limbah Industri Batik. agriTECH, 43 (1) 2023, 1-10.

Jenicek, L., Tunklova, B., Malatak, J., Neskudla, M. & Velebil, J. (2022). Use of Spent Coffee Ground as an Alternative Fuel and Possible Soil Amendment. Materials, vol. 15, no. 19, p. 6722.

Masduqi, A., & Assomadi, A. F. (2010). Operasi & Proses Pengolahan Air. itspress. Surabaya.

National Standardization Agency. (2019). SNI 6989.15:2019. Cara Uji Kebutuhan Oksigen Kimiawi (Chemical Oxygen Demand/COD) Dengan Refluks Terbuka Secra Titrimetri. Jakarta.

Nurdina, P., "Pemanfaatan Arang Aktif Kulit Jengkol (*Phitecellobium lobatum*) Sebagai Filtrasi Untuk Menurunkan Kadar COD dan TSS Pada Limbah Rumah Potong Hewan", Universitas Islam Negeri Banda Aceh, 2023.

Priena, G. H. & Handajani, M. (2023). Utilization of Spent Coffee Grounds as Adsorbent: A Review. IGSC: Proceeding of the 4th ITB Graduate School Conference. (727-739).

Ramazana, R., "Pemanfaatan Arang Aktif Kulit Kakao (*Theobrema cacao L.*) Sebagai Media Filter Dalam Pengolahan Limbah Cair Tahu", Universitas Islam Negeri Ar-Raniry Banda Aceh, 2024.

Rizqi, U., "Filtrasi Air Limbah Rumah Potong Hewan (RPH) menggunakan Filter Dual Media Pasir Dan Arang Aktif Cangkang Kemiri", Universitas Islam Negeri Ar-Raniry Banda Aceh, 2023.

Regulation of Minister of Environment of the Republic of Indonesia No. 5. (2014). Peraturan Menteri Lingkungan Hidup No. 5 Tahun 2014 Tentang Baku Mutu Air Limbah. Jakarta: Kementerian Lingkungan Hidup Republik Indonesia.

Tchobanoglous, G., Burton, F. L., & Stensel, H. D. (2003). Wastewater Engineering: Treatment and Reuse (Fourth Edition). McGraw-Hill Education.

United States Environmental Protection Agency. (2021). Factsheet On Water Quality Parameters: Dissolved Oxygen. United States of America.

Yusibani, E., Ikramullah, Yufita, E., Jalil, Z., & Suhendi, E. (2023). The Effect of Temperature and Roasting Time ON The Physical Properties of Arabica and Robusta gayo Coffee Bean. Journal of Applied Agricultural Science and Technology. 7(2); 100-108 (2023).