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Research Article

Utilization of Coconut Shell Activated Charcoal in Adsorbing Laundry Wastewater

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Abstract

Adsorption involves the attachment of molecules or ions onto the surface of an adsorbent. Activated charcoal is effective in adsorbing organic substances, odors, colors, and various pollutants from water. In this process, toxic particles adhere to the charcoal, reducing pollutant concentrations and improving water quality. This study examines the effectiveness of coconut shell activated charcoal in adsorbing laundry wastewater, specifically focusing on reducing BOD, COD, and coliform levels. A quantitative approach using a completely randomized design (CRD) was employed, with varying charcoal weights (1 g, 2 g, and 3 g) to assess its impact on water quality. Each treatment used 100 ml of laundry wastewater. The results showed that activated charcoal from coconut shells was effective in reducing BOD and COD levels, but not in lowering coliform concentrations. The third treatment (3 g) yielded the most significant BOD reduction, with a final concentration of 20 mg/L and an effectiveness of 96.66%. For COD, the third treatment resulted in a concentration of 71 mg/L and an effectiveness of 93.07%. However, coliform levels remained unchanged in all treatments, exceeding 160,000/100 mL, far above the standard maximum of 3000/100 mL, with 0% effectiveness in reducing coliform.

Keywords: Activated Charcoal; Adsorption; BOD; COD; Coliform; Effluent.

INTRODUCTION

Laundry services are a rapidly growing industry [1], [2]. Not only in major cities but also in suburban areas. Initially, these services provided great convenience, but over time, they have contributed to environmental issues due to the wastewater they produce [3], [4], [5]. Wastewater from laundry processes has the potential to cause significant pollution, especially to water bodies [6], [7], [8].

Laundry wastewater that is not treated beforehand leads to an uncomfortable environment due to the foul odors it emits. In addition to affecting human health, it pollutes water and soil, negatively impacting plant growth and reducing soil fertility. Furthermore, it disrupts the ecosystem by threatening the organisms that inhabit it. Animals exposed to or drinking this wastewater can experience poisoning and even death.

Laundry wastewater contains detergents and other harmful active chemicals that pose a threat to both human health and the environment. Key parameters used to assess the quality of this wastewater include Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and coliform levels. Elevated BOD levels indicate a high concentration of organic matter, which deteriorates water quality. High COD levels are often a result of chemicals in detergents, while the presence of coliform bacteria indicates potential contamination by pathogenic bacteria, which can endanger both human health and the environment [9], [10], [11].

Chemical analysis of laundry wastewater reveals that concentrations of BOD, COD, and coliform exceed permissible limits [12]. Chemical analysis of laundry wastewater shows that the levels of BOD, COD, and coliform exceed the established permissible limits. Elevated levels of BOD, COD, and coliform in laundry wastewater can be harmful to human health and the environment. Therefore, appropriate wastewater treatment is necessary to reduce the concentrations of BOD, COD, and coliform in laundry effluent [13], [14].

One treatment technique suitable for laundry wastewater is adsorption. Adsorption involves the accumulation of molecules or ions on the surface of an adsorbent material [15], [16]. It is an effective method for capturing ions from water, provided the adsorbent has selective adsorption capabilities, a large surface area per unit mass, and strong binding affinity to separate contaminants, whether physically or chemically [17].

Laundry wastewater is a significant source of environmental pollution, mainly due to the presence of hazardous substances such as chemicals from detergents, heavy metals, and organic compounds. With the increasing demand for laundry services, there is a pressing need for effective solutions to mitigate the negative environmental impacts, particularly on water quality. Adsorption is one of the methods that can be employed to address this issue, as it involves removing harmful substances from water using adsorbents like activated carbon.

Activated carbon is widely recognized for its ability to absorb a wide range of pollutants, including organic compounds, odors, colors, and toxic chemicals. Its highly porous structure provides an extensive surface area, enhancing its adsorption capacity for pollutants in water. In the context of laundry wastewater treatment, activated carbon has proven to be effective in removing various contaminants, resulting in cleaner and safer water [18], [19], [20], [21].

One natural material that can be used as a source of activated carbon is coconut shell. Coconut shell has excellent adsorption potential, as it contains active compounds such as lignin, cellulose, and carbon. Activated charcoal derived from coconut shells possesses a large surface area and well-distributed pores, making it highly effective in adsorbing a wide variety of pollutants, including heavy metals and hazardous organic compounds [22], [23], [24].

The use of activated charcoal from coconut shells not only provides an effective solution for treating laundry wastewater but is also environmentally friendly. Utilizing coconut shells as a raw material for activated carbon reduces the amount of waste discarded into the environment, thereby minimizing negative impacts on ecosystems. Moreover, innovations in the utilization of coconut shells continue to evolve, making them a promising alternative material in water purification technologies.

METHODS

This research was conducted between April and the completion of data collection. Wastewater samples were collected from three different laundry businesses in Sukarame District, Bandar Lampung. The quality analysis of the laundry wastewater was carried out at the Standardization and Industrial Service Institute (Balai Standarisasi dan Pelayanan Jasa Industri - BSPJI).

Instrument and Materials

The equipment used in this study included containers, weights, plastic bottles for sample collection, and various laboratory tools for the production and testing of activated carbon. For the chemical analysis, instruments such as BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) testers, as well as tools for coliform bacteria testing, were used. Activated carbon production involved the use of a furnace, oven, analytical balance, UV-visible spectrophotometer, pH meter, and other precision instruments.

The study used 900 ml of wastewater from laundry services. Chemical reagents for BOD and COD testing included $MnSO_4$, NaN_3, $NaOH$, H_2SO_4, $K_2Cr_2O_7$, and several others. Activated carbon was produced using coconut shell as the primary material, which was treated with chemicals like HCl and NaOH to enhance its adsorption capacity.

Research Design

This study employed a **Randomized Complete Design (RCD)** with a single treatment factor: the variation in the mass of activated carbon used (1 g, 2 g, and 3 g). The objective was to determine the effectiveness of varying carbon mass in improving the quality of laundry wastewater. Each treatment involved 100 ml of wastewater, treated with coconut shell-based activated carbon. A total of 12 samples were used in this experiment.

Table 1. Treatment Design and Sample Size for Laundry Wastewater Adsorption Experiment

Treatment	Description	Sample Size
Control	Wastewater without activated carbon	3 samples
P1	Wastewater treated with 1 g carbon	3 samples
P2	Wastewater treated with 2 g carbon	3 samples
P3	Wastewater treated with 3 g carbon	3 samples

Each treatment was allowed 60 minutes of contact time for adsorption, following a systematic repetition scheme to ensure reliable results.

The population consisted of all laundry wastewater in Sukarame District. The sample included wastewater from three selected laundry services. Each treatment used 100 ml of laundry wastewater, with a total of 1200 ml required for the entire study.

Research Procedure

The research involved several key steps, figure 1.

Figure 1. Wastewater Research Methodology

The research was conducted in several stages, starting with a field survey to identify three laundry services in Sukarame District, Bandar Lampung, from which wastewater samples were collected. A total of 1200 ml of laundry wastewater was collected, divided into samples of 100 ml each, and subjected to treatment with activated carbon derived from coconut shells. The activated carbon was prepared through a process of carbonization at 1000°C and chemical activation using

HCl to enhance its adsorption properties. Three different masses of activated carbon (1 g, 2 g, and 3 g) were used to treat the wastewater, with a control sample that received no treatment.

Data Collection and Analysis

After treatment, the wastewater samples were analyzed for key parameters, including Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and coliform bacteria content. BOD measurements were taken by incubating the samples in oxygen-saturated diluents for five days at 20°C, followed by iodometric titration. COD levels were determined using titration after heating the samples with potassium dichromate and sulfuric acid for two hours. Coliform bacteria were tested using the Most Probable Number (MPN) method, where samples were incubated at 37°C for 24 hours and examined for gas formation.

The data collected from these tests were analyzed using statistical methods to determine the effectiveness of the different carbon treatments in reducing contaminants. The effectiveness of the activated carbon in reducing BOD, COD, and coliform levels was calculated as a percentage reduction using pre-treatment and post-treatment data.

Data analysis in this study was conducted by calculating the effectiveness of the reduction in parameters of laundry wastewater after treatment with activated charcoal. The determination of the reduction effectiveness was calculated using the following formula:

$$\text{Effectiveness } (\%) = \frac{A0 - An}{Ao} x \; 100\%$$

Explanation :

A_0 : Concentration of the contaminant before treatment

A_n : Concentration of the contaminant after treatmentng the following formula

A non-parametric Kruskal-Wallis test was used to analyze differences between treatments. This test was chosen due to the non-normal distribution of the data, providing a robust comparison of the effectiveness of various carbon masses in reducing contaminants.

Activated Carbon Production

Activated carbon was produced by carbonizing coconut shells at 1000°C, followed by chemical activation using HCl to enhance pore structure and adsorption capacity. The activated carbon was then dried and used in the adsorption experiments. The physical and chemical properties of the activated carbon, including moisture content, volatile matter, ash content, and iodine adsorption capacity, were characterized according to **Indonesian National Standards (SNI 06-3730-1995)**.

RESULT AND DISCUSSIONS

Research Finding

This study investigated the use of coconut shell activated charcoal to adsorb pollutants from laundry wastewater. The experiment included three treatment groups and one control group, with the results summarized in Table 2.

Table 2. Laboratory Test Results of Laundry Wastewater with Activated Charcoal Treatment

Parameter	Unit	Standard	Control (P0)	Treatment 1 (P1)	Treatment 2 (P2)	Treatment 3 (P3)	Average
BOD	mg/L	30	600	95	54	20	192.25
COD	mg/L	100	1205	187	110	71	393.25
Coliform	cfu/100mL	3000	>160000	>160000	>160000	>160000	>160000

The results from Table 2 reveal a marked reduction in BOD and COD levels after applying the activated charcoal treatment. BOD levels in the control group were initially recorded at 600 mg/L, but the third treatment group reduced this to 20 mg/L, representing a significant improvement. Similarly, COD levels, which were initially at 1205 mg/L, dropped to 71 mg/L after the third treatment. Conversely, no change was observed in coliform levels, which remained greater than 160,000 cfu/100mL across all treatments, suggesting that the activated charcoal treatment was ineffective in removing coliform bacteria from the wastewater.

Table 3. Effectiveness of BOD Reduction

Treatment	BOD Before	BOD After	Effectiveness (%)
P1	600	95	84.16
P2	600	54	91.00
P3	600	20	96.66
Average	600	56.33	90.60

The data presented in Table 3 show a significant reduction in BOD levels across all treatments, with an average reduction of 90.60%. The third treatment, which utilized 3 grams of activated charcoal, achieved the highest level of effectiveness, reducing BOD from 600 mg/L to 20 mg/L, representing an effectiveness rate of 96.66%.

Table 4. Effectiveness of COD Reduction

Treatment	COD Before	COD After	Effectiveness (%)
P1	1205	187	81.75
P2	1205	110	89.26
P3	1205	71	93.07
Average	1205	122.66	88.02

Table 4 reflects the significant reduction in COD levels after treatment with activated charcoal, with an average reduction effectiveness of 88.02%. The third treatment achieved the greatest reduction, with COD levels falling from 1205 mg/L to 71 mg/L, yielding an effectiveness of 93.07%.

Table 5. Coliform Levels

Treatment	Coliform Before	Coliform After	Effectiveness (%)
P1	>160000	>160000	0
P2	>160000	>160000	0
P3	>160000	>160000	0
Average	>160000	>160000	0

As shown in Table 5, the coliform levels remained consistently high, above 160,000 cfu/100 mL, even after the treatment. No reduction was observed in coliform counts in any of the treatments, resulting in 0% effectiveness for all groups.

Discussion

The study results demonstrate that activated charcoal derived from coconut shells was highly effective in reducing BOD and COD levels in laundry wastewater, but ineffective in lowering coliform counts. The third treatment, which involved the use of 3 grams of activated charcoal, showed the most significant improvements in water quality, bringing BOD and COD levels within acceptable regulatory standards. However, the inability of the activated charcoal to reduce coliform levels suggests that additional or alternative treatment methods are necessary to address microbial contamination.

1. **BOD Reduction**

   Biochemical Oxygen Demand (BOD) is a critical parameter for assessing the amount of oxygen required by microorganisms to decompose organic matter in water. Elevated BOD levels indicate a high concentration of biodegradable organic compounds, which can deplete oxygen levels in water bodies, adversely affecting aquatic life. In this study, BOD levels were reduced significantly across all treatments, with the third treatment achieving a reduction of 96.66%, bringing BOD levels to 20 mg/L. This value complies with the maximum permissible limit of 30 mg/L set by the Indonesian Ministry of Environment and Forestry (Regulation No. P.68/Menlhk-Setjen/2016).

   The substantial reduction in BOD can be attributed to the large surface area and porous structure of the activated charcoal, which effectively adsorbs organic pollutants. The highly porous surface of the activated charcoal allows for the capture of organic molecules present in the wastewater, thereby reducing the oxygen demand required for microbial degradation. This explains the substantial reduction in BOD across all treatments, especially the third treatment.

2. **COD Reduction**

   Chemical Oxygen Demand (COD) is a measure of the amount of oxygen required to chemically oxidize organic and inorganic compounds in water. High COD levels indicate the presence of a wide range of chemical pollutants, including those that are resistant to biological degradation. The study found that the use of activated charcoal significantly reduced COD levels, with the third treatment achieving a reduction of

93.07%, bringing COD down to 71 mg/L. This is well within the regulatory limit of 100 mg/L for wastewater discharge.

The effectiveness of activated charcoal in reducing COD can be linked to its ability to adsorb both biodegradable and non-biodegradable pollutants. The charcoal's adsorption capacity allows it to capture complex organic compounds and other contaminants that contribute to high COD levels, resulting in a substantial improvement in wastewater quality.

3. **Coliform Levels**

In contrast to the reductions in BOD and COD, the activated charcoal was ineffective in reducing coliform levels, with no significant change observed across all treatments. Coliform bacteria, including *Escherichia coli*, serve as indicators of fecal contamination and can pose health risks if present in high concentrations. Despite the reduction in organic pollutants, the persistence of coliform bacteria suggests that activated charcoal may not be effective in removing microbial contaminants.

Several factors may explain the ineffectiveness of activated charcoal in reducing coliform levels. Firstly, coliform bacteria are relatively small, and the pores in the activated charcoal may not be sufficient to trap these microorganisms. Secondly, the high initial concentration of coliform bacteria (>160,000 cfu/100 mL) may have exceeded the adsorption capacity of the charcoal. Additionally, coliform bacteria are more likely to be removed through filtration or disinfection processes rather than adsorption.

Statistical Analysis

The normality test results (Kolmogorov-Smirnov and Shapiro-Wilk tests) indicated that the data were not normally distributed ($p < 0.05$), leading to the use of the Kruskal-Wallis test for further analysis. The Kruskal-Wallis test confirmed that there was a statistically significant effect of activated charcoal treatment on the reduction of BOD and COD levels, supporting the conclusion that activated charcoal is effective in improving laundry wastewater quality.

CONCLUSION

The results of this study indicate that coconut shell activated charcoal is highly effective in reducing Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) in laundry wastewater, successfully bringing both parameters within the permissible limits set by the Indonesian government. However, the activated charcoal was ineffective in lowering coliform bacteria levels. This suggests that additional treatment methods, such as advanced filtration or chemical disinfection, are necessary to adequately address microbial contamination in laundry wastewater. Future research should focus on optimizing the use of activated charcoal by integrating it with other purification technologies, such as ultraviolet (UV) disinfection or advanced filtration systems, to provide more comprehensive wastewater treatment. Investigating the use of different adsorbent materials or a combination of adsorbents could further improve the removal of both chemical and microbial contaminants from wastewater. Additionally, scaling up the application of these systems in industrial laundry settings may offer valuable insights into their practical effectiveness and environmental benefits. The success of activated charcoal in reducing BOD and COD highlights its potential as a sustainable and cost-effective solution for laundry wastewater treatment, but it must be combined with other technologies to fully address the range of contaminants present in the wastewater.

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CONFLICT OF INTEREST

"The authors declare no conflict of interest."

REFRENCES

[1] Widiyarini, “Mengurangi pengangguran terdidik dengan meningkatkan semangat kewirausahaan melalui pelatihan jasa laundry,” *J. Sosio e-Kons*, vol. 10, no. 3, pp. 199–206, 2018. https://doi.org/10.30998/sosioekons.v10i3.2844

[2] M. H. Jamily, “Meningkatkan kualitas pelayanan di Laundry Thoyyiba dengan menggunakan metode Servqual dan Quality Function Development,” Oct. 2018.

[3] U. M. Herawati and M. F. Ma’ruf, “Strategi Pemerintah Kota Surabaya dalam memberdayakan masyarakat pasca penutupan lokalisasi,” 2020.

[4] M. Ramdan, L. Siwiyanti, R. Nurmilah, and K. Komariah, *Klasterisasi UMKM dan Produk Unggulan Kota Sukabumi*, E. Saribanon, Ed., Bandung: Widiana Media Utama, 2024. Accessed: Oct. 22, 2024. https://books.google.co.id/books?hl=id&lr=&id=8tUdEQAAQBAJ

[5] S. Eka, “Pemanfaatan arang aktif tempurung kelapa dalam mengadsorpsi limbah cair laundry,” Oct. 2023.
[6] N. Rahmadani, M. Syafri, S. Mustari, and N. H. Nur, “Efektifitas penyaringan sederhana dengan media cipping, arang aktif, dan zeolit dalam menstabilkan kadar BOD dan COD limbah cair usaha laundry rumah tangga,” *Media Publ. Promosi Kesehat. Indones.*, vol. 5, no. 4, pp. 447–452, 2022. https://doi.org/10.56338/mppki.v5i4.2209
[7] R. Khairunnisa, K. P. Utomo, and A. Sulastri, “Identifikasi mikroplastik pada limbah laundry di Kota Pontianak,” *J. Teknol. Lingkung. Lahan Basah*, vol. 12, no. 3, pp. 671–680, 2024. https://doi.org/10.26418/jtllb.v12i3.78352
[8] N. Andalia, M. Ridhwan, Armi, and Husna, “Pengolahan limbah cair laundry dengan menggunakan biosand filter dan activated carbon di LULA LAUNDRY,” vol. 6, no. 2, pp. 1–23, 2016.
[9] N. R. Nirwana, “Pengolahan air limbah domestik grey water menggunakan metode biosand filter dan karbon aktif dalam penurunan kadar BOD dan COD,” Sep. 2021. Accessed: Oct. 22, 2024. https://unipasby.ac.id/
[10] I. Pontiani, R. Purnaini, and P. W. Nugraheni, “Penurunan parameter pencemar limbah laundry menggunakan filter arang cangkang kelapa sawit,” *J. Teknol. Lingkung. Lahan Basah*, vol. 11, no. 1, p. 073, 2023. https://doi.org/10.26418/jtllb.v11i1.59352
[11] P. Nugrahini and A. Nuria, “Effectiveness of EAPR (Electro Assisted Phytoremediation) method for palm oil mill effluent using water hyacinth (*Eichhornia crassipes*),” *Indonesian J. Chem. Sci.*, vol. 13, no. 1, 2024.
[12] S. Yurika, “Analisis kualitas air di wisata pemandian Way Belerang Simpur Desa Kecapi Kecamatan Kalianda Kabupaten Lampung Selatan Provinsi Lampung,” Jul. 2022.
[13] S. Kusmiati, “Analisis cemaran mikroba air minum dalam kemasan berdasarkan masa kadaluarsa (expired date) sebagai referensi mata kuliah mikrobiologi,” Feb. 2021.
[14] A. M. Putri and P. Kurnia, “Identifikasi keberadaan bakteri coliform dan total mikroba dalam es dung-dung di sekitar kampus Universitas Muhammadiyah Surakarta,” *Meida Gizi Indones.*, vol. 13, no. 1, p. 41, 2018. https://doi.org/10.20473/mgi.v13i1.41-48
[15] S. Oko, H. Harjanto, A. Kurniawan, and C. Winanti, “Penurunan kadar zat warna Remazol Brilliant Blue R dengan metode adsorpsi menggunakan serbuk $CaCO_3$ dari cangkang telur dan karbon aktif,” *Metana*, vol. 18, no. 1, pp. 39–45, 2022. https://doi.org/10.14710/metana.v18i1.45766
[16] Y. Hairunisa, “Pembuatan dan karakterisasi selulosa dari limbah kulit buah nanas (*Ananas comosus* L.) sebagai adsorben zat warna Naphtol Yellow,” Sep. 2022. Accessed: Oct. 22, 2024. https://repository.unja.ac.id/
[17] A. Husaini, M. Yenni, and C. Wuni, “Efektivitas metode filtrasi dan adsorpsi dalam menurunkan kesadahan air sumur di Kecamatan Kota Baru Kota Jambi,” *J. Formil (Forum Ilmiah) Kesmas Respati*, vol. 5, no. 2, p. 91, 2020. https://doi.org/10.35842/formil.v5i2.323
[18] K. B. Ginting, “Pengaruh massa bioadsorben dari daun nanas (*Ananas comosus* (L.) Merr) pada proses pemurnian CPO (*Crude Palm Oil*),” Feb. 2024.
[19] E. Karlina, “Desain pengolahan limbah laundry menggunakan media kolom adsorpsi,” Sep. 2022.
[20] J. Ekawati, *Alternatif Bahan Baku Arang Aktif*, Malang: Rena Cipta Mandiri, 2023. Accessed: Oct. 22, 2024. https://books.google.co.id/books?hl=id&lr=&id=_FKwEAAAQBAJ

[21] L. F. Ramadhani, I. M. Nurjannah, R. Yulistiani, and E. A. Saputro, "Review: teknologi aktivasi fisika pada pembuatan karbon aktif dari limbah tempurung kelapa," *J. Tek. Kim.*, vol. 26, no. 2, pp. 42–53, 2020. https://doi.org/10.36706/jtk.v26i2.518
[22] P. T. Resky et al., "Efektivitas media adsorben arang tempurung kelapa terhadap kualitas limbah cair di RSUD Sayang Rakyat Kota Makassar," *Wind. Public Heal. J.*, vol. 3, no. 1, pp. 136–145, 2022. https://doi.org/10.33096/woph.v3i1.355
[23] R. Ahdiaty, "Adsorpsi anion dalam air dengan nanokomposit magnetik Fe_3O_4/karbon aktif," Jan. 2022. Accessed: Oct. 22, 2024. https://dspace.uii.ac.id/handle/123456789/37719
[24] R. Budiman, "Analisis efektivitas aktivasi fisika-kimia zat H_3PO_4 dan $ZnCl_2$ terhadap daya adsorpsi karbon aktif kulit buah kakao pada pengolahan limbah air terproduksi Lapangan X," 2021.