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Physicochemical characteristics of wastewater from laundry businesses in Kambu District, Kendari City, Indonesia

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ABSTRACT

This study aimed to assess the physical and chemical characteristics of wastewater generated by laundry businesses in Kambu District, Kendari City, and to evaluate its compliance with domestic wastewater quality standards. A laboratory-based environmental assessment was conducted by collecting wastewater samples from four laundry businesses in the study area. In situ measurements were performed for temperature and pH, while Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were analyzed according to Indonesian National Standards (SNI) at the Biomolecular and Environmental Laboratory. The results showed that wastewater temperatures ranged from 27°C to 30°C, remaining below the maximum allowable limit of 38°C. The pH values ranged from 7.0 to 8.5 and were within the permissible range. COD concentrations reached 610.50 mg/L at Laundry A, while BOD values ranged from 148.10 mg/L to 251 mg/L across the sampled laundry businesses. Overall, temperature and pH complied with the domestic wastewater quality standards stipulated in the Indonesian Minister of Environment and Forestry Regulation No. P.68/MenLHK-Setjen/2016, whereas BOD and COD values exceeded the recommended limits.

Keywords : Laundry Wastewater; Physicochemical Characteristics; BOD; COD; Kendari City

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INTRODUCTION

Rapid population growth and urban expansion have significantly increased the demand for various domestic services in urban areas. Kendari City recorded a population of 356,747 inhabitants in 2022, with an annual growth rate of 1.91% between 2021 and 2022 (Statistics Indonesia of Kendari Municipality, 2023) and this number is projected to continue increasing. One of the most densely populated and strategically important areas in Kendari City is Kambu District, which functions as a major center for education, healthcare, regional trade, and provincial government activities. These characteristics have contributed to high population density and intensified daily activities within the district.

The increasing intensity of urban activities has led to a growing demand for laundry services, particularly among students, office workers, and residents with limited time for household chores. As a result, laundry businesses have expanded rapidly in Kambu District, with recent surveys identifying approximately 30 active laundry enterprises. While these businesses provide economic benefits and essential services to the community, their operations also generate environmental pressures, particularly in the form of wastewater discharge.

Laundry wastewater is classified as domestic liquid waste generated from clothing washing processes and is characterized by high concentrations of detergent residues. Detergents typically contain surface-active agents (surfactants) such as Alkyl Benzene Sulfonate (ABS) and Linear Alkyl

Sulfonate (LAS) (Purnamasari, 2017; Ramcharan & Bissessur, 2016), along with builders such as Sodium Tripolyphosphate (STPP) bleaching agents, fragrances, foaming agents, and optical brighteners (Altenbaher et al., 2014). In many small-scale laundry operations, wastewater is discharged directly into drainage channels, rivers, or surrounding land without adequate treatment, raising concerns regarding its compliance with environmental quality standards.

According to the Indonesian Minister of Environment and Forestry Regulation No. P.68/MenLHK-Setjen/2016, several key parameters must be monitored to ensure the safety of wastewater discharged into the environment, including pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), total suspended solids (TSS), turbidity, color, and odor. Among these parameters, BOD and COD are widely recognized as primary indicators of organic pollution in wastewater. Elevated BOD and COD values reflect high concentrations of biodegradable and non-biodegradable organic matter, which can reduce dissolved oxygen levels, disrupt aquatic ecosystems, and promote excessive microbial growth (Hang, 2010; Tripathi et al., 2025).

Despite the rapid growth of laundry businesses in Kambu District, scientific information regarding the physicochemical characteristics of wastewater generated by small-scale laundry operations in this area remains limited. Most existing studies on laundry wastewater have focused on large urban centers or industrial-scale facilities, while localized assessments in medium-sized cities, such as Kendari, are still scarce. This lack of site-specific data hinders accurate evaluation of environmental risks and limits the development of effective wastewater management strategies tailored to local conditions. Therefore, a detailed assessment of the physical and chemical characteristics of laundry wastewater in Kambu District is necessary for environmental monitoring and wastewater management.

RESEARCH METHODS

The study was conducted in Kambu District, Kendari City, which covers an area of 25.35 km² and consists of four sub-districts. The district has an estimated population of approximately 25,162 inhabitants, with increasing population density due to migration. Kambu District functions as a major center for education, healthcare, and economic activities, hosting several higher education institutions, schools, healthcare facilities, and government offices.

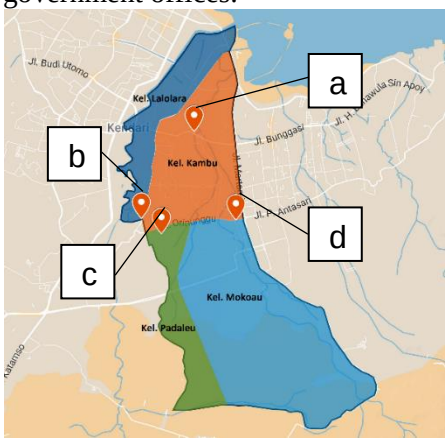

Figure 1. Spatial Distribution And Sampling Points Of Laundry Wastewater In Kambu District, Kendari City: (A) Laundry A, (B) Laundry B, (C) Laundry C, And (D) Laundry D

This study was conducted from May to July 2024 in Kambu District, Kendari City, Southeast Sulawesi, Indonesia. Wastewater samples were collected from four small-scale laundry businesses located in the Kambu, Lalolara, Padaleu, and Mokoau sub-districts. Site selection was based on several criteria, including accessibility for wastewater sampling and permission granted by the laundry business owners (Yuliana, 2020). The selected laundries represent typical small-scale operations commonly found in densely populated urban areas. Wastewater samples were collected directly from the final effluent outlets of each laundry facility. In situ measurements were performed to determine physical parameters, including color, odor, temperature, and pH. Temperature and pH were measured on-site to minimize potential changes in physicochemical conditions during sample

transportation. Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were analyzed in the Biomolecular and Environmental Laboratory, Department of Biology, Halu Oleo University. Laboratory analyses were conducted in accordance with Indonesian National Standards (SNI). BOD measurements were carried out to determine the amount of dissolved oxygen required for microbial decomposition of organic matter, while COD analysis was performed to assess the total oxygen demand needed to oxidize both biodegradable and non-biodegradable organic compounds present in the wastewater. The measured physicochemical parameters were analyzed descriptively and compared with the domestic wastewater quality standards stipulated in the Indonesian Minister of Environment and Forestry Regulation No. P.68/MenLHK-Setjen/2016. Compliance was assessed by evaluating whether the observed values of temperature, pH, BOD, and COD met the regulatory threshold limits.

RESULTS AND DISCUSSION

Laundry businesses are distributed across all sub-districts in Kambu District, with 18 businesses located in Kambu Sub-district and four businesses each in Lalolara, Padaleu, and Mokoau Sub-districts. The four laundry businesses selected as sampling locations in this study operate under informal business permits granted verbally by local authorities. Two of the sampled laundry businesses operate in facilities that are physically separated from the owners' residences, while the remaining two operate in shop-house (shophouse) buildings. Groundwater extracted from bore wells is the primary water source used for laundry activities. Commercially available detergents are commonly used across all businesses. Field observations indicated that each laundry business processes approximately 100–200 kg of laundry per day. Wastewater generated from laundry activities is discharged directly into the drainage system without prior treatment. In most cases, the laundry wastewater outlets are connected to greywater drainage channels, including those of the four sampled businesses.

Table 1. Geographic Coordinates of Laundry Wastewater Sampling Locations In Kambu District, Kendari City

No.	Sample	Geographic Coordinates
1	Laundry A	4°0′55.822″ S, 122°31′38.132″ E
2	Laundry B	4°1′1.9854″ S, 122°30′55.835″ E
3	Laundry C	4°1′10.749″ S, 122°31′9.9878″ E
4	Laundry D	4°1′0.9235″ S, 122°32′5.1909″ E

Color observation was conducted to assess the visual (organoleptic) condition of laundry wastewater. The observed laundry wastewater samples were collected from the first washing cycle, as this stage produces the most contaminated wastewater due to the presence of stains and organic matter released from clothing surfaces. The first washing process also involves the use of larger amounts of detergent, which contributes to noticeable changes in wastewater color. The color of laundry wastewater collected from each laundry business is presented in Figure 2.



Figure 2. Visual Appearance Of Laundry Wastewater Samples Collected From Four Laundry Businesses In Kambu District: (A) Laundry D, (B) Laundry C, (C) Laundry B, And (D) Laundry A.

Color observation was conducted at the sampling sites to ensure that the observed color accurately reflected the actual condition of the laundry wastewater at the time of sampling. Increased color intensity indicates a higher concentration of various pollutants in the wastewater. The results of organoleptic color observations for laundry wastewater from each sampling location are presented in Table 2.

Table 2. Results Of Organoleptic Color Observations Of Laundry Wastewater

No.	Laundry Business	Sample Color
1	Laundry D	Light gray
2	Laundry C	Medium gray
3	Laundry B	Dark gray
4	Laundry A	Brownish

Odor assessment was conducted using an organoleptic approach to determine the presence of odor in laundry wastewater. This parameter is important, as the presence of specific odors may indicate the existence of odor-producing microorganisms and foreign chemical compounds that could pose risks to human health (Afrianti et al., 2022). Temperature measurements were carried out in accordance with the Indonesian National Standard (SNI 06-6989.23-2005) using a mercury thermometer (Ramadhan, 2024). The pH measurements showed that all samples had values below 9.0, with the highest pH (8.5) recorded in Laundry D and the lowest (7.0) in Laundry C. All samples complied with the regulatory quality standard, which specifies an acceptable pH range of 6.0–9.0. The results of organoleptic, temperature, and pH analyses of laundry wastewater from each laundry business are presented in Table 3. The results of organoleptic, temperature, and pH of laundry wastewater from each laundry business are presented in Table 3.

Table 3. Results of Organoleptic, Temperature, and pH Analysis of Laundry Wastewater and Their Compliance with Quality Standards

No	Sample	Odor	Temperature (°C)	Quality Standard (°C)	pH Value	Quality Standard	Remarks
1	Laundry D	Odorous	27	38	8.5	6.0–9.0	Compliant
2	Laundry C	Odorous	29	38	7.0	6.0–9.0	Compliant
3	Laundry B	Odorous	30	38	7.2	6.0–9.0	Compliant
4	Laundry A	Odorous	28	38	8.0	6.0–9.0	Compliant

COD analysis was conducted using a standard method, namely the closed reflux method, in accordance with Indonesian National Standard SNI 6989.2:2019. The principle of the closed reflux method is to accelerate the oxidation of organic matter through heating without reducing the sample volume. The analyzed samples were mixed with a dichromate solution and sulfuric acid under heated conditions. The dichromate oxidizes organic compounds present in the sample, producing Cr^{3+} ions, the absorbance of which was measured at a wavelength of 600 nm using a spectrophotometer. The measured absorbance values were converted into COD concentrations using a calibration curve. The calibration curve was constructed based on standard solution concentrations and their corresponding absorbance values measured with the spectrophotometer. The absorbance values of the standard solutions used for calibration are presented in Table 4.

Table 4. Absorbance Values Of Standard Solutions

No.	Concentration (mg/L)	Absorbance
	0	0
1	100	0,1011
2	150	0,15
3	500	0.47
4	1000	0,8760
5	1250	0,1150

Based on the calibration data, a regression curve was constructed and used to determine COD concentrations in the laundry wastewater samples. COD concentrations were calculated by evaluating the linearity of the regression curve, as indicated by the regression coefficients obtained. The regression equation was derived from the relationship between absorbance (y-axis) and concentration (x-axis).

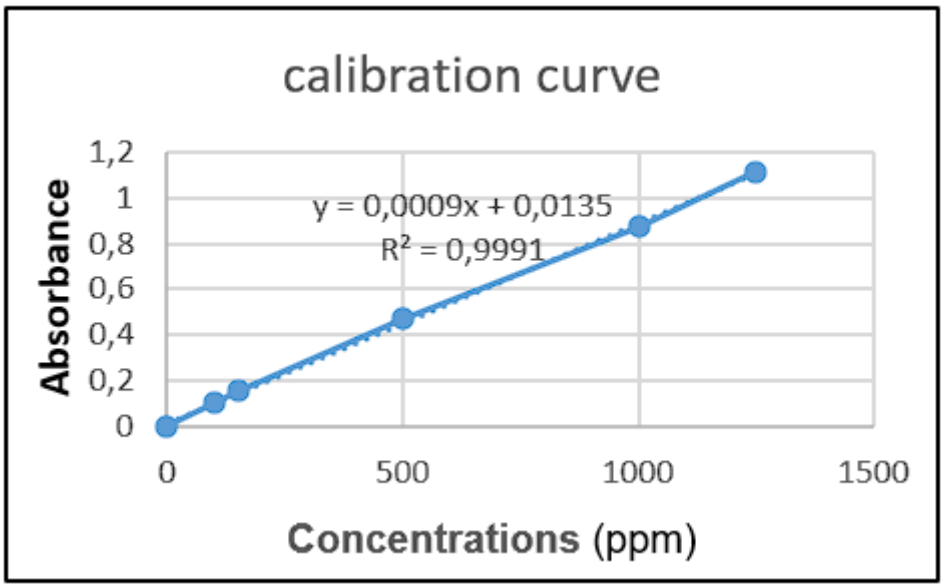

Figure 3. Calibration Curve Showing The Relationship Between Absorbance And Concentration Of Standard Solutions.

Based on the calibration curve, a strong correlation coefficient (R) of 0.9991 was obtained, with a linear regression equation of $y = 0.0009x + 0.0135$. The high correlation value indicates a strong linear relationship between concentration and absorbance. Ideally, the correlation coefficient for COD determination should approach 1.0 to ensure analytical reliability. The absorbance values of

the laundry wastewater samples were subsequently substituted into the linear regression equation to calculate COD concentrations. The results of COD measurements in laundry wastewater samples are presented in Table 5.

Table 5. Results Of COD Measurements Using The Spectrophotometric Method

No.	Sample	Absorbance	COD Concentration (mg/L)	Quality Standard (mg/L)	Remarks
1	Laundry D	0.3917	420.10	100	Exceeded
2	Laundry C	0.6289	684.00	100	Exceeded
3	Laundry B	0.6528	710.40	100	Exceeded
4	Laundry A	0.3917	610.50	100	Exceeded

Biological Oxygen Demand (BOD) is a parameter that represents the amount of dissolved oxygen required by microorganisms, primarily bacteria, to decompose organic matter under aerobic conditions. The organic matter measured in the BOD test consists of readily decomposable organic compounds. The test samples were added to an oxygen-saturated dilution water supplemented with nutrient solutions and subsequently incubated in the dark at a constant temperature for five days to prevent photosynthetic oxygen production. Under these conditions, only microbial decomposition occurs, resulting in oxygen consumption, and the remaining dissolved oxygen is measured as DO5. BOD values were calculated based on the difference between dissolved oxygen concentrations measured on day 0 and day 5. A glucose–glutamic acid solution was used as the standard control in the BOD test. The results of BOD measurements for laundry wastewater samples are presented in Table 6.

Table 6. Results of BOD Measurements of Laundry Wastewater

No.	Sample	BOD Concentration (mg/L)	Quality Standard (mg/L)	Remarks
1	Laundry D	148.10	30	Exceeded
2	Laundry C	228.00	30	Exceeded
3	Laundry B	317.00	30	Exceeded
4	Laundry A	251.00	30	Exceeded

Variations in the color of laundry wastewater observed in this study, ranging from light gray to dark gray and brownish, reflect differences in pollutant loads among the sampled laundry businesses. Darker and brownish wastewater, particularly observed at Laundry A and Laundry B, indicates higher concentrations of dissolved and suspended organic matter released during the washing of heavily soiled clothing. These findings suggest that increased washing intensity and detergent usage contribute to elevated organic and colloidal content in laundry wastewater. Similar observations were reported by Pontiani et al. (2023), who demonstrated that color intensity in laundry wastewater increases with the amount of laundry processed and the level of dirt on clothing.

All laundry wastewater samples exhibited a detectable detergent-related odor, indicating that the wastewater was freshly generated and discharged directly from washing machines. The dominance of detergent odor suggests minimal microbial decomposition at the time of sampling, as organic matter had not yet undergone significant biodegradation. This condition is consistent with the relatively high BOD values measured in this study (148.10–317 mg/L), which indicate a high availability of biodegradable organic matter that may later contribute to oxygen depletion if discharged untreated. Odor characteristics associated with detergent compounds have also been reported as indicators of potential environmental and health concerns (Afrianti et al., 2022).

The temperature of laundry wastewater across the four sampling locations ranged from 27°C to 30°C, remaining below the maximum allowable limit of 38°C. Although these values indicate compliance with regulatory standards, the upper range of observed temperatures (30°C) approaches the optimal growth range for aquatic microorganisms (25–35°C). Under such conditions, elevated microbial activity may accelerate organic matter decomposition, thereby increasing oxygen demand in receiving waters. While temperature alone did not pose an immediate environmental risk in this study,

continuous discharge of wastewater at similar temperatures may intensify the impacts of high organic loads, particularly when combined with elevated COD and BOD concentrations (Ningrum, 2018).

The pH values of laundry wastewater ranged from 7.0 to 8.5, indicating slightly alkaline conditions typical of detergent-based effluents and remaining within the regulatory standard of 6.0–9.0. The highest pH value (8.5) was recorded at Laundry D, likely reflecting the use of alkaline or phosphate-based detergents. Although pH values were compliant, pH plays a critical role in controlling microbial activity and chemical toxicity. At pH values approaching the upper limit, ammonium may be converted into free ammonia, which is toxic to aquatic organisms, thereby increasing ecological risk when combined with high organic pollution loads (Mackereth et al., cited in Zammi, 2018). These findings align with previous studies indicating that detergent composition and washing practices strongly influence wastewater pH (Chien, 2005; Tumimomor et al., 2020).

In contrast to temperature and pH, COD concentrations measured in this study were substantially elevated, ranging from 420.10 to 710.40 mg/L, which is 4–7 times higher than the domestic wastewater standard of 100 mg/L. The highest COD concentration was observed at Laundry B (710.40 mg/L), indicating a substantial presence of oxidizable organic and inorganic compounds, including surfactants and detergent additives. These values are consistent with previous reports of COD concentrations exceeding 600 mg/L in laundry wastewater (Wicheisa, 2018; Pungus, 2019). High COD levels reflect a significant organic pollution load that can rapidly deplete dissolved oxygen when discharged into receiving waters.

Similarly, BOD concentrations ranged from 148.10 to 317 mg/L, exceeding the regulatory limit of 30 mg/L by up to tenfold. The highest BOD concentration recorded at Laundry B (317 mg/L) indicates intense microbial oxygen demand, suggesting that a large fraction of the organic matter present is readily biodegradable. Elevated BOD levels are closely associated with detergent components such as surfactants and builders, which contribute substantially to organic loading in laundry wastewater (Purnama et al., 2015). The combination of high BOD and COD concentrations implies a strong potential for dissolved oxygen depletion, eutrophication, and degradation of aquatic ecosystems if the wastewater is discharged without treatment (Hidayah, 2018; Pamungkas, 2016).

Overall, the integration of compliant physical parameters (temperature and pH) with excessively high organic pollution indicators (COD and BOD) demonstrates that laundry wastewater in Kambu District poses a significant environmental risk despite meeting certain regulatory criteria. The measured COD (420.10–710.40 mg/L) and BOD (148.10–317 mg/L) concentrations far exceed the thresholds stipulated in the Indonesian Minister of Environment and Forestry Regulation No. P.68/MenLHK-Setjen/2016, underscoring the urgent need for appropriate wastewater management and treatment strategies to reduce organic pollutant loads prior to discharge.

CONCLUSION

This study elucidates the physical and chemical characteristics of laundry wastewater from the four laundry businesses in Kambu District, Kendari City. The temperature values complied with the quality standard stipulated in the Indonesian Minister of Environment and Forestry Regulation No. P.68/MenLHK-Setjen/2016, with a maximum allowable temperature of 38°C. The highest temperature was recorded in wastewater from Laundry B (30°C), while the lowest temperature was observed at Laundry D (27°C). The observed wastewater color ranged from light gray to dark gray and brownish, and all samples exhibited a characteristic detergent odor. Moreover, pH values of laundry wastewater from all sampled businesses were within the acceptable standard range of 6.0–9.0. The highest pH value (8.5) was recorded at Laundry D, while the lowest pH value (7.0) was observed at Laundry C. In contrast, COD and BOD concentrations in all laundry wastewater samples exceeded the permissible limits, with regulatory thresholds of 100 mg/L for COD and 30 mg/L for BOD. The highest COD concentration was recorded at Laundry B (710.40 mg/L), while the lowest COD concentration was observed at Laundry D (420.10 mg/L). Similarly, the highest BOD concentration was recorded at Laundry B (317 mg/L), whereas the lowest BOD concentration was found at Laundry D (148.10 mg/L).

Overall, although temperature and pH parameters met the established quality standards, the elevated COD and BOD concentrations indicate a high organic pollution load in laundry wastewater from

Kambu District, highlighting the need for appropriate wastewater management and treatment prior to discharge into the environment.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest associated with this study**.**

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