Correlation between Water Quality and Surfactant Pollution in the Porong River

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Abstract. The condition of the Porong River has experienced a decline in water quality caused by detergent pollution containing surfactants. Accumulation of surfactants that have not been well-degraded can have negative impacts on the aquatic ecosystem. The aim of this research is to analyze the water quality parameters and surfactant concentrations in the Porong River, as well as to determine their correlation. The method used in this study is the descriptive survey method. Data collection was carried out at 3 stations using purposive sampling method. Data were collected in three replicates. Based on the data obtained from the water quality parameter measurements, the temperature ranges from 27.8 to 29°C, TDS levels range from 249.9 to 652.1 mg/L, TSS levels range from 4.1 to 37.9 mg/L, pH values range from 6.7 to 6.8, DO concentrations range from 5 to 5.6 mg/L, nitrate concentrations range from 1.09 to 1.23 mg/L. The results of surfactant measurements in the water range from 3.6 to 7.8mg/L. The relationship between water quality parameters indicates a positive correlation or interdependence among them. Furthermore, high surfactant content in the water leads to a decline in water quality, thereby adversely affecting aquatic ecosystems.

1 Introduction

The Porong River is one of the rivers located in East Java, Indonesia. It has a length of approximately 42 kilometers and flows through several regencies, including Sidoarjo Regency and Mojokerto Regency, before discharging into the Java Sea. The Porong River is a livelihood for many people, particularly fishermen. However, it has experienced pollution due to the mudflow from Lapindo, which has been active since 2006 and has led to a decline

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in water quality in the river [1]. Water quality in rivers has become a significant environmental issue in recent years, especially in developing countries [2]. Several factors contributing to river water quality problems include increased pollution, land use, and inadequate wastewater infrastructure. Population growth and increased industrial activities result in the discharge of untreated wastewater into rivers [3]. The East Java Environmental Agency (2018) has reported that the water quality of the Porong River is polluted. One of the factors contributing to pollutant input in the Porong River is domestic waste. The high population density around the Porong River increases domestic waste production[4].

The Porong River is polluted due to the discharge of domestic waste, including inorganic detergent waste [5]. LAS surfactant is one of the surfactant types commonly used in cleaning and detergent products. The presence of LAS surfactants in the Porong River can be attributed to the discharge of domestic and industrial waste containing detergents into the river without adequate treatment. When detergent waste reaches the river, the LAS surfactant contained in it can dissolve in the river water and become one of the pollutant components 5. Poorly degraded LAS surfactant exposure in the water negatively impacts the aquatic ecosystem, including aquatic biota such as fish, invertebrates, and aquatic macrophytes. LAS surfactants can disrupt the integrity of the organism's cell surface, damage the protective layer on fish gills, and cause respiratory disturbances and behavioral changes in aquatic organisms[6].

Observations through water quality parameters of the Porong River and surfactant concentration and their effects on the health of aquatic biota can provide important information about the impact of surfactant pollution on living organisms in the river [7]. Monitoring and analysis of pH, dissolved oxygen (DO) concentration, and total suspended solids (TSS) can provide an overview of water quality conditions and the level of surfactant pollution. If unhealthy or hazardous levels are detected, appropriate corrective and management measures should be taken to minimize negative impacts on fish hematology performance and overall fish health[8].

2 Materials and Methods

Figures and tables, as originals of good quality and well contrasted, are to be in their final form, ready for reproduction, pasted in the appropriate place in the text. Try to ensure that the size of the text in your figures is approximately the same size as the main text (10 point). Try to ensure that lines are no thinner than 0.25 point.

2.1 Data Collection Method

Sampling in this study follows a purposive sampling method, which involves selecting sampling points based on specific criteria or human activities. Data collection encompasses physical and chemical water parameters, aiming to capture variations in pollutant sources. Three observation stations are chosen based on differences in wastewater pollutant sources, categorizing areas with potential surfactant contamination from detergent waste.

2.2 Water Quality Measurement

The temperature measurement by inserting an Hg thermometer into the river water body for 1–2 minutes to obtain accurate results[9]. TSS measurement uses the gravimetric method conducted at the Freshwater Fisheries Laboratory, Sumberpasir. A water sample of 100 mL is placed in a bottle for TSS measurement. An empty filter paper with a diameter of 47 mm is weighed using an analytical balance (A), then 100 ml of the water sample is homogenized and filtered using Whatman paper with a diameter of 47 mm. The filtered sample is then dried in an oven at a temperature of 150°C for approximately 1 hour, then cooled for about 5 minutes. The sample on the Whatman paper is weighed using an analytical balance (B), and then the TSS content is calculated using the Equation 1 [10] .

$$\text{TSS (mg/L)} = \frac{(\text{B}-\text{A})}{\text{Sample water volume(ml)}} \text{x } 1000 \tag{1}$$

TDS measurement is carried out using a TDS meter by inserting the iron part of the TDS meter into the sample water to be measured. After the TDS meter is immersed in the sample water, the TDS meter will automatically start calculating the content of dissolved solids in the sample, and it is waited for about ±30 seconds until the reading on the TDS meter becomes constant. pH measurement is performed using a pH meter, which is first calibrated with pH 4, 7, and 10 buffers. Then, rinse the electrode and immerse it in the sample water for about ±2 minutes. Press the "hold" button when the value on the pH meter screen becomes constant [10]. DO measurement by inserting the DO meter sensor into the sample water. Then, let the DO meter stand for about 10 seconds until the reading on the DO meter screen becomes constant and does not fluctuate[11]. Nitrate content is measured using the spectrophotometer method. A 12.5 mL water sample is filtered using filter paper and then placed in a porcelain dish and agitated. Next, add 0.25 mL of phenol disulfonic acid and NH_4OH in a 1:1 ratio until a yellow color is formed. Add distilled water until the volume returns to 12.5 mL, then the water sample and distilled water are placed in a cuvette. The spectrophotometer is set at a wavelength of 410 nm [12].

2.3 Surfactant Concentration Measurement in Detergent

A standard series was prepared by diluting LAS to 100 mg/L from a 1000 mg/L stock solution. The LAS solution was further diluted to obtain concentrations of 0.5; 1.0; 2.0; 3.0; and 5.0 mg/L. Liquid extraction involved adding phenolphthalein indicator and 1N NaOH to the test sample, titrating with 1N H_2SO_4, then adding methylene blue solution and chloroform. After phase separation and addition of NaCl, the chloroform phase was collected, and this process was repeated twice. The collected chloroform phase was transferred to a volumetric flask. Measurements, including setting the blank and measuring absorbance, were conducted for both standard and sample solutions.

2.4 Data Analysis Method

Data analysis was conducted to determine the concentration of surfactants in detergents at each station. The data were analyzed statistically using a simple linear regression test. Simple linear regression analysis of water quality aims to understand the relationship between one independent variable (such as temperature, TDS, TSS, pH, DO, CO2, nitrate, ammonia, orthophosphate, TOM, and salinity) and the dependent variable (surfactant concentration).

3 Results and Discussion

3.1 Results of Water Quality Analysis in the Porong River

The water quality measurements in this study, as supporting data, encompassed physical and chemical parameters of the water and are presented in Table 1.

Table 1. Results of Water Quality Analysis in the Porong River.

Parameters	Unit	Location 1	Location 2	Location 3	Water Quality Standards*
Temperature	°C	28.2	28.9	30	< 30
TDS	mg/L	389	713	776	< 1000
TSS	mg/L	5.4	9.35	37.2	< 100
pH	-	7.1	7.0	7.2	6−9
DO	mg/L	6.4	5.5	4.1	> 3
Nitrate	mg/L	0.5	0.47	1.33	< 20

*Indonesian Government Regulation no. 22 of 2021

East Java Governor Regulation No. 6 of 2010 states that the Porong River, based on its water quality classification, is designated as Class III within its specified region[13]. Class III extends from the village of Porong to the estuary, which corresponds to sampling points 1, 2, and 3 in this study. The water quality standards for the river should meet the criteria as per Indonesian Government Regulation no. 22 of 2021to support the optimal growth and survival of organisms, especially fish [14].

Based on the water quality measurements, the results are in accordance with the water quality standards set by Government Regulation No. 22 of 2021 regarding the Implementation of Environmental Protection and Management. Changes in river water quality can be influenced by various human activities and events occurring in the vicinity of the river. Additionally, differences in groundwater flow paths or water source locations and geological conditions in water bodies can also affect variations in water quality at different locations [15].

The temperature values in the waters of the Porong River indicate compliance with the water quality standards, which specify a maximum temperature of 30°C. Temperature plays a crucial role in determining water quality in biological, chemical, and physical aspects. It affects the growth rate and reproduction rate of aquatic organisms within it[16]. The average temperature measurement results at station 3 showed higher values compared to the other stations. This variation in water temperature is influenced by topography and the seasons. River water flowing from upstream areas tends to be cooler, while downstream areas are generally warmer[17].

The TDS and TSS concentrations in the waters of the Porong River in this study showed that station 3 had the highest concentration compared to the other stations. High TDS concentration can be influenced by anthropogenic activities, bedrock, and surface runoff from the land, which can lead to the dissolution of waste materials into the river water[18]. The high TSS concentration at station 1 is indicated to be a result of the water's surfactant concentration directly affecting TSS. The accumulation of surfactants that are not properly treated can potentially increase TSS[19].

The pH concentration of the water in this study ranged from 6.25 to 7.47, indicating that the water pH concentration in the Porong River still meets the water quality standard for pH, which ranges from 6 to 9 as stated in Government Regulation No. 22 of 2021. A stable pH in river water has important benefits for maintaining ecosystem integrity and human health[20].

The dissolved oxygen (DO) concentration in the waters of the Porong River in this study showed that station 3 had the lowest DO concentration compared to stations 1 and 2. Low DO levels can increase the vulnerability of organisms to other pollutants[21]. Organisms exposed to low DO levels are more susceptible to the negative effects of toxic chemical pollutants such as surfactants because their immune systems are weakened[22].

The nitrate concentration in the waters of the Porong River showed favorable values according to water quality standards. Nitrate (NO3-) is a stable oxidative form of nitrogen and is an essential component of the natural nitrogen cycle[23]. Therefore, the presence of nitrate in the environment can occur naturally through the nitrogen cycle.

3.2 Analysis of Surfactant Concentrations in the Porong River

The color differences observed in the study of anionic surfactant concentrations in detergents yielded the following results: station 1 had a pale or faint color, station 2 had a light purple color, and station 3 had a bright blue color. This is due to the increase in detergent concentration, causing methylene blue to lose its brightness and become paler[24]. The reaction between the detergent and methylene blue results in the complexation of detergent molecules binding to the dye and reducing the intensity of the blue color[25].

Based on these color test results, it is indicated that station 1 has a higher surfactant concentration compared to the surfactant concentrations at stations 2 and 3. This is supported by the fact that station 1 represents an area near residential areas and is often used as a direct disposal site for household waste by the local residents. The results of surfactant concentration measurements in anionic detergents conducted in the waters of the Porong River over three repetitions can be seen in Table 2.

Table 2. Results of Surfactant Concentrations in the Porong River.

Location	Surfactant Concentrations (mg/L)			Average (mg/L)
	Repetition-1	Repetition-2	Repetition-3	
1	7.8	7.2	6.60	7.20
2	4	4.6	4.2	4.27
3	3.6	4.2	3.6	3.80

Based on the results of surfactant concentration calculations in Table 2, it is known that the highest surfactant concentration was found at point 1 with an average surfactant concentration of 7.20 mg/L, point 2 was 4.27 mg/L, and point 3 was 3.80 mg/L. The high surfactant concentration in detergents in the Porong River has exceeded the water quality standards set by Regulation No. 22 of 2021, which is a maximum of 0.2 mg/L. This indicates that the excessive use of anionic surfactants in detergents is not balanced with wastewater treatment before it is discharged into the river. The significant impact of exceeding these standards will lower the water quality status of the Porong River[26]. xcessive surfactant concentrations in river waters can have negative effects on the aquatic ecosystem and the organisms living in it[27]. Excessive surfactants can reduce the dissolved oxygen levels in the water. Low oxygen levels can disrupt respiration in aquatic organisms[28].

3.3 Regresion Analysis Results

The simple linear regression analysis of surfactant concentration with water quality parameters in the Porong River, including temperature, TSS, TDS, pH, DO, and nitrate, can be seen from the significance results in Table 3. Based on Table 3, it is known that the significance values of surfactant concentration on temperature are 0.030, on TSS are 0.465, on TDS are 0.023, on pH are 0.233, on DO are 0.273, and on nitrate are 0.205. This represents that surfactant concentration (X) affects the three water quality parameters (Y), such as temperature, TSS, TDS, pH, DO, and nitrate in the Porong River. The extent of the influence of surfactant on water quality can be seen from the coefficient of determination (R2), which indicates that surfactant's influence on temperature is 51.5%, on TSS is 0.78%, on TDS is 54.4%, on pH is 19.5%, on DO is 16.8%, and on nitrate is 21.8%. Furthermore, regarding the positive or negative results of the regression coefficients, it represents that a 1% increase in surfactant concentration affects the increase or decrease in water quality in the Porong River. The calculated regression coefficients show that a 1% increase in surfactant concentration can increase the temperature by 2.705, decrease TSS by 0.094, increase TDS by 0.356, increase pH by 0.042, increase DO concentration by 0.037, and increase nitrate by 0.029 in the Porong River. The regression coefficients between surfactant and water quality for all water quality parameters are positive, except for the TSS parameter.

Table 3. Results of Regresion Analysis.

No.	Parameters	Signifikansi (sig. <0.5)	Koefisien Determinasi (R^2)	Koefisien Regresi (x)
1.	Temperature	0.030	0.515	2.705
2.	TSS	0.465	0.078	-0.094
3.	TDS	0.023	0.544	0.356
4.	pH	0.233	0.195	0.042
5.	DO	0.273	0.168	0.037
6.	Nitrate	0.205	0.218	0.029

The positive correlation between surfactant and temperature indicates that the amount of surfactant in the water directly influences the water temperature. This is because water temperature can affect surfactant activity. At higher temperatures, surfactant activity may increase, which can enhance the detergent's effectiveness in forming microemulsions and removing dirt from surfaces [29].

The positive correlation between surfactant and pH means that the higher the surfactant concentration in the Porong River, the higher the pH level detected. Surfactants tend to increase the pH of water because surfactants are generally basic[30]. For example, quaternary ammonium, which is often used in cleaning and disinfectant products, is a surfactant. If wastewater containing quaternary ammonium is released into water, quaternary ammonium can react with water and release ammonium ions (NH4+) into the water. Ammonium ions can react with water to form hydroxide ions (OH-) in a process called hydrolysis[31]. Hydroxide ions are basic and can increase the pH of water.

The positive correlation between surfactant and nitrate indicates that the amount of surfactant in the Porong River directly influences the nitrate concentration in the water. Surfactant-containing wastewater, including organic matter such as nitrate, can lead to eutrophication. Eutrophication occurs when there is an increase in nutrient concentration in water. These nutrients can come from organic matter in surfactant wastewater [32]. The increase in nutrients triggers excessive algal growth or algal blooms, which affects other water quality parameters, including biological, physical, and chemical aspects of the water.

The positive correlation between surfactant and TDS indicates that a higher surfactant concentration in the water can increase the TDS level in the water. This happens because surfactants in the water can increase the solubility of dissolved substances, including TDS. This can occur because surfactants help create conditions that support the solubility of dissolved substances in water [33].

The negative correlation between surfactant and TSS means that the surfactant concentration in the Porong River indirectly affects the TSS level in the water. This can happen because surfactants can dissolve in water and become particles that are soluble in water, which can increase the TDS in the water [34]. Therefore, monitoring water quality parameters such as temperature, TSS, TDS, pH, dissolved oxygen, nitrate, and other water parameters regularly is necessary to monitor the water's condition and identify potential issues associated with the presence of surfactants.

4 Conclusions

The analysis of water quality parameters in the Porong River revealed values within the acceptable range specified by Government Regulation No. 22 of 2021 for Class III river environments. However, surfactant concentrations in detergents at observation points exceeded permissible levels, indicating inadequate wastewater treatment before discharge. A positive correlation was observed between surfactant concentration and certain water quality parameters, particularly temperature, TDS, pH, DO, and nitrate, while negative correlations occurred for parameters unaffected by surfactants. This underscores the complexity of interrelations among biological, physical, and chemical water quality parameters.

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