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# Impact of Industrial Activities on Buduran River Water Quality in Sidoarjo Regency Using The STORET Method

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## ABSTRACT

The Buduran River in Sidoarjo Regency is a water source used by the community for domestic, agricultural, and fishery purposes. Increasing industrial and residential activities along the river have raised concerns about water pollution, particularly by organic matter and heavy metals. This study aims to analyze the water quality status of the Buduran River based on physicochemical parameters using the STORET method. Water samples were taken from two locations with two repetitions, a total of 8 samples, and tested for temperature, pH, BOD, COD, and the heavy metal Pb. The results showed that temperature and pH were in accordance with the Class II quality standards of the Republic of Indonesia Government Regulation Number 22 of 2021. The levels of BOD, COD, and the heavy metal Pb exceeded the established threshold. The BOD parameter at location points 1 and 2, namely 12.3 mg/L and 20.1 mg/L, respectively, exceeded the quality standard limit of 3 mg/L. The COD parameter at the second location point exceeded the quality standard limit of 29 mg/L because it was above 25 mg/L. The Pb metal parameter at location 1 was 1.63 and the second location was 1.22 mg/L. Both exceeded the quality standard limit. This indicates that the river in Buduran is experiencing water pollution. The role of the government and industrial managers in managing rivers due to industrial activities in mentoring and implementing technology.The scoring calculation using the STORET method showed that the water quality status of the Buduran River in Sidoarjo was moderately polluted at all points, with a score of -12 at locations 1 and 2 and a score of -18. These findings indicate the need for better waste management to maintain the sustainability of the river ecosystem.

## INTRODUCTION

Water pollution is one of the environmental problems caused by human activities. One such human activity is the impact of industry. This activity produces waste containing pollutants, such as heavy metals, that are discharged into water bodies. Most heavy metals are non-biodegradable substances. Water pollution by industrial waste also increases the concentration of hazardous chemicals, which can contaminate the food chain and damage the natural habitats of various aquatic species (Suryanto et al., 2021).

The Buduran River in Sidoarjo Regency is approximately fifty meters from nearby industries, including food processing plants. The river has been designated a class two river in accordance with Government Regulation Number 22 of 2021. This classification allows it to be used for various purposes, including, but not limited to, water recreation, freshwater fish farming,

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cattle farming, and drinking water with appropriate treatment requirements. The Buduran River supports an aquatic ecosystem encompassing a variety of living organisms (plankton, fish, and microorganisms) and abiotic (water, minerals, and sediment). However, the increase in industrial and domestic activities along the river has raised concerns about the potential for liquid waste pollution, which could impact river water quality and disrupt the ecosystems balance.

The food processing industry uses various additives and chemicals in its production processes, such as preservatives, bleaching agents, and cleaning agents for production equipment. The presence of metal pollution in river waters has resulted in changes in water quality at various levels, including physical, chemical, and biological levels. For example, mercury (Hg), cadmium (Cd), lead (Pb), iron (Fe), and chromium (Cr) are examples of metals that have the potential to become toxic compounds that can harm living organisms (Waluya, 2015). Lead (Pb) is a type of heavy metal widely used in the manufacturing sector. Lead is hazardous and difficult to degrade organically in the environment (Putri et al., 2022). Besides water, soil, and air (atmosphere), heavy metals can penetrate all environmental layers. As a result of industrial processes, household waste, combustion, and fuel movement, heavy metals enter these environmental layers. This will impact water quality and the organisms living in it if pollutants are allowed to enter the water (Sopian et al., 2023). Lead metal has toxic effects on aquatic organisms, inhibiting biological processes, and potentially causing human health problems, such as neurological disorders, kidney disease, and long-term carcinogenic effects. This research is urgently needed to analyze the water quality status of the Buduran River using the STORET method to determine the level of pollution and its influencing factors. Previous studies have shown that industrial activity is often a major cause of declining river water quality through increased levels of pollutants such as BOD, COD, and heavy metals (Environmental Agency, 2023).

The STORET (Storage Retrieval) method is a system developed by the EPA in the United States to manage and analyze water quality data. The STORET method is used to assess whether a water quality parameter meets or exceeds established standards. This approach essentially determines water quality conditions by comparing current data with relevant quality requirements (Safar HS, 2022). Based on research by Khasanah et.al 2021 STORET measures various water quality indicators, such as temperature, acidity (pH), dissolved oxygen (DO), dissolved organic matter (BOD), dissolved chemicals (COD), and heavy metals. Each parameter has a standard quality value that must be met for water to be used for various purposes, including as a source of drinking water, irrigation, or fisheries. STORET compares measurement results with predetermined threshold or standard values and provides a score that describes the water quality status.

The purpose of this study is to determine water quality using the STORET method, which is based on physicochemical criteria, and to provide recommendations for environmentally friendly management. Understanding water quality in the Buduran River in Sidoarjo Regency is expected to provide insight into the right choices to make in water management.

## RESEARCH METHODS

### Location

This study was conducted in the Buduran River area of Sidoarjo, using four sampling points, each with two sampling points, resulting in a total of 8 samples. The distance between sampling points was approximately 500 meters. The sampling locations were determined based on industrial and residential activities along the river.

**Figure 1.** Research Location

**Research Variables**

The independent variables in this study are the Physico-Chemical Parameters that affect water quality, namely: pH, Temperature, COD, BOD and heavy metal Pb. The dependent variable includes the status of water quality, which is determined through the analysis of physicochemical parameters, acting as the dependent variable in this study. Good, slightly polluted, moderately polluted, and heavily polluted are the four levels that will be used to classify this water quality.

**Data Analysis**

The measurement results for each water quality parameter are described descriptively to illustrate the actual condition of the Buduran River.

Laboratory analysis based on SNI 6989.82:2018 Water and wastewater – Part 82: Test method for metals using an Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). Sample analysis includes COD, BOD and heavy metal Pb.

Each measured physicochemical parameter is scored based on categories consistent with the STORET standard (Zhang et.al, 2020). Scoring is determined through the following steps in the STORET method:

Class A: Very good, score = 0 (meets quality standards)
Class B: Good, score = -1 to -10 (light pollution)
Class C: Moderate, score = -11 to -30 (moderate pollution)
Class D: Poor, score = ≥ -31 (severe pollution)

Interpretation of measurement results is compared with the Government Regulation of the Republic of Indonesia Number 22 of 2021 regarding applicable air quality standards based on the relevant river class, namely class two.

## RESULTS AND DISCUSSION

The results and discussion section contains the results of the analysis of river water quality data and the quality status of the river.

**River Water Quality**

The Buduran River is classified as Class II. Environmental factors such as temperature, pH, COD, BOD, and lead and chromium are among the water quality parameters examined. Table 1 shows a comparison between the measured values and the Class II water quality criteria stipulated by Government Regulation number 22 of 2021.

**Table 4.** Results of River Water Quality Analysis in Buduran

| Parameter | Units | Point 1 | Point 2 | Quality Standard Class II | Information |
|---|---|---|---|---|---|
| Temperature | °C | 31,8 | 32,5 | Deviasi ±3 | accordance |
| pH | - | 7,1 | 7,1 | 6 - 9 | accordance |
| BOD | mg/L | 12,3 | 20,1 | 3 | exceeding |
| COD | mg/L | 18 | 29 | 25 | exceeding |
| Pb | mg/L | 1,63 | 1,22 | 0,03 | exceeding |

Water temperature ranged from 31.2 degrees Celsius to 32.5 degrees Celsius at each of the four sampling stations. At sampling point 3, the temperature reached its highest peak of 32.5 degrees Celsius. In accordance with Government Regulation Number 22 of 2021, this temperature remained within the acceptable range, with a deviation of ±3, ensuring it was within the acceptable range. Considering the temperature parameters, it can be concluded that the river water quality remains within the acceptable range for water quality standards for its intended use. Agustina and Atina (2022) conducted a study that found that the amount of sunlight reaching the water affects water temperature. Direct sunlight can reach the water surface based on the exposed location of the measuring device. This is one potential cause of high river water temperatures. The river water temperature will increase.

The pH values at the four points ranged from 7.1 to 7.5. This range is within the permissible standard of 6 to 9. Therefore, the water quality in terms of pH complies with applicable standards. pH plays a crucial role in determining the solubility of various chemicals and the metabolism of aquatic organisms. The healthy pH range for aquatic ecosystems and humans is generally between 6.5 and 8.5 (WHO, 2020). Nursaini and Harahap (2022) state that variations in CO2 and O2 concentrations affect pH. Natural processes have their own ways of stopping pH changes, or at least slowing them down, as not all living things can tolerate pH changes.

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COD levels ranged from 12 to 29 mg/L. COD levels at points 3 and 4, at 29 and 26 mg/L, respectively, exceeded the 25 mg/L quality limit. This indicates a significant concentration of organic contaminants in the area. The amount of organic matter in water can be increased by dumping large amounts of household waste into water bodies. Water quality will deteriorate in part due to the increased levels of organic matter. Increased levels of biochemical oxygen demand (BOD and COD) are one indicator of this problem (Kurnianti et al., 2020). Decomposing microbes depend on oxygen for survival, which is why water with high concentrations of biochemical oxygen demand (BOD and COD) can have low oxygen levels. This has a domino effect on the aquatic environment, making it less favorable for fish and aquatic plants (Sara et al., 2018).

Lead levels in all waters are quite high, ranging between 1,627 and 2,298 mg/L. This level is much higher than the quality standard of 0.03 mg/L (Gani et.al, 2023). These levels of heavy metal contamination pose a significant threat to aquatic life and human health. Lead, a trace mineral, can be dangerous to humans and other living creatures. Many common household items and products can contaminate our water supply and bodies with lead. Some examples include: batteries, paint, crayons, cosmetics, printing ink, solder, fishing weights, air rifle ammunition, furniture, varnish, soil, and so on (Ahmad, 2021).

**River water quality status based on the STORET method**

The Storet method is used to determine water quality status. Minimum, maximum, and average values are obtained through laboratory tests. These values are compared with the Class II quality criteria stipulated by Government Regulation Number 22 of 2021. The lowest, highest, and average values are used to assign scores to these values. The overall score indicates the level of pollution in the Buduran River, ranging from lightly polluted to heavily polluted, or still meeting quality criteria. In March and April, monthly measurements were conducted twice at each of the four sample locations. Table 4.2 shows the results of the scoring system, and Table 4.3 shows the revised water quality classification by the Ministry of Environment and Forestry.

**Table 2.** Determination of Value System to determine Water Quality Status

| Total Parameters | Value | Quality Status |
|---|---|---|
| <10 | Maksimum | -2 |
| | Minimum | -2 |
| | Rata-rata | -6 |
| ≥10 | Maksimum | -4 |
| | Minimum | -4 |
| | Rata-rata | -12 |

**Table 3.** Classification of water quality based on Storet Method scores

| Class | Score | Information |
|---|---|---|
| A (Excellent) | 0 | Meet quality standards |
| B (Good) | -1 s/d -10 | Light pollution |
| C (Poor) | -11 s/d -30 | Moderate pollution |
| D (Heavily Polluted) | ≥-31 | Heavy pollution |

Source : Decree of the Minister of Environment Number 115 of 2003

The score will be calculated based on sample points to determine the water quality status of the Buduran River. The following is the calculation for the water quality analysis Location Point 1.

At the headwaters of the Buduran River, in a rural area bordered by green rice fields and farmland, is Location 1. A Class C water quality score of -18 indicates moderate pollution according to Government Regulation Number 22 of 2021, which is the water quality criteria for Class II.

**Table 4**. Scoring Results for Location Point 1 on Class II Water Quality Criteria

| Parameters | Unit | Standard | Sample 1 | Sample 2 | Average | Score |
|---|---|---|---|---|---|---|
| pH | | 6 sampai 9 | 7.1 | 7.1 | 7.1 | 0 |
| Suhu | °C | Deviasi ±3 | 33.2 | 30.5 | 31.85 | 0 |
| BOD | mg/L | 3 | 7.63 | 16.9 | 12.265 | -6 |
| COD | mg/L | 25 | 16 | 20 | 18 | 0 |
| Pb | mg/L | 0,03 | 1.713 | 1.541 | 1.627 | -6 |
| | | | Total | | | -12 |

Location 1 is located in an area before residential areas, where the river is surrounded by vacant land and greenery, minimizing domestic waste and agricultural runoff. This lack of domestic waste also doesn't guarantee the river's water quality, as some waste is still dumped into the river.

BOD, lead, and chromium levels were very high, exceeding applicable water quality standards, according to the analysis in Table 4. With a score of -18, the water quality at this location was categorized as moderately polluted (Harahap et.al., 2020). Household and industrial waste prior to location 1 were the sources of high BOD levels. In its most basic form, organic waste is anything that can be broken down by microbes into smaller pieces. Biochemical oxygen demand (BOD) concentrations will increase if this waste is discharged into water bodies. The increase in BOD levels is thought to occur because water flow from residential areas prior to the location receives a significant amount of wastewater during its journey (Effendi, 2003). Biological oxygen demand (BOD) levels in river water are likely high if the water contains a large amount of organic material, such as bacteria that decompose waste from homes or businesses. The higher the BOD level, the more dissolved oxygen the microbes need to decompose the organic material. As a result, dissolved oxygen levels in the river will decrease drastically (Natipulu and Putra, 2024).

Lead concentrations ranged from 1,541 mg/L at the lowest level to 1,173 mg/L at the highest. Both are considered unacceptable, indicating that rivers containing excessive amounts of lead pose a threat to human health. One mineral that can be hazardous is lead, which is a trace element. Air, water from leaded pipes, batteries, cosmetics, paint, crayons, printing ink, solder, fishing weights, air rifle bullets, furniture, varnish, sewage, and a number of other sources can all contribute to the presence of lead in the environment and in humans (Ahmad et al., 2021). Human activities, including industrial processes, household waste, and other wastewater sources, can lead to significant increases in chromium heavy metal concentrations. Several mechanisms, including adsorption by aquatic organisms, precipitation, dilution, dispersion, and overflow, remove heavy metals from water bodies. Chromium metal in water also undergoes these reactions (Lukmanulhakim, 2023).

**Location Point 2**

Based on Government Regulation Number 22 of 2021, location point 3 is located in a former industrial area, obtaining a score of -24 on the class II water quality criteria, thus entering the moderately polluted class C category.

**Tabel 5.** Scoring Results for Location Point 2 on Class II Water Quality Criteria

| Parameters | Unit | Standar Class II | Sampel | | Average | Score |
|---|---|---|---|---|---|---|
| | | | March Result | April Result | | |
| pH | | 6 - 9 | 7.1 | 7.1 | 7.5 | 0 |
| Temperature | °C | Deviasi ±3 | 34.6 | 30.4 | 32.5 | 0 |
| BOD | mg/L | 3 | 24.8 | 17.03 | 16.49 | -6 |
| COD | mg/L | 25 | 26 | 32 | 29 | -6 |
| Pb | mg/L | 0,03 | 1.411 | 1.036 | 1.223 | -6 |
| Total | | | | | | -18 |

Location 3 is located in the area after industrial activity and a combination of domestic waste from residential areas. This combination has potentially degraded the water quality of the Buduran River, categorizing it as moderately polluted. In addition to the industrial area, there are also coffee shops along the river that likely discharge domestic waste into the river.

Table 5 shows that BOD, COD, Pb levels are higher than those considered safe for water quality. Location 3's moderate water pollution score, at -18, is due to the high COD value (Bamiro et.al, 2020). The presence of pollution sources, such as industrial waste, pesticides, or fertilizers, is

indicated by high COD levels in the river water, which can disrupt the river's ecological balance. Because more oxygen is needed to oxidize organic and inorganic elements in water, water quality can decline when COD levels are high (Harlina, 2020). This can lead to a decrease in dissolved oxygen concentration in the water and negatively impact aquatic life (Natipulu and Putra, 2024).

Liquid waste can be classified as domestic or industrial waste, depending on its origin. Organic and inorganic contaminants, both commonly found in waste, are usually in dissolved or suspended form (Candra, 2006). Liquid waste contaminants are harmful to aquatic life and alter the physical, chemical, and biological characteristics of aquatic ecosystems; consequently, liquid waste poses significant environmental sustainability risks (Ristyana, 2022). Businesses, factories, and households all have a responsibility to treat their liquid waste before discharging it into the environment. Pollution and changes in environmental conditions can result from waste with concentrations higher than permitted limits (Leonard et al., 2024). Most household waste is biodegradable despite its high chemical pollutant content (Sulistia, 2019). Hazardous compounds found in industrial waste pose a threat to human life. In addition to being a hazardous substance, industrial waste is characterized by the presence of toxins, high temperatures, irritants, odors, flammability, and reactions with biological tissues.

**Determination of Quality Status**

Assessments at each sampling point allow us to determine the water quality of the Buduran River. To achieve this level of water quality, the Class II water quality standard was modified to align with the current category. Table 6 shows the aggregate results for the Class II water quality standard from 2 points, as measured by the scoring system.

**Table 6**. Comparison of Scoring Results of Class II Water Quality Criteria

| Sampel | Scoring |
|---|---|
| Location 1 | -12 (Moderate pollution) |
| Location 2 | -18 (Moderate pollution) |

Based on Table 6, which contains the results of the STORET method used to determine the water quality status of the Buduran River in Sidoarjo in March and April 2025, the river is classified as moderately polluted, with scores ranging from -11 to -30. This classification is based on the classification of each sampling point as class II. The combined score at points 1 and 2 in a heavily polluted condition is -18, while points 3 and 4 received a score of -24. This is due to many criteria exceeding the quality standards, such as BOD, COD, Pb metal. Due to the influence of pollutants from industrial and domestic activities around the Buduran River, class II pollution has emerged, ranging from moderate to severe. These findings indicate that the significant increase in pollutant concentrations at points 3 and 4 may indicate pollution that requires serious attention in water quality management efforts in the area (Zhang et al., 2020). These results are also in line with research conducted by several previous researchers which showed a relationship between pollution and human activities, such as industry and waste processing, which significantly affect water quality (Rahayu et al., 2020).

## CONCLUSION

The results showed that temperature, pH, total dissolved solids, and total dissolved solids levels at all sample locations were within the acceptable range for Class II quality according to Government Regulation Number 22 of 2021. Significant levels of organic pollution were indicated by the BOD indicator, which exceeded the quality criteria at each test location. Specifically, at point 2, COD was higher than the quality criteria, indicating the presence of non-biodegradable organic molecules. The concentration of the heavy metal Pb significantly exceeded the threshold at all locations, indicating serious heavy metal pollution, likely originating from industrial activities.

Based on scoring calculations used the STORET method, the water quality status of the Buduran River in Sidoarjo is moderately polluted at all locations, with a score of -12 at location 1 and -18 at location 2. Both locations are categorized as moderately polluted. The government needs to conduct regular monitoring of industrial and domestic activities around the Buduran River, especially those sectors that have the potential to produce organic waste and heavy metals. Businesses and industries should implement more effective wastewater treatment technologies, particularly wastewater treatment plants (IPAL), which can reduce BOD, COD, and Pb levels.

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