THE ASSESSMENT OF CITARUM RIVER WATER QUALITY IN MAJALAYA DISTRICT, BANDUNG REGENCY

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ABSTRACT

Citarum River is one of the biggest rivers in Java Island and the primary source of Jakarta's water supply. Named the dirtiest river globally in 2013, the Indonesian government is committed to improving the Citarum River's water quality by 2025. However, the Majalaya District, the center of the textile industry area in the upstream part of the Citarum River, was indicated to have significantly contributed to the river pollution. Hence, it is essential to conduct a study to evaluate the water quality in the Citarum River, especially in the Majalaya District. This study compared water quality data measured using Standard Method to Indonesia's water and wastewater quality standards. The results showed a considerable decrease in water quality from upstream to downstream of the Citarum River from 2013 to 2021. Concurrently, it was also found that the factory effluent far exceeded the permissible limit.

Keyword: *Citarum River, Majalaya Industrial Area, Water Quality*

1. INTRODUCTION

The expeditious growth of the urban population has been a critical factor of the rapid development in Java Island, Indonesia, over the last few decades. The island of Java covers 7% of Indonesia's territory and abides by 151.59 million people, or 56.10% of the country's population [1]. This fact subsequently catalyzes the emergence of significant water problems due to severe water pollution caused by rapid industrial growth. An example of the most critical issue is the Citarum River's water quality contamination, dubbed one of the ten most polluted rivers globally [2]. The Citarum River provides 80% of raw water to the capital city of Jakarta and supplies water to over 28 million people in Java Island [3]. However, Blacksmith Institute’s findings revealed that the contamination of the Citarum River directly affects over 500 thousand people. In addition, over 5 million people are impacted indirectly due to the chemical pollution disposed into the river and carried away by the stream.

The Citarum River's primary source of pollution is domestic waste in household wastewater and garbage, industrial waste, livestock waste, and fishery waste. According to the data from the Ministry of Environment and Forestry, 54% of the Citarum River's water is heavily polluted, 23% is moderately polluted, 20% is mildly polluted, and only 3% satisfies the water quality standard [4]. The Majalaya textile industry area, located upstream of the Citarum River, accounts for over 40% of the country's textile production [5]. According to data from the Regional Environmental Management Board (BPLHD) for Bandung Regency in 2012, the Bandung Regency region has 217 industries, and Majalaya District has 66 medium-scale industries (nearly entirely textiles). Additionally, the data reported that the wastewater polluting the Citarum River in the Majalaya area originates from a vast variety of industries with scattered sewerage [6].

One of the efforts made by the government in overcoming the problem of water quality pollution in Indonesia is the passage of a law governing the management of hazardous and toxic waste in the Law of The Republic of Indonesia Number 32 of 2009 Concerning

Protection and Management Environment [7]. However, this law has not been fully implemented in practice. In Bandung Regency's industrial sector, less than half of the industries have implemented appropriate waste management [8].

Hence, as a result of the severity of the pollution and damage to the Citarum river, which resulted in heavy losses to health, economy, social, ecosystem, and environmental resources, as well as jeopardizing the achievement of environmental protection and management objectives, the government ratified Presidential Regulation Number 15 of 2018 on the Acceleration of Pollution Control and Damage to the Citarum River [9][10]. To expedite the control of damage to the Citarum watershed in an integrated way, the government established the Citarum River Basin Pollution and Damage Control Team, hereinafter referred to as the Citarum River Basin Task Force (Satgas DAS Citarum) [11]. Among the actions conducted in response to the Presidential Decree is the installation of an aquarium above the water flow of the Cikakembang River, the tributary of Citarum River located on the border of Padamulya and Sukamukti villages in Majalaya District, Bandung Regency, in 2020. The aquarium is 1.5 meters long, 80 cm high, and 80 cm wide and serves as a waste control aquarium for the textile industry and domestic waste. Regrettably, in January 2022, it was found that the aquarium ceased to function [12].

The effort to revitalize the Citarum River Basin has come to fruition as the West Java Provincial Government report stated that the Citarum River is no longer the dirtiest in the world, as presented at the COP26 World Leaders Summit in Glasgow, Scotland, in 2021. The plan is for the Citarum River's water quality to reach class 2 of raw water standards by 2025, with a Water Quality Index (IKA) of 60 points. Meanwhile, at the start of the program in 2018, the Citarum river's IKA was 33.43, classified as highly polluted, and from 2020-2021 the IKA of the Citarum river was 50-55 or moderately polluted [13].

Therefore, to support the fulfillment of the target, further studies are needed to thoroughly analyze the water quality in the Citarum River, particularly in the Majalaya District, which has been the hub of the textile industry for the past decades. This paper will investigate the water quality in the Citarum River in 2013 – 2021 compared to the water quality standards set by the government. Among the listed parameters, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and ammonia (NH_3) are chosen to be observed in this study to provide an overview of the pollution conditions in the Citarum River.

2. LITERATURE REVIEW

2.1. Water Quality Parameters

Chemical, physical, and biological aspects of water can all be evaluated or monitored to determine the required water quality criteria. In more detail, an explanation of the evaluated parameters is presented as follows.

2.1.1. Dissolved Oxygen (DO)

DO is a gaseous form of molecular oxygen derived from the atmosphere or photosynthesis. Once dissolved in water, it becomes available for consumption by living organisms and can be involved in various chemical reactions occurring in the aquatic environment. DO is a critical parameter for determining water quality in streams, rivers, and lakes [14]. In general, the bigger the DO concentration, the higher the quality of the water. The actual concentration of DO changes according to the water's pressure, temperature, and salinity. DO is expressed in a variety of units but is most commonly presented as mg/L or as a percentage of saturation (DO%). The unit mg/L is self-explanatory; it indicates the amount of gaseous oxygen dissolved in one liter of water.

2.1.2. Biochemical Oxygen Demand (BOD)

Bacteria and other microbes feed on organic compounds. The BOD is a chemical process that determines the quantity of DO required by aerobic biological organisms in water to degrade organic matter in a given water sample over a certain period [15]. It is commonly employed as a strong indicator of water-borne organic contamination. It is often expressed in milligrams of oxygen consumed per liter of sample during a five-day incubation at 20°C (BOD5). The bigger the value, the faster the stream's oxygen supply is depleted, which results in a decrease in the amount of oxygen available to higher types of aquatic life. The effects of high BOD levels are identical to those of low dissolved oxygen levels: aquatic creatures become stressed, suffocate, and die [16].

2.1.3. Chemical Oxygen Demand (COD)

The COD is a parameter that is used to quantify all organic compounds, including biodegradable and non-biodegradable. For the same sample, COD values are always greater than BOD values [15].

2.1.4. Ammonia (NH_3)

Aquatic plants are capable of absorbing NH_3 and converting it to proteins, amino acids, and other chemicals. Above a certain threshold, ammonia can increase the growth of algae and aquatic plants. Bacteria can also nitrify excess ammonium to form nitrate (NO3-), reducing dissolved oxygen [17]. Typically, the reported number is the sum of the two forms and is denoted by the abbreviation total ammonia or simply ammonia. Additionally, pH affects the relative proportions of the two types present in water significantly [16].

2.2. Water Quality Standards

In order to assess the water quality of the Citarum River in Majalaya District, this study refers to the national water quality standards for rivers and other bodies of water as stipulated in Government Regulation Number 22 of 2021 (PP 22/2021) concerning the Implementation of Environmental Protection and Management [18]. The standard used is the quality standard for water classified as second class, which includes water used for water recreation infrastructure/facilities, freshwater fish farming, livestock farming, irrigation of crops, and other designations requiring the same water quality intended use.

Additionally, this research utilized the Governor of West Java's Decree Number 39 of 2000 (Kepgub Jabar 39/2000) on Water Designation and Water Quality Standards in the Citarum River and Its Tributaries in West Java as a benchmark for evaluating the Citarum River's water quality [19]. According to its designation, the standard employed in this study is class B, which denotes water suitable for human consumption. The **Table 1** below summarizes the water quality standards for key water quality parameters from the two legal instruments.

Table 1. Water quality standards based on class

Parameter	Unit	Government Regulation No. 22 of 2021	Governor of West Java's Decree No. 39 of 2000
		Class II	Class B
DO	mg/l	4	6
Ammonia (NH_3-N)	mg/l	0.2	0.5
BOD_5	mg/l	3	6
COD	mg/l	25	10

In addition to the raw water quality standard, the Minister of Environment and Forestry of The Republic of Indonesia Number 16 of 2019 Concerning Second Amendment to Regulation of The Minister of Environment Number 5 of 2014 Concerning Wastewater Quality Standards is used as a reference in this study. The industrial wastewater quality standard establishes the maximum allowable wastewater discharge into the environment. The standard serves to determine the maximum pollutant load or the maximum load that can be discharged into the environment without violating the standard. The quality standards for wastewater are listed in **Table 2**.

Table 2. Industrial wastewater quality standard

Parameter	Unit	Minister of Environment and Forestry's Decree No. 16 of 2019
NH_3-N	mg/l	8
BOD_5	mg/l	60
COD	mg/l	150
Maximum Discharge	m^3/ton product	100

3. METHODOLOGY

3.1. Study Area and Sampling Locations

Citarum River is one of the biggest and longest rivers in Java Island located in the administrative area of West Java Province, Indonesia. With a total catchment area of 12,000 km^2, as presented in **Figure 1**, the Citarum River flows 297 km from Cisanti spring at Wayang Mountain down to the Java Sea.

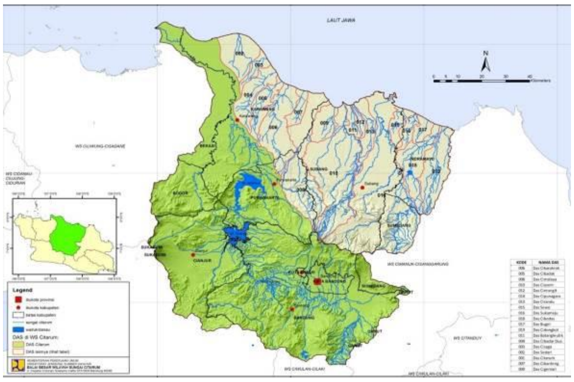

Figure 1. Location of Citarum River Basin (Source: Citarum River Basin Organization)

The location of this study was in the upper part of the Citarum River in Majalaya District, a renowned textile industry area. Several monitoring points were used as reference points, including Wangisagara, Majalaya, Koyod Bridge, and Sapan. The monitoring location can be seen in **Figure 2**.

Figure 2. The location of monitoring points

3.2. Laboratory Analysis

In this study, two types of data were used to evaluate the water quality of the Citarum river, which were data obtained from the Directorate of Water Resources Engineering, Ministry of Public Works and Housing (Bintek SDA, PUPR) and Perum Jasa Tirta II (PJT II). In addition, independent experimental works were also carried out to compare the water quality parameters of the Citarum River and textile factory effluent in the Majalaya District. The results were used to review the obtained water quality data and compared with water and wastewater quality standards in Indonesia.

Water sampling in the Citarum River was done once a month throughout the year with two times repetition (Duplo) for each sampling point. The method used by Bintek SDA, PUPR and PJT II referred to the Standard Methods published by the American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF) [14]. In detail, the methods used for measurement are presented in **Table 3**.

Table 3. Water quality measurement methods used by Bintek SDA, PUPR & PJT II

Parameters	Unit	Method
DO	mgL^{-1}	APHA 23rd Ed. 4500-O G Membrane-Electrode Method
NH_3-N	mgL^{-1}	APHA 23rd Ed. 4500-NH_3.C Titrimetric Method
BOD	mgL^{-1}	APHA 23rd Ed. 5210 B 5-Day BOD Test
COD	mgL^{-1}	APHA 23rd Ed. 5220 C Closed Reflux, Titrimetric Method

Meanwhile, the methods used for the independent laboratory test can be seen in **Table 4**.

Table 4. Water quality measurement methods for the independent laboratory test

Parameters	Unit	Method
DO	mgL^{-1}	Dissolved Oxygen Probe (Polarographic Electrode)
BOD	mgL^{-1}	Manometric, mercury-free, and electronic pressure sensor
COD	mgL^{-1}	Reaction Digestion
NH_3-N	mgL^{-1}	Nessler

4. RESULTS AND DISCUSSION

4.1. The Citarum River Water Quality in Dry Season 2013-2016

The Citarum River water quality analysis was performed using data from Bintek SDA, PUPR from April to October in 2013-2016. Multiple parameters were evaluated, including DO, NH_3, BOD, and COD.

In **Figure 3**, the DO measurement data from the upstream to the downstream of the Majalaya District consisting of Wangisagara, Majalaya, and Koyod monitoring posts section is presented and compared with the Government Regulation Number 22 Year 2021 class 2. In general, the DO concentration declined between 2013 and 2016. Similarly, an equivalent situation occurred when comparing the DO concentration upstream to the downstream conditions. Over a four-year period, it was noticed that the DO value was less than the established quality threshold of 4 mg/L at least 18 times.

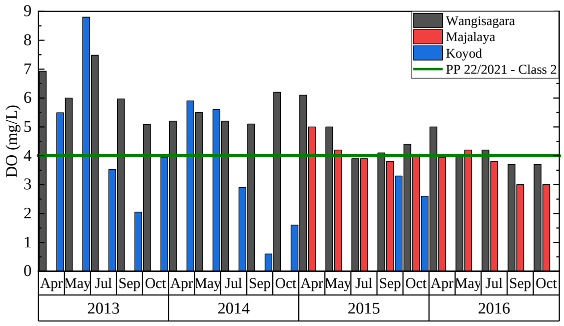

Figure 3. DO measurement in 2013-2016

Meanwhile, the results of the NH_3 measurement indicated that the general state of the Citarum river's water quality was fairly good. The maximum permitted concentration of NH_3, 0.5 mg/L, was surpassed only 6 times in 2013-2014. This rise was purportedly due to increased domestic wastewater disposal. The complete results of the NH_3 concentration measurement are shown in **Figure 4**.

Furthermore, the data of BOD and COD concentration measurements reported in **Figure 5** and **Figure 6** demonstrated that the trends obtained were similar, particularly regarding the fluctuation over the observed four-year period. Between 2013 and 2014, BOD and COD values increased significantly, correlating with the results of the NH_3 measurement. The BOD test revealed that 30 occurrences exceeded the 3 mg/L BOD limit for the water quality standard. Similarly, 17 occurrences exceeded the COD threshold of 25 mg/L.

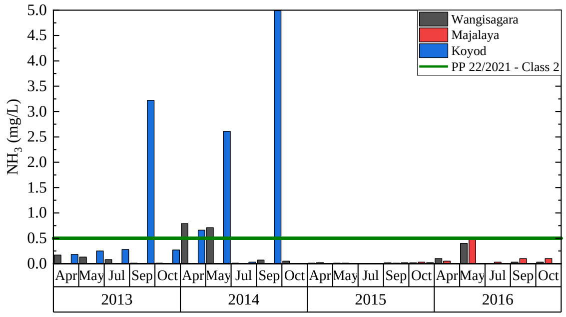

Figure 4. NH_3 measurement in 2013-2016

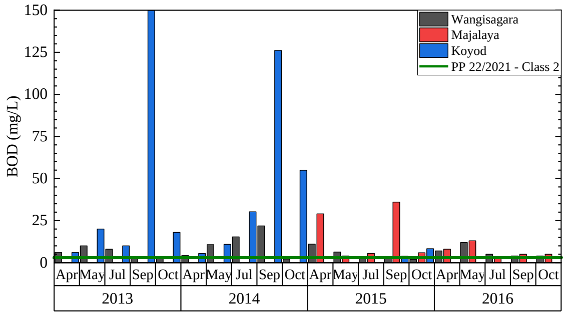

Figure 5. BOD measurement in 2013-2016

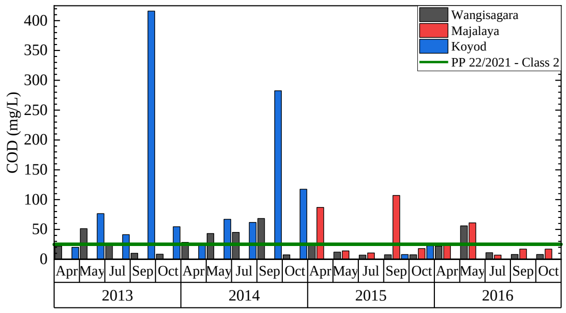

Figure 6. COD measurement in 2013-2016

4.1. Water Quality Measurement of Factory Effluents in Majalaya

To ascertain the causes of the decline in water quality downstream of the Citarum River on the Majalaya District, measurements of the quality of wastewater discharged from different factories in the Majalaya area were conducted on April 17-21, 2017. **Figures 7** and **Figure 8** compare the DO and COD measurements to wastewater quality standards established in Minister of Environment and Forestry of the Republic of Indonesia Number 16 of 2019 (Minister's Decree 16/2019).

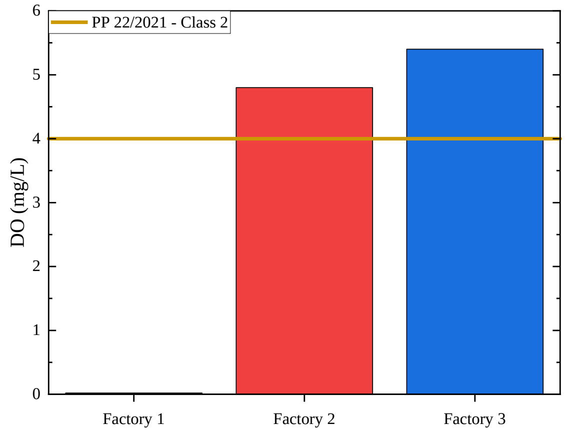

Figure 7. DO values of factory effluents

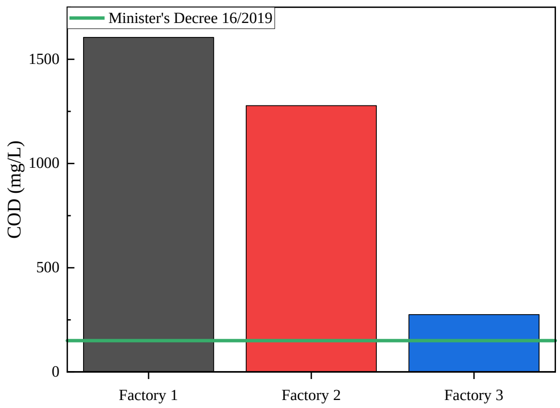

Figure 8. COD values of factory effluents

As can be seen from the aforementioned data, the DO concentration for factories 2 and 3 was greater than the class 2 water quality standard, while the DO concentration for factory 1 was almost zero. On the other hand, the COD concentrations of all three factories did not meet the standard. Although the textile companies were provided with a wastewater treatment system, they fell short of meeting the effluent requirement. The three factories' treated effluent was discharged directly into the river. This was thought to result in a deterioration of the water quality downstream of the Majalaya District.

4.2. The Citarum River Water Quality in 2017-2021

The Citarum River water quality was also analyzed using PJT II water quality data. The data available were monthly data measured from 2017 to 2021. This analysis used measurement data at the Wangisagara, Majalaya, and Sapan monitoring posts sequentially from upstream to downstream. The parameters evaluated were DO, NH_3, BOD, and COD. According to Government Regulation Number 22 of 2021 class 2 and Governor of West Java's Decree Number 39 of 2000 class B, the measurement value was compared with water quality standards.

Based on the results of the DO measurement, it can be seen that the value obtained fluctuates throughout the year. The DO values at the Wangisagara and Majalaya monitoring posts comply with the class 2 water quality standard, which requires a minimum of 4 mg/L. However, it has not been able to meet the class B level, which requires a minimum of 6 mg/L. On the other hand, the measurement results indicated that the majority of Sapan data did not meet the two standards. Ultimately, the measurement results can be seen in **Figure 9**.

Meanwhile, as illustrated in **Figure 10**, a significant proportion of the NH_3 measurement results complied with the standard set for class 2 and class B, which were 0.2 mg/L and 0.5 mg/L respectively. It is noteworthy that the results of the NH_3 measurement at the end of 2021 show a significant increase in the Majalaya and Sapan monitoring posts.

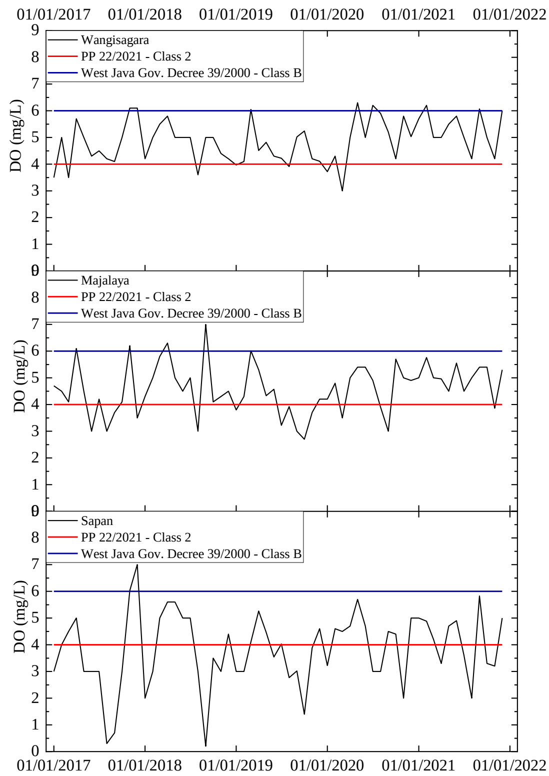

Figure 9. DO measurement in 2017-2021

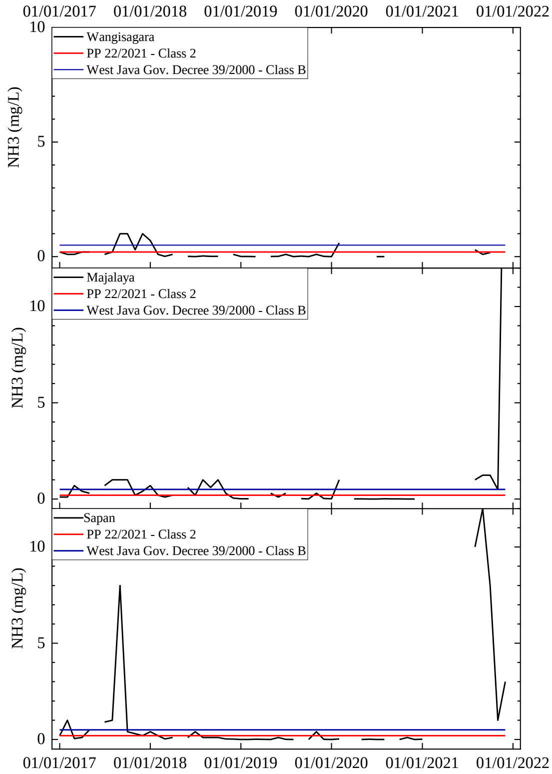

Figure 10. NH_3 measurement in 2017-2021

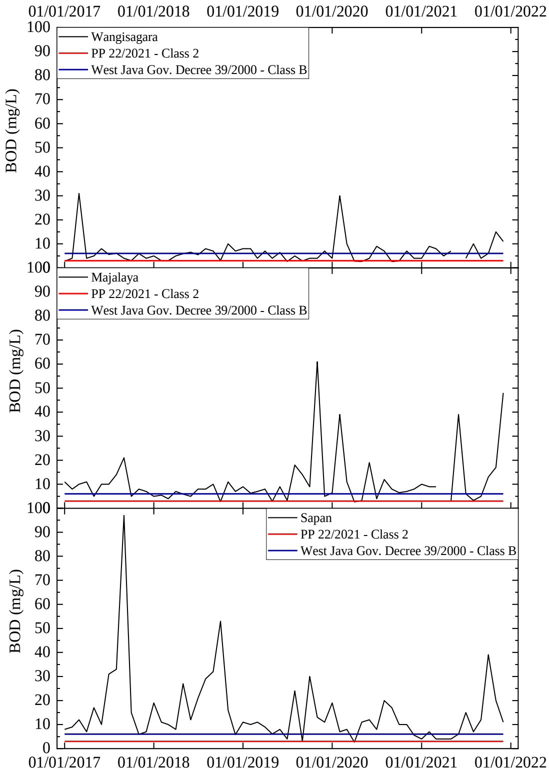

Figure 11. BOD measurement in 2017-2021

As illustrated in **Figure 11**, most BOD concentrations at the Wangisagara monitoring station did not meet the class 2 water quality standards with a maximum value of 3 mg/L. Meanwhile, at the Majalaya and Sapan monitoring posts, the BOD value continued to increase that it could not meet both the class 2 and the class B water quality standard with a maximum value of 6 mg/L.

In line with the results of the BOD measurement, the measured COD far exceeded the required standards, as shown in **Figure 12**. The results of the three monitoring stations did not meet the class B quality standard, which required a COD value of no more than 10 mg/L. Meanwhile, compared with the class 2 water quality standard with a maximum COD value of 25 mg/L, the measurement results at the Wangisagara and Majalaya monitoring posts were still relatively adequate. Regrettably, the measurement values at the Sapan monitoring station were significantly higher than the class 2 water quality standard's upper limit.

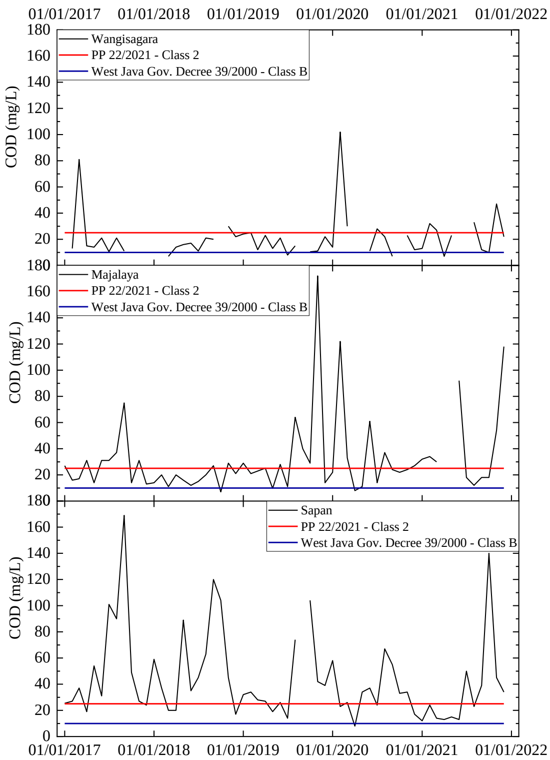

Figure 12. COD measurement in 2017-2021

Overall, the Citarum River's water quality fluctuated from 2013 to 2021. The results acquired indicated that, on average, the Citarum river's water quality did not reach the class 2 and class B standard. Additionally, it can be seen that the data presented in some graphs were not continuous because the recorded data contains "Under Range" values. This demonstrated the necessity for more advanced technology with a broader reading range to obtain complete and more reliable measurement data.

4.3. Seasonal Comparison of the Citarum River's Water Quality

Furthermore, the water quality of the Citarum River on the Majalaya District was compared during the rainy and dry seasons. In the rainy season, data from PJT II were used from 2017 to 2021. While in the dry season, the data range used is 2013-2016 using data from Bintek SDA, and 2017-2021 using data from PJT II. The data for 2013-2016 only covers the dry season because it is believed to reflect the critical conditions that exist throughout the year in the Citarum River. Therefore, it is vital to evaluate the seasonal pattern in water quality.

The DO values during the rainy and dry seasons were compared in **Figure 13** and **Figure 14**. The two graphs depicted the average DO concentrations measured during the rainy and dry seasons corresponding to the water quality standards for class 2 and class B. Based on these results, the DO concentration decreased further downstream. However, in general, the average DO value fluctuated substantially over the defined year range. Hence, it could not be stated with certainty that the measurement results in the dry season provide a critical value that accurately represents the condition of the Citarum River for one year.

Meanwhile, measurements of NH_3 in the rainy season (**Figure 15**) and the dry season (**Figure 16**) indicated that the concentration of NH_3 risen dramatically in 2021. In the dry season, it was evident that an increase occurred when comparing the concentration from upstream to downstream of the Majalaya District. In general, the results obtained indicated that the dry season's NH_3 concentration was higher than the rainy season's.

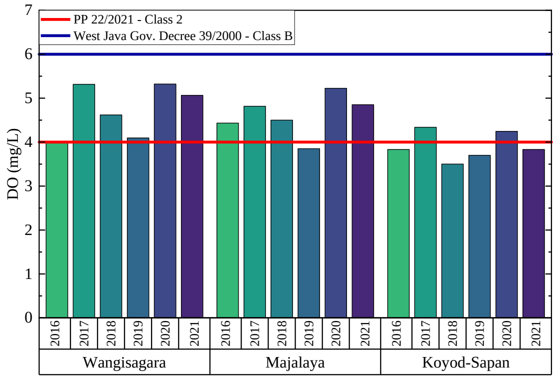

Figure 13. DO concentration in rainy season

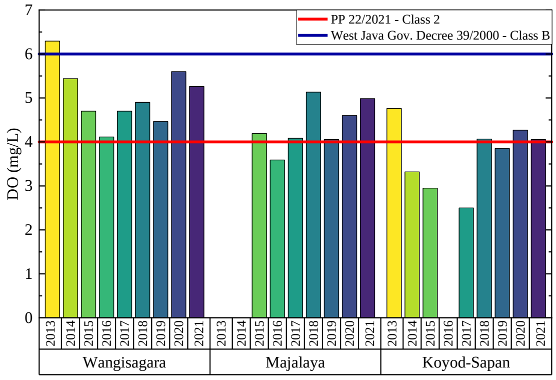

Figure 14. DO concentration in dry season

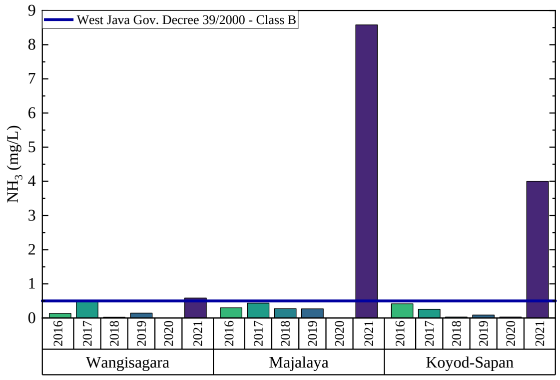

Figure 15. NH_3 concentration in rainy season

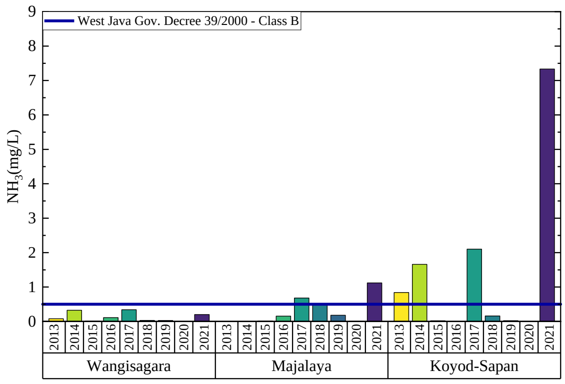

Figure 16. NH_3 concentration in dry season

Furthermore, BOD measurement data in the rainy season and dry season were shown in **Figure 17** and **Figure 18**. Typically, the concentration of BOD increases from upstream to downstream. When comparing the data in the 2017-2021, there was a considerable increase in BOD concentrations in 2019-2021 during the rainy season; this was inversely proportional to the dry season conditions, which showed the highest BOD value occurred in 2017-2018. In addition, a very high BOD value was recorded downstream in 2013-2015; however, since there was no documented data for the 2013-2016 rainy season, this value could not be compared.

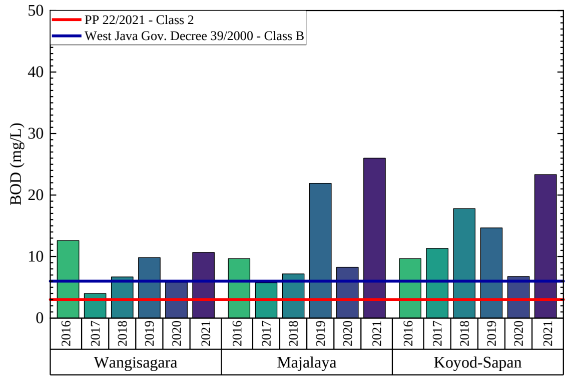

Figure 17. BOD concentration in rainy season

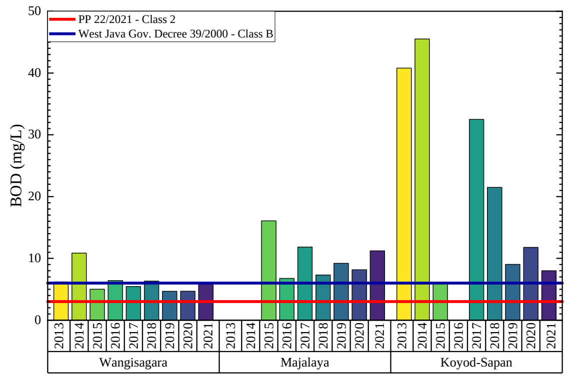

Figure 18. BOD concentration in dry season

Finally, a comparison of the COD values measured during the rainy season (**Figure 19**) and the dry season (**Figure 20**) revealed a similar trend to the BOD concentrations. A more comprehensive data collection is required to further study the seasonal variation in the water quality of the Citarum river.

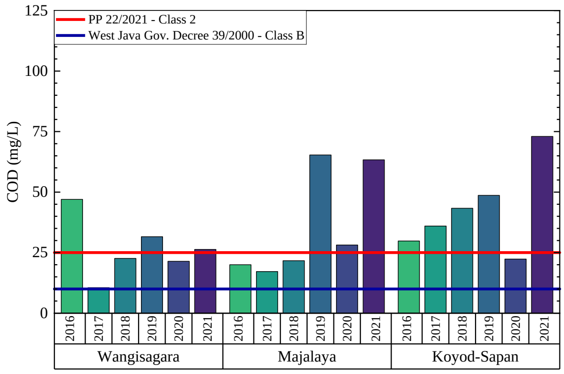

Figure 19. COD concentration in rainy season

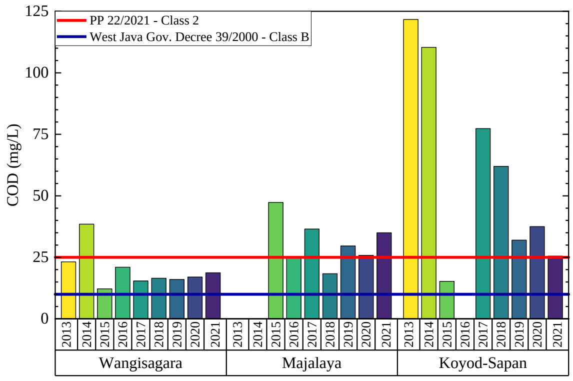

Figure 20. COD concentration in dry season

5. CONLUSIONS

The pollution of the Citarum river, especially in the Majalaya District, was caused by household and industrial wastewater in its surrounding area. Generally, there has been a decline in water quality from 2013 to 2021. Only the upstream part of the Majalaya District satisfied the class 2 water quality standard, while the class B quality standard remains formidable. Concurrently, the NH_3, BOD, and COD concentrations increased further downstream, causing the water quality to deteriorate.

The exceedingly high COD concentrations measured in several textile factory effluents in the Majalaya District are consistent with the downstream pollution condition. Therefore, to better understand the impact of wastewater disposed into the Citarum River on its water quality, other organic and heavy metal parameters shall be properly measured for both the river body and the factory effluent.

6. RECOMMENDATIONS

1. In order to gain a greater understanding regarding the behavior of water pollution in the Citarum River, a future study that considers a more extended river section to the downstream area is needed.
2. There are many under-range values in the obtained water quality data. For this reason, more advanced technology or comprehensive method is needed to acquire higher data quality and produce better analysis.

7. ACKNOWLEDGEMENT

This work was supported by the provision of water quality testing instruments from Korea Advanced Institute of Science and Technology (KAIST) and research funding by Sangji University.

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