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Risk-Based River Management: Case Study of Pocong River, Bangkalan Regency

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Abstract
Watershed (DAS) is a land area that includes rivers and their tributaries, which functions to accommodate, store, and channel rainwater to lakes or the sea naturally. In Bangkalan Regency, the Pocong River plays an important role in the local ecosystem. This river is used for various needs, such as irrigation, industry, and household consumption. The upstream part of the Pocong River, which is classified as class I, is used for drinking water and recreation, while the downstream part, in class II, is used for fish farming and crop irrigation. However, with increasing human activity, the water quality of the Pocong River has decreased due to pollution from domestic, agricultural, and industrial waste. Research using MIKE21 software will model the water quality in both parts of the river to provide an overview of the water quality conditions in the Pocong River. This study aims to model the quality of the upstream part of the Pocong River, class I and the downstream part, class II. The expected results of this study are to provide structured data and information regarding the water quality model of the Pocong River in the upstream and downstream parts.

Keywords: Water Quality, MIKE 21, Pocong River

1. Introduction

A River Basin Area (DAS) is a land area that includes rivers and their tributaries, its function is to accommodate, store, and channel rainwater to lakes or the sea naturally. In Bangkalan Regency, the DAS includes springs, reservoirs, and rivers, with land boundaries as topographical dividers and sea boundaries to waters that are still affected by land activities. The river flow pattern in this area leads to the Madura Strait and the Java Sea. The Pocong River, which stretches about 12 km from its spring, crosses residential, trade, industrial, and office areas. This river is very important for domestic, agricultural, and industrial water needs and supports the local ecosystem. The Pocong River in Bangkalan Regency plays an important role in the lives of local people in terms of economy, social, and environment. The river water is used for various purposes such as agricultural irrigation, industry, and household needs. The upstream part of the Pocong River, which is included in class I, is used for drinking water and recreation, while the downstream part, which is included in class II, is used for freshwater fish farming, crop irrigation, and activities that require lower water quality.

The use of the Pocong River as a source of drinking water in the upstream makes it very important to maintain water quality at a very high level. In addition, recreational activities such as swimming and other water tourism also rely on the cleanliness and clarity of the water in this section. However, pollution from human and industrial activities around the river has resulted in a significant decline in water quality. Downstream, the use of river water for fish farming and agricultural irrigation requires water quality that is good enough to support the productivity of these sectors. However, industrial and domestic waste pollution has caused serious problems for farming and agricultural activities, which in turn can affect the local economy and community welfare. The water quality in the Pocong River does not all meet class II water quality standards for parameters such as BOD, COD, TSS, Ammonia, and Total Coliform (DLH Bangkalan, 2023). With the increasing human activity around the river, water quality has decreased significantly. Pollution is mainly due to domestic, agricultural, and industrial waste.

Efforts in managing the water quality of the Pocong River can be done through initial observation of the pollution of the Pocong River from upstream to downstream, where the points or segments of the decline in the quality of the Pocong River water will be studied in depth. Determination of water quality and distribution of pollution in the Pocong River are needed as a consideration for conducting modeling simulations. Modeling can be interpreted as a logical explanation of how a system works or its components react. This study will model the distribution of pollutants from upstream to downstream of the river according to simulations using MIKE21 software. MIKE 21 is a two-dimensional hydrodynamic modeling software developed by DHI (Danish Hydraulic Institute), very popular for modeling the distribution of river pollution due to its various advantages. This software has advanced hydrodynamic capabilities to simulate water flow and pollutant distribution accurately, allowing for realistic analysis of various river conditions. MIKE 21 can also integrate various types of environmental data such as weather data, water quality, and land use, and handle complex flow conditions and pollution scenarios. The intuitive user interface makes it easy for users to build models, run simulations, and analyze results. The software has been validated and verified through case studies around the world, providing a high level of confidence in its results. The software was chosen for its ability to accurately model water dynamics and pollution (DHI, 2020).

2. Objective

The objectives of this research are as follows:

1. Quality model of Pocong River upstream class I and downstream class II
2. Analyzing the water quality of the Pocong River based on existing conditions in two seasons, namely the west season and the east season.

3. Literature Review

1. River Water Class Quality Standards

Guidelines used to determine the level of river water quality based on its designation. This standard is usually regulated by the government through environmental regulations or rules, such as in Indonesia through Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. This standard divides water quality into several classes, including: class I, class II, class III and class IV

2. MIKE 21 Software

MIKE 21 is a two-dimensional (2D) model-based software developed by DHI (Danish Hydraulic Institute) to model surface water flow, water quality, and environmental dynamics in water areas. This software is widely used in hydrodynamic studies, coastal planning, river, lake, reservoir, and other water area management.

4. Methodology

This study aims to model the water quality of the Bangkalan River. The study began with direct observation and identification of pollution sources, both point sources and nonpoint sources. After this initial stage, a specific section or segment of the river to be studied was determined. The research location is in Bangkalan Regency, East Java Province. The selected river section is approximately 12 km long and starts from upstream to downstream. This river section is divided into five segments based on population and industrial density, and there are 13 sampling points along the river to represent the categories of point source and nonpoint source pollutants. The parameters used in this study include Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Temperature, Total Suspended Solids (TSS), Ammonia and Total Coliform. After the data of the Pocong River in Bangkalan Regency was collected, data analysis was carried out with a modeling system using MIKE 21 software to model and simulate each parameter study in the test.

5. Analysis and Discussion

5.1 Identification of Existing Conditions of Water Quality of Pocong River, Bangkalan Regency

Pocong River, Bangkalan Regency has different characteristics and water quality. This is because the environmental conditions around the river can affect the characteristics or quality of water. Sampling is carried out at each point and stored in a cooler box. The results of water sampling are immediately taken to the laboratory for testing according to test parameters. The results of the Pocong River test, Bangkalan Regency based on segmentation show that the water quality of the Pocong River, Bangkalan Regency is at a safe level. The results of the water sample test are shown in tables 1 and 2.

Table 1: Results of Pocong River Water Sampling, Bangkalan Regency, East Season 2024.

No.	Pickup Point	BOD	COD	TSS	Temperature	Ammonia	*T. Coliform*
1.	Point 1 (River)	1.79	5.37	30	28.0	0.050	500
2.	Point 2 (River)	2.25	7.97	32	28.0	0.073	575
3.	Point Source 1	31.20	49.85	113	28.5	0.219	800
4.	Point Source 2	27.12	47.25	93	28.5	0.210	888
5.	Point 3 (River)	2.37	12.00	37	28.0	0.087	1200
6.	Point Source 3	11.60	24.81	52	28.5	0.099	1380
7.	Point Source 4	23.11	39.72	67	29.0	0.101	1500
8.	Point 4 (River)	2.55	18.17	39	28.0	0.111	2000
9.	Point Source 5	13.60	26.80	69	28.5	0.098	2300
10.	Point 5 (River)	2.79	22.88	41	29.0	0.135	2440
11.	Point Source 6	22.55	31.20	87	29.5	0.166	2800
12.	Point Source 7	21.00	29.11	77	29.5	0.151	3020
13.	Point 6 (River)	2.82	22.91	45	29.0	0.150	3790
	CLASS I	2	10	40	Dev 3	0.1	1000
	CLASS II	3	25	50	Dev 3	0.2	5000

Source: Laboratory analysis results 2024

Table 2: Results of Water Sampling of Pocong River, Bangkalan Regency, West Season 2023.

No.	Pickup Point	BOD	COD	TSS	Temperature	Ammonia	*T. Coliform*
1.	Point 1 (River)	1.69	4.44	30	27	0.045	450
2.	Point 2 (River)	2.11	7.09	32	27.2	0.069	555
3.	Point 3 (River)	2.21	11.01	36	27.2	0.077	1150
4.	Point 4 (River)	2.39	16.56	36	27.5	0.099	1500
5.	Point 5 (River)	2.56	22.76	39	28	0.131	2200
6.	Point 6 (River)	2.66	22.86	42	28	0.145	4550
	CLASS I	2	10	40	Dev 3	0.1	1000
	CLASS II	3	25	50	Dev 3	0.2	5000

Source: Bangkalan River Water Quality Environment Agency, Bangkalan Regency Environmental Agency 2023

Primary data on the quality of the Pocong River in Bangkalan Regency is the result of sampling and laboratory analysis in 2024 which will be compared with the river water quality standards according to Government Regulation Number 22 of 2021 Attachment VI. The quality standards for the Pocong River in Bangkalan Regency in this segmentation are included in class I water quality and are approaching class II quality. This will have an impact on the ecosystem of the Pocong River in Bangkalan Regency and will have a negative impact on the community around the riverbanks if they continue to use river water that is not suitable for use by the community.

5.2 Modeling Results

This simulation aims to create and calibrate existing data and water quality sampling data so that it can be used, this simulation is also used to obtain river model coefficients. The input data used is the data used when the model was first formed, namely river water quality sampling data. Trial and error is carried out by testing the calibration model which aims to compare model prediction data with observation results.

BOD Simulation

The BOD simulation results from field observations are similar to the simulation results at the sampling points shown in Figures 1 and 2.

Figure 1: Dry Season BOD Simulation

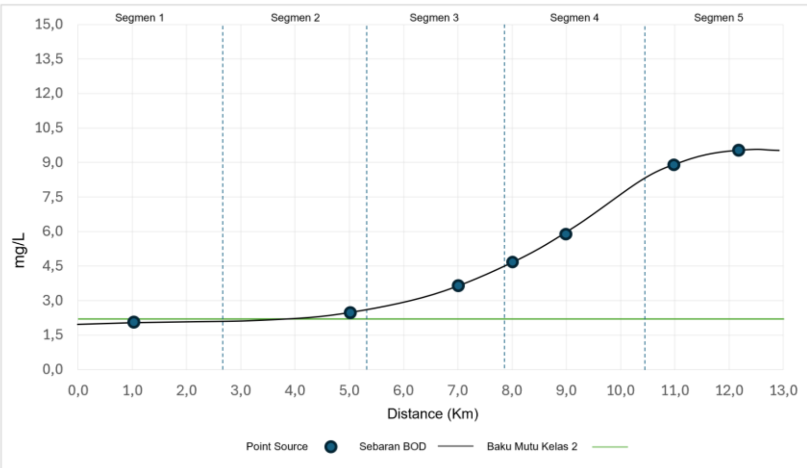
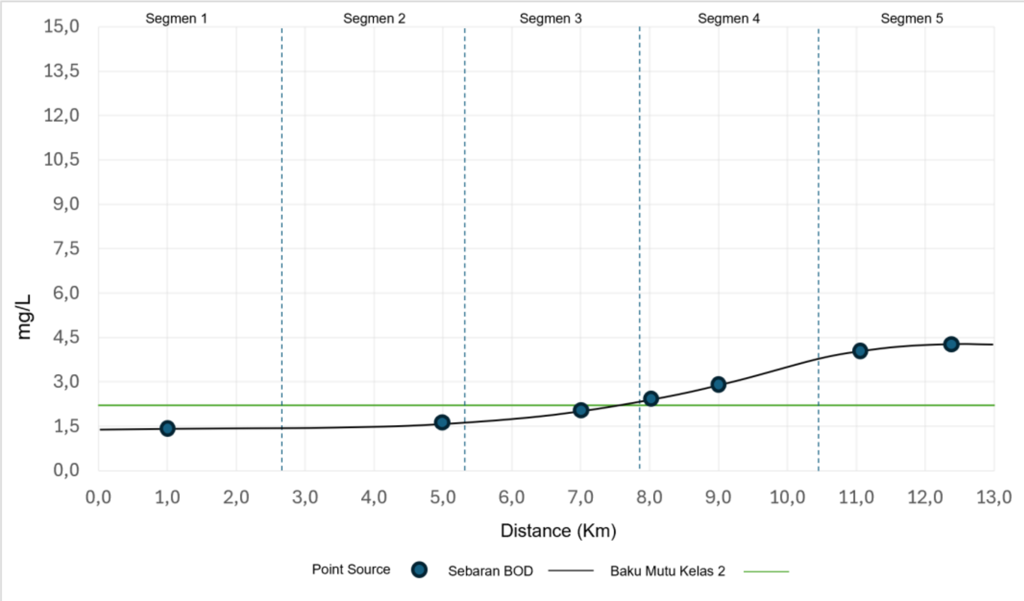


Figure 2: Rainy Season BOD Simulation



The figure above shows the distribution of Biochemical Oxygen Demand (BOD) concentrations along the Pocong River, with the distance from the pollution source as a reference. The following is a description and analysis of the data displayed in this graph. The Y-axis shows the BOD concentration in milligrams per liter (mg/L), which is used to measure the level of organic pollution in water. The higher the BOD value, the greater the oxygen requirement to decompose organic matter in water, indicating a higher level of pollution. The X-axis shows the distance from the pollution source (point source), in kilometers (Km). The data is divided into five segments, each showing changes in BOD concentration at certain points along the distance.

In the early segments (Segments 1 and 2), the BOD concentration is relatively low and close to the Class 2 quality standard limit, which is depicted by a thin green line around the level of 3 mg/L. Starting from Segment 3 to Segment 5, the BOD concentration increases gradually and quite significantly, especially after a distance of 5 km. At this point, there is a spike in the BOD value that continues to increase until it reaches a peak at the end of the segment. This trend shows that the further the distance from the source of pollution, the higher the BOD concentration, which may indicate the presence of accumulated organic waste flow or the lack of oxygen recovery processes in the area.

The green horizontal line indicates the Class 2 water quality standard, which is typically used for specific purposes such as recreation or irrigation. In this graph, the BOD concentration begins to exceed the quality standard after Segment 2, indicating that the water quality no longer meets the quality standard for Class 2.

The increase in BOD values along the water flow can be caused by the presence of settlements around the Pocong River, which causes an increase in the amount of organic material dissolved or carried by the river flow from the initial pollution point. This increase indicates that the water becomes more polluted as the distance from the source point increases, indicating that organic pollution continues to increase or does not experience effective natural decomposition. If this increasing trend continues, it is likely to affect biota and water use at a greater distance from the source point, especially if the BOD concentration continues to exceed the required quality standards.

COD Simulation

The COD values from field observations are similar to the simulation results at the sampling points as shown in Figures 3 and 4.

Figure 3: Dry Season COD Simulation

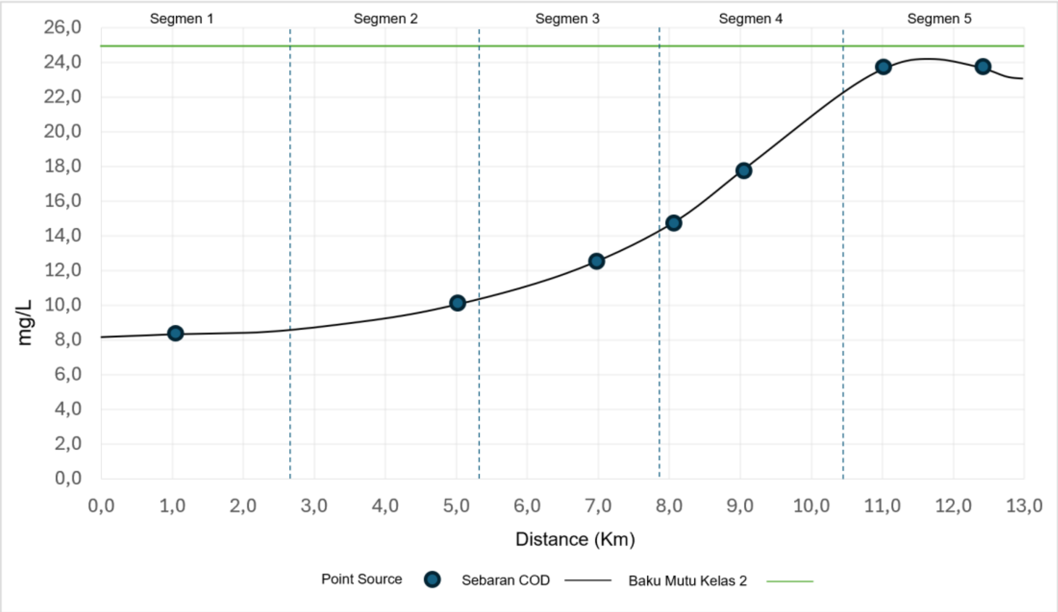
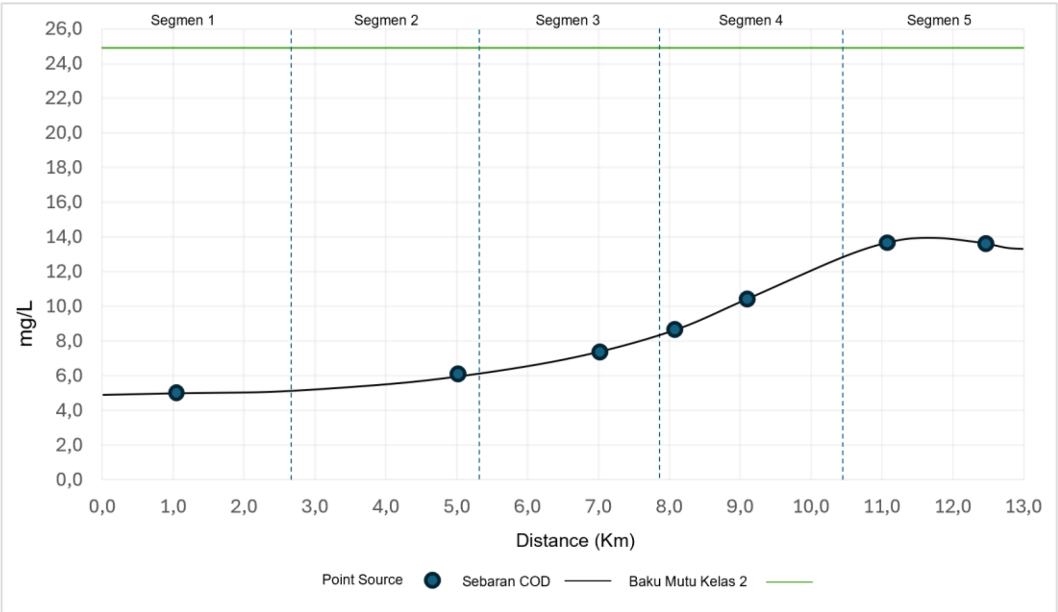


Figure 4: Rainy Season COD Simulations



The figure above shows the distribution of Chemical Oxygen Demand (COD) concentrations along the Pocong River, with the distance from the source of pollution as a reference. The following is a description and analysis of the data displayed in this graph.

In Segments 1 and 2, COD concentrations were relatively low, around 8 mg/L. From Segment 3 to Segment 5, a gradual increase in COD concentrations was seen, with a significant spike starting from a distance of 7 km to a peak at around 11-12 km. In Segment 5, COD concentrations reached their highest value and slightly exceeded the Class 2 quality standard line, which was around 25 mg/L, before appearing to decline slightly.

The green horizontal line indicates the water quality standard for Class 2, which is usually used for certain activities such as recreation or agriculture. At the end of Segment 5, the COD concentration slightly exceeds this standard limit, indicating a potential hazard to water quality pollution if left untreated. The increase in COD values indicates the accumulation of pollutants dissolved in water, both from organic and inorganic sources, which are not effectively decomposed along the river flow.

This significant trend of increasing COD concentrations indicates the potential for serious water quality degradation, especially in the final segment, which may indicate a lack of natural degradation processes or the presence of additional sources of pollution along the flow. Water quality that exceeds Class 2 quality standards at certain distances can have an impact on the ecosystem and water use for certain needs in Bangkalan Regency.

TSS Simulation

In the TSS simulation, the results of field observations are similar to the simulation results at the sampling points as shown in Figures 5 and 6.

Figure 5: Dry Season TSS Simulation

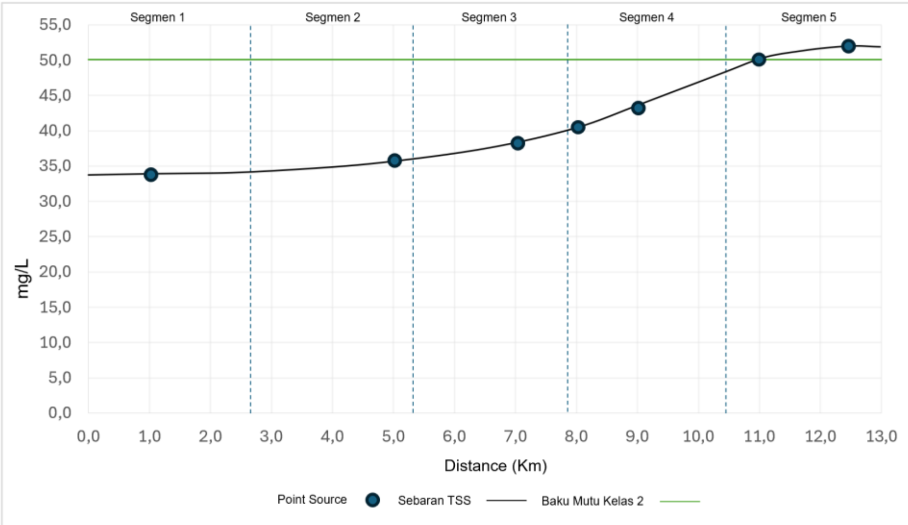
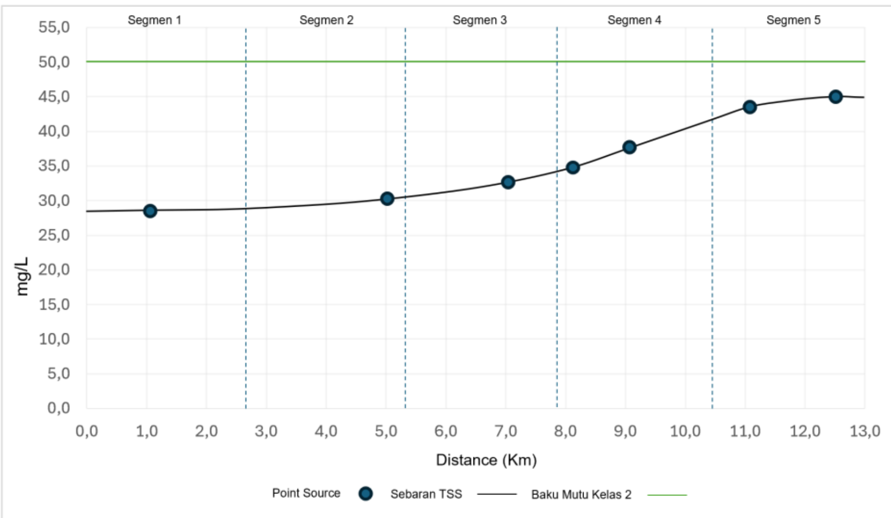


Figure 6: Rainy Season TSS Simulation



Distribution of Total Suspended Solids (TSS) concentration along the Pocong River in Bangkalan Regency, which is a water source for PDAM in the area. The following is a description and analysis of the data that can be obtained based on this image. In Segments 1 and 2, TSS concentrations are relatively low and stable, indicating few suspended particles that may still be within safe limits for processing by PDAM. Starting from Segment 3 to Segment 5, there is a gradual increase in TSS concentration, with the highest value achieved at a distance of around 11-12 km from the point of pollution. This increase in TSS concentration can be caused by waste flow, soil erosion around the river, or the entry of solid materials from pollution sources along the river.

The horizontal green line shows the Class 2 water quality standard for the TSS parameter, which is usually used as a safe limit for water to be further processed, such as for PDAM. In Segment 5, the TSS value is close to or slightly exceeds this quality standard, indicating that the water quality is starting to decline and requires more intensive treatment to meet clean water standards. An increase in the TSS value that exceeds the quality standard limit at a certain distance from the source of pollution indicates the potential for water quality problems for PDAM Bangkalan Regency. High TSS levels can reduce the efficiency of the water treatment process, because it requires additional filtration to remove suspended particles. This can also have an impact on the cost of treatment and the quality of water distributed to the community.

If this increasing trend continues without any waste management measures, the water quality in the Pocong River as a source of PDAM could be increasingly threatened, so further handling efforts are needed such as erosion control, solid waste management, and environmental conservation around the river. Overall, this graph illustrates a significant increase in TSS concentrations along the Pocong River, especially in the last segments, which has the potential to affect the quality of PDAM water. Effective environmental management efforts will be very important to ensure that water remains suitable for processing and distributing to the people of Bangkalan Regency.

Temperature Simulation

In the temperature simulation, the results of field observations are similar to the simulation results at the sampling points as shown in Figures 7 and 8.

Figure 7: Dry Season Temperature Simulation

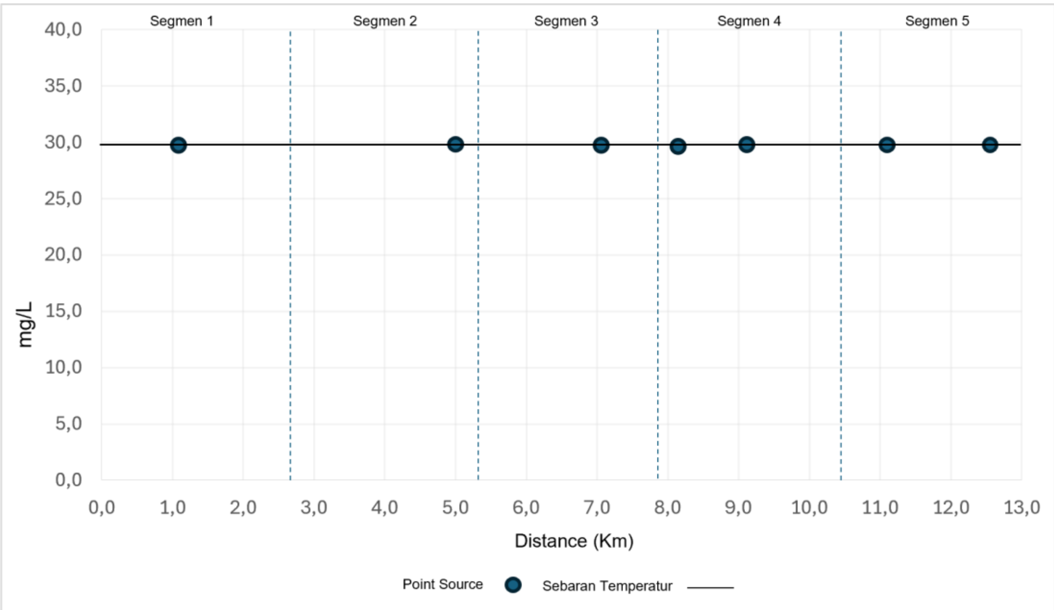
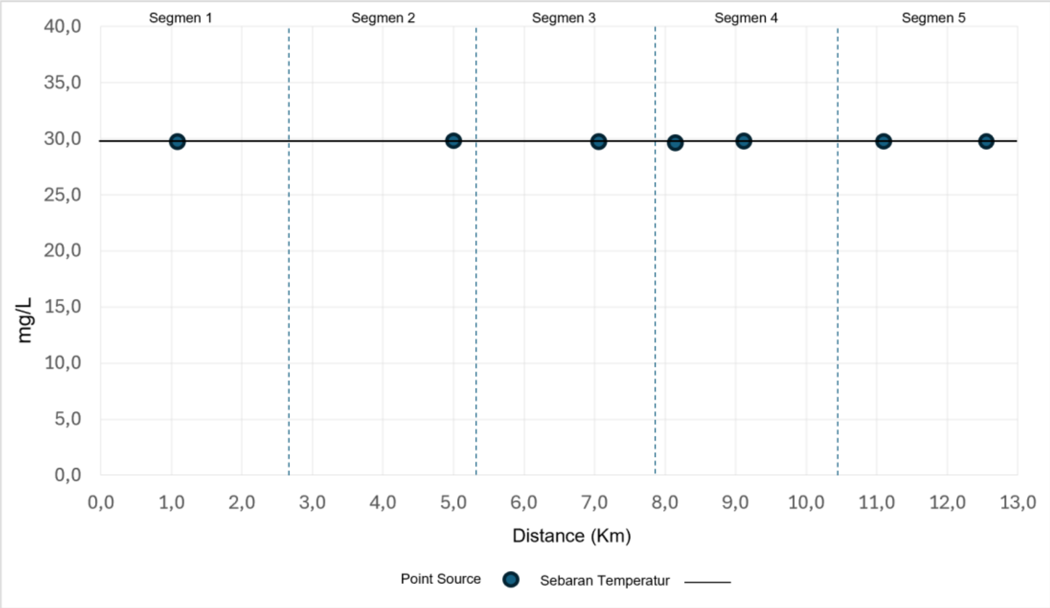


Figure 8: Rainy Season Temperature Simulation



The temperature values remain stable throughout the segments, with no significant fluctuations or changes from Segment 1 to Segment 5. The temperature is consistently around 30 °C. This condition indicates that there is no significant temperature change along the river, which could mean that there is no additional waste heat flowing into the river from industrial sources or other activities.

A stable water temperature of around 30 °C can be a good enough condition for the PDAM treatment process, because high temperature fluctuations can affect the efficiency of the water treatment process. However, a temperature value of 30 °C is quite high for raw water standards, especially if it is used for drinking water. Lower water temperatures are usually desired for raw water because it will be more comfortable to process and consume. It is important for PDAM to consider this temperature in the cooling process if necessary, so that the temperature of the distributed water is more in accordance with public comfort and health standards. This temperature stability can be an indication that there is no hot waste disposal or industrial activity along the river that significantly affects the water temperature. To maintain the quality of the Pocong River water source as a source for PDAM, it is important to continue to monitor the temperature and other parameters, because significant temperature changes can affect the aquatic ecosystem and overall water quality.

Ammonia Simulation

In the Ammonia simulation, the results of field observations are similar to the simulation results at the sampling points as shown in Figures 9 and 10.

Figure 9: Dry Season Ammonia Simulation

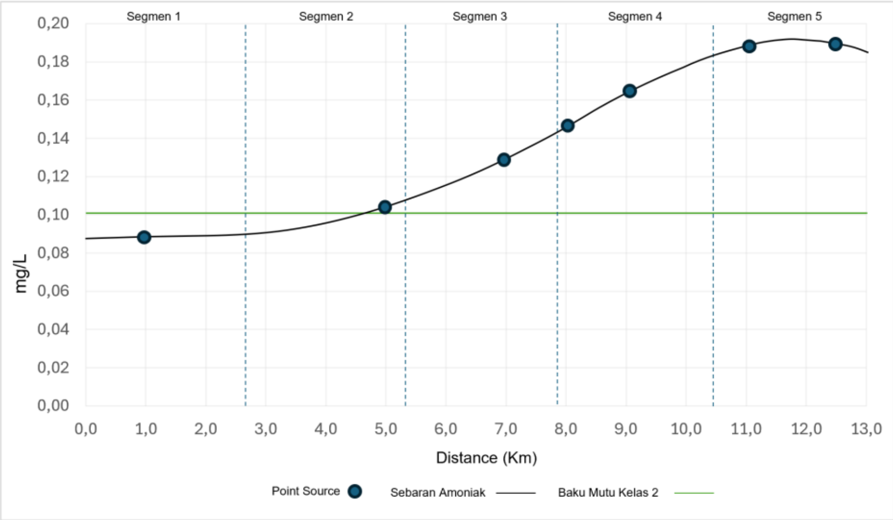
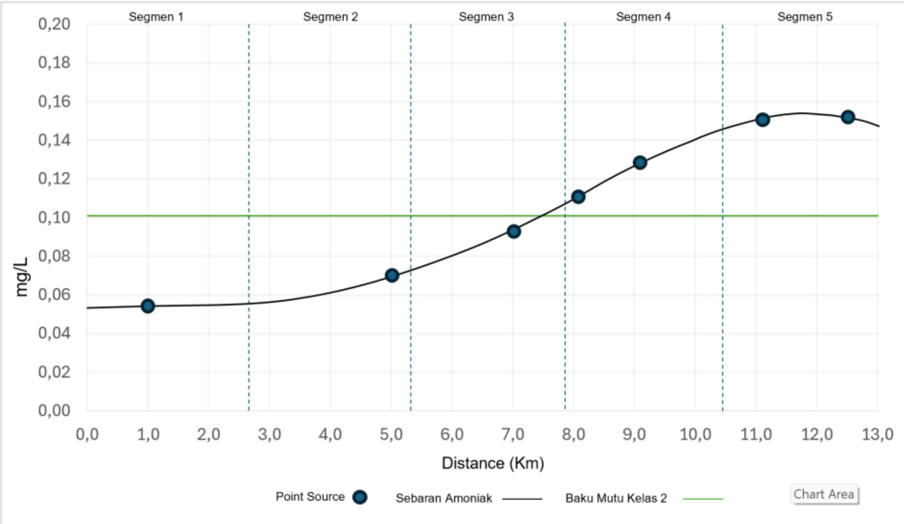


Figure 10: Rainy Season Ammonia Simulation



In Segment 1, ammonia concentrations were relatively low, slightly below 0.1 mg/L. Ammonia concentrations began to increase in Segment 2 and continued to rise gradually until they reached a peak in Segment 5 at around 0.18 mg/L. This gradual increase indicates accumulation or additional ammonia load along the river, which may have come from waste sources or activities along the stream.

The horizontal green line shows the water quality standard for Class 2, which is at 0.1 mg/L. In Segment 3 to Segment 5, the ammonia concentration exceeds this standard, indicating that the water quality is starting to fail the required standard.

The increase in ammonia concentration above the quality standard indicates a risk to the water quality to be processed by PDAM Bangkalan Regency. Excess ammonia in raw water can increase the need for additional treatment, such as oxidation or aeration, to reduce ammonia levels. If ammonia concentrations continue to increase or are not controlled, this can affect the cost and complexity of the treatment process, and potentially reduce the quality of water distributed to the community. In addition, high ammonia levels in water can be a problem for the aquatic environment, because it can cause eutrophication or reduce the quality of habitat for aquatic organisms. This increasing trend in ammonia may indicate the presence of additional pollution sources or natural degradation processes that are not sufficient to decompose ammonia along the flow. Further monitoring of pollution sources along the river and the implementation of effective waste prevention and management measures are needed to maintain the water quality of the Pocong River as a source for PDAM. Overall, this graph shows a significant increase in ammonia concentrations, especially in the downstream section, which can have a negative impact on the quality of water to be processed by PDAM. Continuous management and monitoring efforts are essential to ensure that water remains safe to be processed and distributed to the people of Bangkalan Regency.

Total Coliform Simulation

In the Total Coliform simulation, the results of field observations are similar to the simulation results at the sampling points as shown in Figures 11 and 12.

Figure 11: Dry Season Total Coliform Simulation

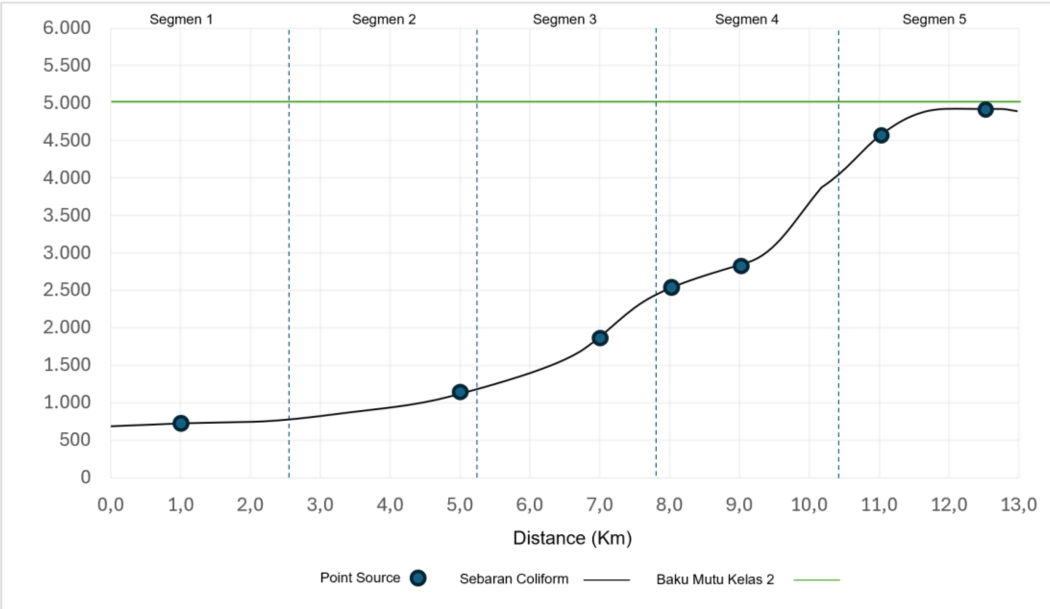
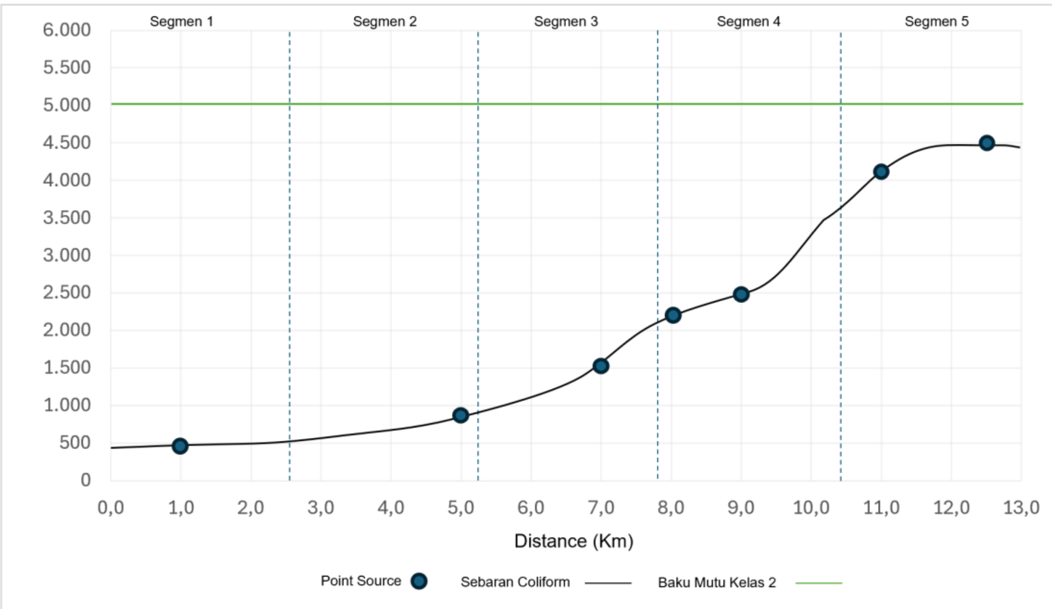


Figure 12: Rainy Season Total Coliform Simulation



In Segment 1, the coliform concentration is relatively low, around 1000 per 100 ml. The coliform concentration starts to increase in Segment 2 and continues to rise significantly to more than 5000 per 100 ml in Segment 5. This increasing trend indicates the accumulation of coliform bacteria along the river, which may originate from domestic waste, animal waste, or wastewater discharge without sufficient treatment.

The horizontal green line indicates the water quality standard for Class 2 water quality, which is around 5000 per 100 ml. In Segment 5, coliform concentrations are close to or slightly above this standard, indicating a potential for water quality degradation that could impact human health if used without adequate treatment.

Increased coliform concentrations above the quality standard limit indicate a health risk if the water is used without intensive treatment. Excess coliform requires a more thorough disinfection process, such as chlorination or additional filtration, to ensure the water is safe for consumption. If coliform concentrations continue to increase or are not controlled, the cost and complexity of water treatment by PDAM will increase, and can increase health risks for consumers if the treatment process is not optimal. In addition, high coliform levels can affect river ecosystems, reduce water quality, and endanger aquatic organisms that live in them.

This significant trend of increasing coliform indicates the presence of biological pollution sources that need to be addressed, especially in areas closer to the downstream. Monitoring and management of domestic waste around the river is essential to reduce this biological contamination. Environmental improvement and waste management efforts, such as the construction of waste treatment plants and supervision of wastewater discharge, are essential to maintain the quality of the Pocong River as a source of clean water.

Overall, this graph shows a significant increase in coliform concentrations along the Pocong River, which can affect the quality of water used by PDAM Bangkalan Regency. Pollution control efforts and improving the treatment process are essential to ensure water is safe for public consumption.

6. Conclusion

Water quality modeling of the Pocong River shows that the upstream part generally meets class I quality standards, while the downstream part drops to class II due to increased human activities such as domestic waste disposal and runoff from agricultural areas. Analysis of water quality based on existing conditions in two seasons shows significant fluctuations, where the rainy season (west season) tends to dilute pollutants such as BOD and COD but increases TSS due to runoff, while the dry season (east season) worsens pollutant concentrations due to low water discharge, especially in the downstream segment. Overall, water quality in the downstream part often exceeds quality standards, especially in the dry season, so better waste management, season-based mitigation, and regular water quality monitoring are needed to maintain the sustainability of the Pocong River as an important resource for the community.

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