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Distribution of Water Quality Parameters Using Equation Multiple Linear Regression

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ABSTRACT

Mayang River in Jember Regency has a strategic role in fulfilling people's lives and is a source of water for 79 irrigation areas with a total area of 16,471 hectares. Community use of the Mayang River has the potential to provide input of organic material from waste which can reduce river water quality. The aim of this research is to analyze the spatial distribution of water quality parameters, namely TSS, TDS, pH, DO and BOD. This research uses multiple linear regression techniques to determine the value of the distribution or spatial distribution of Mayang River pollution, as well as identifying water quality variables that are correlated in each region. The research results show that water quality parameters that have a strong correlation are pH (r = 0.74), DO (r = 0.72) and TSS (r = 0.65), moderate correlation with BOD parameters (r = 0.48) and low correlation with BOD parameters. TDS parameters (r = 0.25). Based on the analysis results, it is known that water quality parameters are correlated with different activities in each region. The results of this research can be used as a strategy for monitoring water quality in the Mayang River to control the impact of human activities in the surrounding area.

1. INTRODUCTION

Mayang River flows for 145.5 km in Jember Regency, making it one of the longest rivers in the region providing water source for 79 irrigation areas with a total area of 16,471 ha (Jatmiko & Andriyani, 2023). Therefore, the water quality of the Mayang River is crucial agricultural productivity and river use by the community. Society in The Mayang River stretches from Mayang District to Mumbulsari District utilize its water resources for various purposes. The variety Community activities around the Mayang River can cause waste, including domestic, agricultural and livestock waste, which if disposed of inside River bodies can reduce water quality (Wahyuningsih *et al*., 2021).

The decline in river water quality can be seen from the water quality parameters. The water quality conditions of the Mayang River do not meet the class II water quality criteria for the TSS parameter with a value of 76 mg/L (Dinas Lingkungan Hidup Kabupaten Jember, 2018). Then in 2020, water quality measurements were carried out at several sample points, showing that the quality standard was classified as class III in several locations. This increases the potential threat to the agricultural sector which depends on river water for irrigation and as a source of raw water for Water Treatment Plants (IPA) for PDAM in the Wirolegi area. IPA quality standards are classified as class I water quality standards according to Government Regulation No. 22 of 2021 (PP RI No. 22 2021), so that if a river exceeds the quality standards then it cannot be used as raw material for drinking water.

Water quality determines the suitability and suitability of water for certain uses (Mutoffar & Fadillah, 2022). In determining the condition of river water quality, monitoring can be done through water quality measurements. Measurements of the water quality of the Mayang River were carried out at 12 points in 2020. However, these sampling points were deemed not to adequately represent the characteristics outside the sampling points. Therefore, it is necessary to identify water quality characteristics that are visualized throughout the water area. Visualization of the water quality in question can be done using the spatial water quality assessment method.

Spatial water quality assessment of pollutant sources can provide information in identifying and predicting the water quality of a body of water (Kovačič & Ravbar, 2013). An important approach to controlling the quality of water resources is to develop effective models for predicting water quality. This research uses spatial analysis of multiple linear regression equations, to analyze the relationship between various water quality parameters and the factors that influence them.

Based on the study above, the aim of this research is to present a model of the spatial distribution of water quality parameters and their relationship with activities around the Mayang River flow. The spatial distribution of water quality is useful as a water quality monitoring process to prevent or control further impacts from human activities around the Mayang River flow.

2. MATERIALS AND METHODS

Research location is on the Mayang River section from Mayang District to Mumbulsari District, Jember Regency. The Mayang River in this section is the middle river, which has an important role in meeting irrigation water needs located in the downstream part of the river and as a location for raw water intake for PDAM intake in the Wirolegi area. The research location is presented in Figure 1.

2.1. Material

Data used in the research is secondary data from 2020. This data includes water quality samples and potential sources of pollution. The water quality parameters measured include the parameters Total Suspended Solid (TSS), Total Dissolved Solid (TDS), Potential of Hydrogen (pH), Dissolved Oxygen (DO), and Biochemical Oxygen Demand (BOD). Potential sources of pollution include the coordinates of settlements, livestock, sand mines and rice fields.

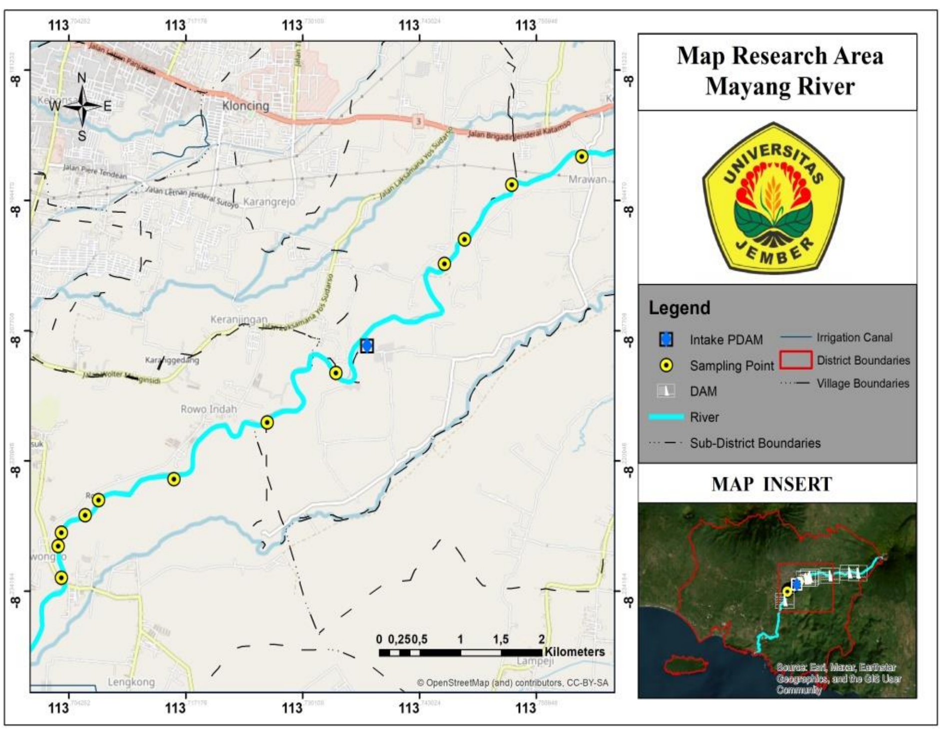


Figure 1. Location of Mayang river

2.2. Methods

Method used in the research is to use multiple linear regression techniques to predict the distribution of water quality. The analysis method used begins with identifying river water quality; the second stage is building a multiple linear regression equation model; third, namely identifying the validity of the distribution of river water quality parameters.

2.3. Determining the Research Location

The research location was chosen based on secondary data analysis, where water quality measurement samples were taken from 12 predetermined points. The sample points were determined because each point has different potential.

2.4. Secondary Data Inventory

Secondary data inventory was carried out to collect data obtained from previous research. The data used in the research is secondary data from 2020. This data includes water quality sampling points which include the parameters pH, TSS, TDS, DO, and BOD, as well as potential pollutant source points.

2.5. Euclidean Distance

The stages of determining distance using Euclidean Distance were analyzed using ArcMap 10.3, aiming to visualize the proximity of potential sources of pollution within a distance of the research area in raster format. The sources of pollution in question include proximity to settlements, sand mines, livestock and rice fields in the research area. The stages in this analysis begin by inputting the coordinates of the pollutant source point, then calculating the distance using the Euclidean Distance tool to produce a visualization of potential pollutant sources. The Euclidean Distance calculation is presented in Equation 1.

$$ED = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (1)$$

where *ED* is Euclidean distance, x_1 is latitude coordinates 1, x_2 is latitude coordinates 2, y_1 is longitude coordinates 1, and y_2 is longitude coordinates 2.

2.6. Determining Distance to Sampling Points

Distance determination in the analysis uses the Extract Multi Values to Points tool. The Extract Multi Values to Points process begins by inputting the sampling points as input point features and the Euclidean Distance raster from sources of pollutants such as settlements, farms, sand mines, and rice fields as input rasters. This process yields distance values in meters stored in the attribute table of the layer.

2.7. Multiple Linear Regression Analysis

Multiple linear regression analysis is conducted to compute the linear regression resulting from combinations of independent variables used in the model to predict the dependent variable (Fernandes *et al*., 2023). The independent variables are derived from the distance values to potential pollutant sources from sampling points generated by the Extract Multi Values to Points process, while the dependent variable is obtained from water quality parameter values. The calculation of multiple linear regression is presented in Equation 2.

$$Y = a + b_1 X_1 + b_2 X_2 + ... + b_n X_n \quad (2)$$

where Y is dependent variable, X_1, X_2, … X_n are independent variable, a is constant, b_1, b_2, … b_n are regression coefficients

2.8. Validity of Water Quality Prediction

Validity of multiple linear regression is determined by examining the value of R-Squared. According to Paramita *et al*., (2024), the coefficient of determination, or R-squared, is a value indicating the extent to which independent variables relate to the dependent variable. The calculation of the coefficient of determination is performed using the regression statistics feature in the Analysis ToolPak in Microsoft Excel 2010.

2.9. Distribution Model Water Quality Parameters

Spatial distribution of water quality parameters is analyzed based on equations derived from multiple linear regression calculations using the raster calculator tool in ArcMap 10.3 software. Spatial distribution shows predicted values computed from the values at each sampling point to predict values in unsampled areas.

3. RESULTS AND DISCUSSION

Mayang River, which is the research area, flows through the Mayang, Sumbersari, Ajung and Mumbulsari sub-districts. Potential sources of pollution in the research area consist of settlements, sand mines, livestock and rice fields. Land use activities in the research area have the potential to contribute sources of pollutant discharge into rivers. River utilization based on land use in the study area is presented in Figure 2.

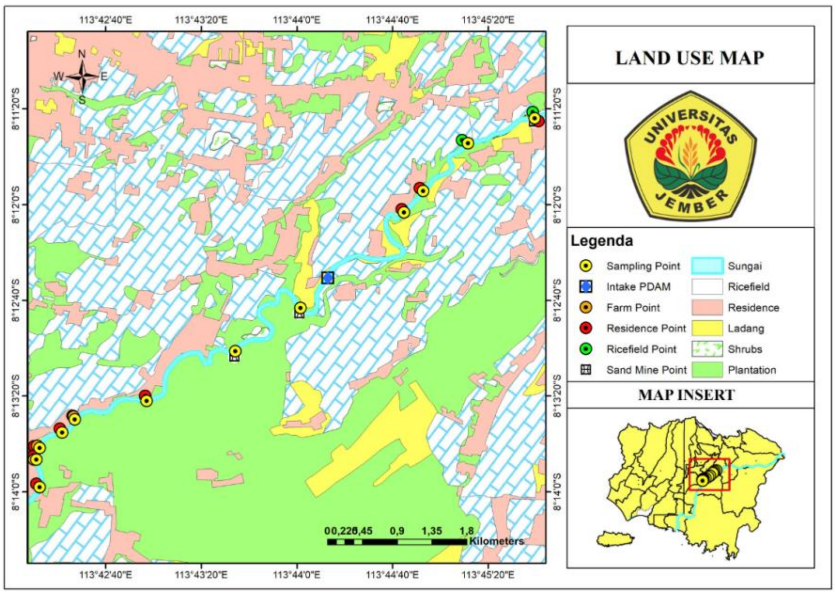


Figure 2. Map of land use

Residence | Cattle Farm | Sand Mine | Cornfield

Figure 3. Potential pollutants

The concentration of pollutants entering the river can disrupt the life of organisms in the water and reduce water quality. Sources of pollution in the research area based on the characteristics of the waste produced consist of domestic and non-domestic waste. According to Aprilia *et al*. (2023), domestic waste sources generally come from residential areas and non- domestic waste sources come from agricultural and livestock activities, so that pollutant sources for the Mayang River in this section include waste from residential and livestock areas, sand mining activities, as well as pollutants from agriculture such as residue from the use of fertilizers and pesticides. Examples of pollutant sources in the research area are presented in Figure 3.

3.1. Mayang River Water Quality

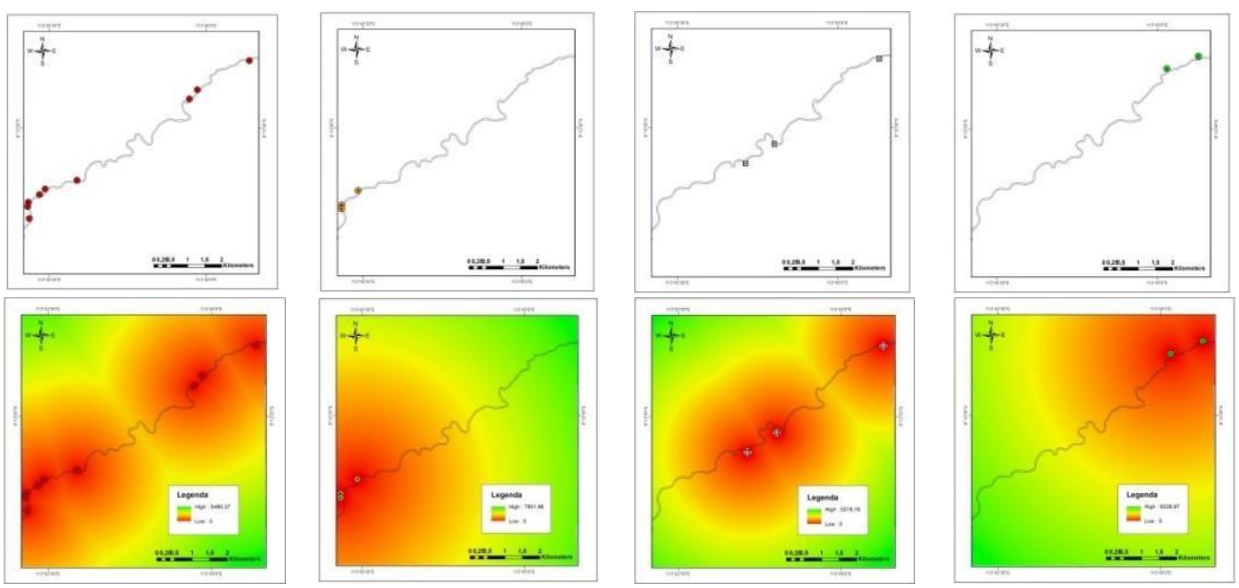
Data on the water quality of the Mayang River for the section from Mayang District to Mumbulsari District at 12 sampling points is presented in Table 1. Based on five (5) parameters measured at 12 sample points, the water quality of the Mayang River exceeds the class II quality standard criteria for the TSS parameter which is at the point M.10 and M.12. Meanwhile, the other four (4) parameters, namely TDS, pH, DO and BOD, are still classified as class I quality standards according to Government Regulation Number. 22 (2021).

Table 1. Mayang river water quality

Points	Water Quality Parameters				
	TSS (mg/L)	TDS (mg/L)	pH	DO (mg/L)	BOD (mg/L)
M.1	35.48	204.00	8.13	7.86	0.59
M.2	31.33	231.41	8.32	7.89	0.64
M.3	36.33	198.08	8.24	7.79	0.62
M.4	38.37	211.41	8.23	7.64	0.52
M.5	29.29	181.41	8.07	7.61	1.08
M.6	43.08	220.74	7.87	7.08	1.86
M.7	34.41	196.22	7.97	7.40	1.50
M.8	44.98	261.26	7.59	7.40	0.57
M.9	48.06	252.37	7.93	7.35	0.58
M.10	74.54	228.08	7.99	7.22	0.61
M.11	36.15	205.11	7.97	7.50	1.47
M.12	105.92	202.74	7.87	7.10	0.80

3.2. Euclidean Distance Model of Pollution

Sources Distance calculations using Euclidean Distance tools produce raster maps as shown in Figure 4. Euclidean distance is used to measure distances in raster or vector format, expressed in cell size (Yunanto & Susetyo, 2019). The potential pollutant sources closest to river areas have a significant impact, evident from the red-colored river areas, whereas the lowest impact is indicated by green color. According to (Padillah & Firman, 2024), the proximity factor between clean water sources and pollution sources, if the distance is less than 10 meters, will lead to rapid pollution potential caused by these pollutants.



(a) (b) (c) (d)

Figure 4. Euclidean Distance Model: (a) Residence, (b) Farm, (c) Sand Mine, (d) Ricefield

3.3. Distance of Pollutant Sources to Sampling

Points Calculation of distances between potential pollutant sources and sampling points aims to assess the likelihood of pollution affecting the sampling points. The distance calculation results are presented in Table 2.

Table 2. Distance of potential pollutant sources to the sampling point

Point Sampling	Residence (m)	Farm (m)	Sand Mine (m)	Ricefield (m)
M.1	61.7746	7043.0600	27.6264	82.8793
M.2	840.2250	6160.8800	899.8760	61.7746
M.3	39.0697	5341.6300	1686.8000	824.1760
M.4	27.6264	4984.4100	1855.9100	1195.6200
M.5	1817.6800	3237.8400	82.8793	2988.8900
M.6	1297.2700	2257.2700	87.3624	3969.4700
M.7	55.2529	958.9990	1260.2600	5263.8300
M.8	39.0697	39.0697	2185.8100	6124.4100
M.9	39.0697	237.6520	2401.4300	6355.5800
M.10	82.8793	61.7746	2732.2200	6692.7800
M.11	78.1393	27.6264	2854.0900	6834.9600
M.12	61.7746	363.3690	3011.2800	7032.7600

3.4. Multiple Linear Regression Analysis

Multiple linear regression analysis aims to determine the extent of influence of independent variables on dependent variables (Sari *et al*., 2022). Potential pollutant sources in the study area tend to impact the water quality of the Mayang River. The results of the multiple linear regression analysis yield an equation, presented in Table 3. This equation represents the distribution of predicted water quality values along the Mayang River, spanning from the Mayang District to the Mumbulsari District, used to determine the distribution of water quality parameters. The results of the multiple linear regression analysis indicate that water quality parameters have a significant impact on the prediction values. The magnitude of the R-Squared value indicates that the regression equation effectively explains the variation in the dependent variable with respect to the independent variables (Faagna *et al*., 2024).

3.5. Total Suspended Solid (TSS)

Spatial Distribution of TSS Parameters in Figure 5.a shows a range of TSS concentrations, with the lowest value recorded at 30.6111 mg/L and the highest at 123.415 mg/L. The TSS distribution model at 12 sampling points indicates that TSS values at points M.2 to M.7 meet the requirements for drinking water source materials (government regulation number 22, 2021). The TSS distribution results demonstrate correlation between predicted values and measurements for the TSS model. Independent variables model the TSS distribution with an R^2 value of 0.65 in Table 3.

Table 3. Multiple linear regression equations

Parameters	Multiple Linear Regression Equations (Y = a + bx1 + bx2 + bx3 + bx4)	R^2
TSS	Y = -155.38340 + ("ED_Residence.tif" * 0.009111) + ("ED_Farm.tif" * 0.02729) + ("ED_ SandMine.tif" * 0.01034) + ("ED_ Ricefield.tif" * 0.02832)	0.65
TDS	Y = 349.01258 - ("ED_ Residence.tif" * 0.01218) - ("ED_ Farm.tif" * 0.02141) + ("ED_ SandMine.tif" * 0.00078) - ("ED_ Ricefield.tif" * 0.01883)	0.25
pH	Y = 7.70202 + ("ED_ Residence.tif" * 0.00010) + ("ED_ Farm.tif" * 0.00006) + ("ED_ SandMine.tif" * 0.00012) - ("ED_ Ricefield.tif" * 0.00002)	0.74
DO	Y = 7.92472 - ("ED_ Residence.tif" * 0.00004) - ("ED_ Farm.tif" * 0.00002) + ("ED_ SandMine.tif" * 0.00005) - ("ED_ Ricefield.tif" * 0.00012)	0.73
BOD	Y = 1.47276 + ("ED_ Residence.tif" * 0.00007) - ("ED_ Farm.tif" * 0.00010) – ("ED_ SandMine.tif" * 0.00031) + ("ED_ Ricefield.tif" * 0.00004)	0.48

TSS is a key parameter in determining water quality degradation. TSS concentration indicates the amount of suspended solid particles in water, including various solid particles dissolved in wastewater such as soil, fibers, and other organic materials, which can affect sunlight penetration into the water (Hermansyah *et al*., 2024).

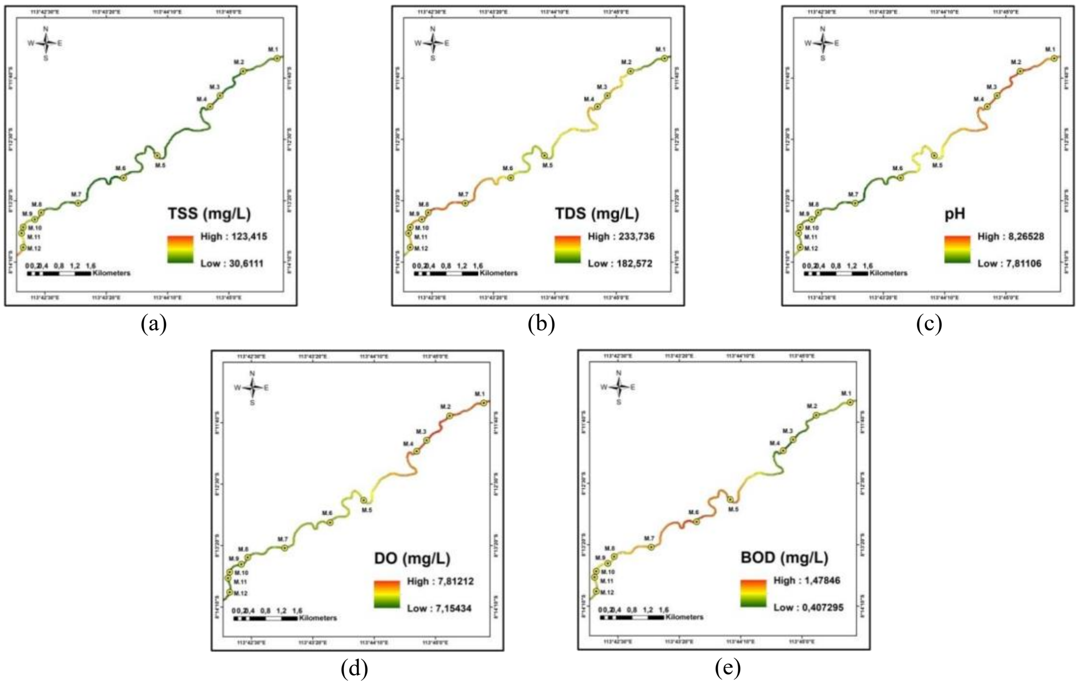


Figure 5. Spatial distribution water quality parameters: (a) TSS, (b) TDS, (c) pH, (d) DO, (e) BOD

Table 4. Mayang river water quality prediction

Points	Water Quality Parameters				
	TSS (mg/L)	TDS (mg/L)	pH	DO (mg/L)	BOD (mg/L)
M.1	34.59	195.11	8.13	7.77	0.76
M.2	33.28	205.28	8.26	7.80	0.63
M.3	39.57	219.15	8.21	7.80	0.45
M.4	43.79	220.08	8.20	7.27	0.44
M.5	35.2	200.54	8.03	7.43	1.22
M.6	37.15	290.43	7.90	7.35	1.46
M.7	46.68	228.96	7.81	7.33	1.19
M.8	53.73	233.02	7.35	7.29	1.03
M.9	58.22	225.39	7.88	7.27	0.96
M.10	63.48	222.34	7.90	7.25	0.88
M.11	65.08	220.99	7.92	7.24	1.86
M.12	69.29	210.4	7.95	7.22	0.79

The highest TSS concentrations are found at points M.9 to M.12, indicating compliance with Class III water quality standards. The high TSS concentrations in this stream are due to inputs of suspended materials originating from residential and livestock waste carried by the river flow. According to Murjani *et al*. (2024), high TSS concentrations can be influenced by waste from human activities, as there are residential areas and livestock farms located near the river. The influence of high TSS concentrations is also attributed to sand mining activities near the Mayang River, which can result in increased sediment concentrations within the river (Sinaga *et al*., 2024).

3.6. Total Dissolved Solid (TDS)

Distribution of TDS content in the spatial distribution model in Figure 5.b shows values ranging from a minimum of 182.572 mg/L to a maximum of 233.736 mg/L. The distribution of TDS parameters in the Mayang River indicates compliance with Class I water quality standards. Spatial distribution results correspond well with measurement data, still meeting Class I water quality criteria with values greater than 1000 mg/L. Table 3 shows that TDS parameters exhibit a low correlation based on variations in independent variables (R^2=0.25). TDS parameters are used to determine the total amount of dissolved solids in water, which generally consist of inorganic substances in the form of ions found in water bodies (Pandiangan *et al*., 2023).

Concentration TDS in rivers increases when they receive contaminants originating from human activities carried by the river flow. Factors influencing the TDS content in the Mayang River include nearby livestock activities and dense residential settlements. According to Pratiwi & Setiorini (2023), high TDS levels, if not properly managed, can pollute water bodies and potentially harm aquatic life.

3.7. Potential of Hydrogen (pH)

Based on Figure 5.c, the spatial distribution of TDS parameters indicates good water quality conditions, complying with Class I water quality standards. The distribution ranges from a minimum value of 182.572 mg/L to a maximum of 233.736 mg/L. Table 3 shows that the correlation of independent variables can influence the pH distribution model with an R^2 value of 0.74, indicating that potential pollutant sources have a strong correlation with the pH model. The pH content at points M.1 to M.12 meets Class I water quality standards with values ranging between pH 6 and pH 9.

pH parameter is a crucial chemical indicator for monitoring water stability. pH values in rivers decrease when they receive waste from human activities (Amru & Makkau, 2023). A-decrease in pH indicates a decline in river water quality (Novita *et al*., 2023). The decline in pH can be caused by human activities near the river that utilize river water for domestic purposes such as bathing and washing, which then flow into the river.

3.8. Dissolved Oxygen (DO)

The spatial distribution of DO in Figure 5.d shows a range of DO concentrations from 7.15434 mg/L to 7.81212 mg/L. The evaluation results of the model using the coefficient of determination (R^2) indicate a value of 0.73 (Table 3). This result suggests a strong relationship with the influence of potential pollutant sources in the study area. The distribution of DO parameters indicates compliance with Class I water quality standards, where the DO content in the Mayang River reflects good quality.

The DO distribution model at sampling points M.1 to M.12 shows relatively high values. High DO levels in water indicate good water quality (Ghozali *et al*., 2024). Dissolved oxygen (DO) content is an important chemical parameter used to analyze water pollution (Wahyuningsih *et al*., 2019). Human activities around river flows that produce waste can increase the oxidation process in rivers,

3.9. Biochemical Oxygen Demand (BOD)

The spatial distribution model of BOD is presented in Figure 5.e. The spatial distribution of BOD concentrations in the study area ranges from 0.407295 mg/L to 1.47846 mg/L. Table 3 indicates a moderate influence based on the BOD equation model with an R^2 value of 0.48. BOD levels in the study area show values of n $\geqslant$ 2 mg/L, which are classified as Class I water quality standards. This indicates that the DO concentration distribution model meets the requirements for drinking water source materials.

BOD parameter is used to determine the level of air quality from a pollution source. A high BOD value indicates low air quality, because the higher the BOD value, the more dissolved oxygen needed by microbes to decompose organic matter (Vikriansyah *et al*., 2024). BOD levels in the study area are influenced by human activities in settlements located around the river. Waste from these activities can cause an increase in organic matter levels in rivers if the activities are not controlled. High levels of organic matter cause the need for dissolved oxygen in waters to increase (Tyassari *et al*., 2024). Resulting in higher demand for dissolved oxygen (DO) (Hardina *et al*., 2024).

4. CONCLUSION

The results of the distribution of water quality parameters show that four water quality parameters (TDS, pH, DO, and BOD) meet class I quality standards, while the TSS parameter shows quality that exceeds class II quality standard criteria in the downstream part of the river. Calculation of the coefficient of determination shows that the parameters have a strong correlation with potential sources of pollution, namely TSS (R^2 = 0.65), pH (R^2 = 0.74) and DO (R^2 = 0.73). Medium correlation on BOD (R^2 = 0.48), and low correlation on TDS (R^2 = 0.25).

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