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Mathematical model distribution of some water quality parameters in the reservoir

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Abstract. Sutami Reservoir is one of the largest reservoirs in East Java Province and is very useful in the life of people in Malang. However, the water quality of Sutami reservoir currently degrades due to waste. This study aims to determine water quality using the pollution index method and mathematical modeling. Polynomial regression is the most suitable mathematical model. It was obtained by statistical testing and adjusted based on population index data. Sutami Reservoir is classified as a reservoir with a eutrophic trophic status. The load capacity in eutrophic conditions at the monitoring station revealed that the levels exceeded the maximum pollution load limit. The relevant authorities need to take action to overcome the waste problems which contribute to the degradation of water quality in Sutami reservoir.

Keywords: water quality, pollution index, mathematical model, regression

1. Introduction

The water quality (WQ) of watershed systems is affected by high anthropogenic pressures, including domestic wastewater discharges and industrial and agricultural activities [1]. The deterioration of the water environment has led to the reduction of available water resources and damaged a healthy aquatic ecosystem. The water environment system is very complicated and depends on weather, water body hydraulic characteristics, pollutant discharge, and the aquatic biological impact. Therefore, it is necessary to predict the water quality evolution process [2]. The main purpose of the water quality monitoring system is to generate sufficient and timely information to establish water quality management plans and make environmental policies [3].

Sutami Reservoir or also known as Karangkates Reservoir, is one of the largest reservoirs in East Java, built-in 1964-1973. This reservoir is located in Karangkates Village, Sumberpucung, Malang Regency. It has three main benefits: the first as a flood control reservoir for the 50-year return period, the second as a provider of irrigation water sources in the downstream area with a discharge of 24 m3/second in the dry season to serve 34,000 Ha. The last one is a hydropower plant with 488 million kWh/year [4]. In addition, this reservoir is used as a tourist attraction and freshwater fisheries.

The Sutami Reservoir gets its water source from the Brantas River. The current condition of the Brantas River has decreased the quantity and quality of its water. In the upstream area of the Brantas River, there is environmental damage and the conversion of protected forest functions into agricultural, industrial, and other building areas. It causes the river water quality to decrease due to pesticides and chemical fertilizers. In addition to the consequences of agriculture, the increase in water pollution is also caused by domestic waste and industrial waste disposal. According to the President Director of Perum Jasa Tirta I, around 60% of the waste that pollutes the Brantas River comes from household waste. The rest comes from industrial waste and toxic and hazardous materials. Under these conditions, the reservoir water will be polluted by these wastes, namely organic agricultural waste, domestic and industrial waste, and other toxic or hazardous materials. It can worsen the condition of the reservoir water in the Sutami Reservoir because this reservoir gets its water supply from the Brantas River [5]. Due to the increasing pollution of the Sutami Reservoir, it is necessary to determine the water quality status and the pollution load capacity.

A water quality model is the mathematical representation of pollutant fate and transport within a water body that may be coupled with a mathematical expression of the movement of pollutants from land movement from land-based sources to a water body [6]. Process-based hydrodynamic and water quality models have been widely applied for simulating and predicting temperature dynamics and constituent transport in surface water bodies such as lakes, rivers, and estuaries [7], [8], [9], [10], [11], [12], [13]. The linear regression analyses are used for the water quality parameters. They measure higher and better levels of significance in their correlation coefficient. The systematic calculation of regression analysis provides indirect means for the fast monitoring of water quality [14]. This study aimed to determine water quality, water quality status, and mathematical modelling (regression analysis) of water quality status in Sutami Reservoir.

2. Material and Methods

2.1. Study location

Sutami Reservoir is located in Karangkates Village, Sumber Pucung District, Malang Regency (Figure 1). The water quality monitoring is carried out by Perum Jasa Tirta I. The water quality monitoring stations in the Sutami Reservoir are divided into 3, namely the Upstream Sutami Reservoir Monitoring Station, the Middle Sutami Reservoir Monitoring Station, and the Downstream Sutami Reservoir Monitoring Station. The Upstream Sutami Reservoir Monitoring Station is divided into two depths, namely Depth I (0.3 m) and Depth II (4 m). The Middle Sutami Reservoir Monitoring Station is divided into three depths, namely Depth I (0.3 m), Depth II (5 m), and Depth III (10 m). At the Downstream Sutami Reservoir Monitoring Station, it is divided into three depths, namely Depth I (0.3 m), Depth II (5 m), and Depth III (10 m) (Figure 2).

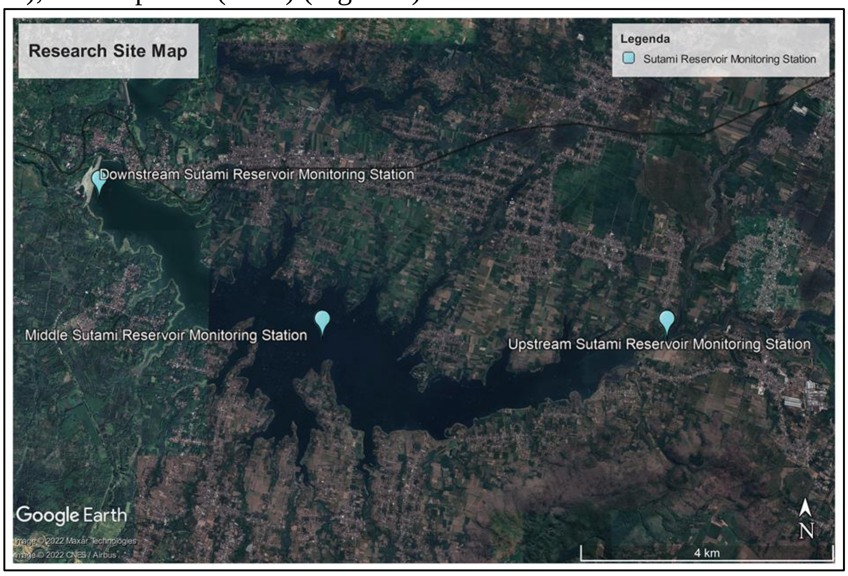


Figure 1. Research site map

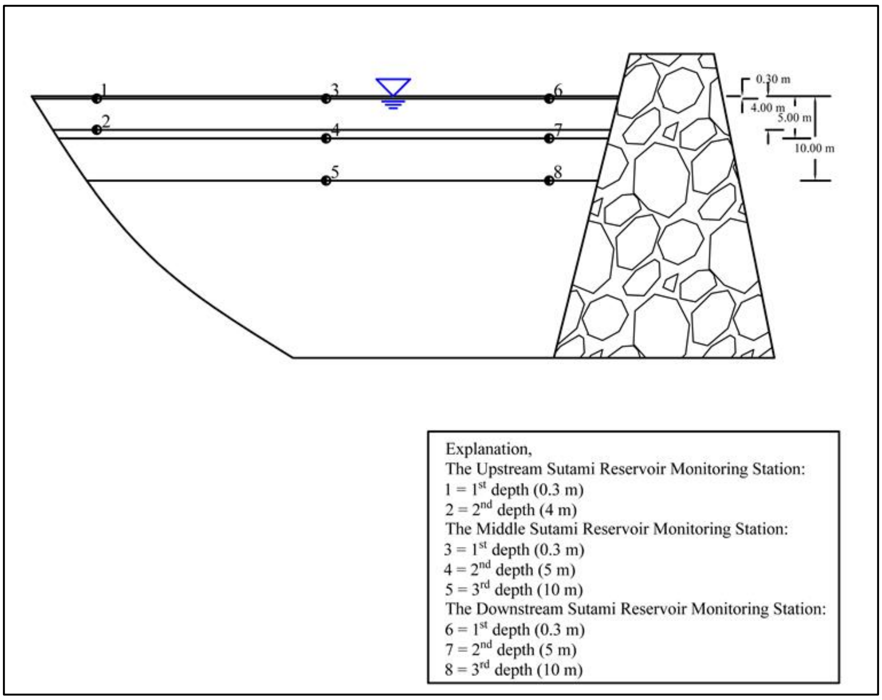


Figure 2. Details of the depth of the Sutami Reservoir Monitoring Station

2.2. Data Collection

Field data are essential for models to predict assumed scenarios or future events [15]. This study uses secondary data. The data collection used in this study to obtain a mathematical model of the water quality status of the Sutami Reservoir is as follows:

1. Rainfall data around the Sutami Reservoir consisting of St. Kalipare, St. Geophysics, St. Sumberpucung, St. Kepanjen, St. Ngajum, St. Karangsuko, and St. Gondanglegi in 2010-2019.
2. Data on water quality BOD, COD, DO, NH3-N, TSS, and pH in the Upper Sutami Reservoir at Depth I (0.3 m) and Depth II (4 m) in 2015-2019.
3. Data on water quality BOD, COD, DO, NH3-N, TSS, and pH in the Middle Sutami Reservoir at Depth I (0.3 m), Depth II (5 m), and Depth III (10 m) in 2015-2019.
4. Data on water quality BOD, COD, DO, NH3-N, TSS, and pH in the Sutami Downstream Reservoir at Depth I (0.3 m), Depth II (5 m), and Depth III (10 m) in 2015-2019.

2.3. Work steps

In general and concise, the steps in this research are as follows:

a. Collecting rainfall data at rainfall stations around the Sutami Reservoir consisting of St. Kalipare, St. Geophysics, St. Sumberpucung, St. Kepanjen, St. Ngajum, St. Karangsuko, and St. Gondanglegi to determine the average rainfall area using the arithmetic mean method. The average or arithmetic method is very simple in determining the average rainfall in a certain area [16].
b. Determine the dry season in the area around the Sutami Reservoir. In determining the dry season, using the BMKG rules, the dry year is the amount of rainfall less than 85% of the average rainfall observed [17].
c. Collecting water quality data in the Sutami Reservoir at each water quality monitoring station.
d. Grouping the water quality data in the Sutami Reservoir at each water quality monitoring station for the dry season.

e. Conduct a data homogeneity test at each water quality monitoring station using the F test. The amount of F is in the form of a ratio (ratio). Fcr values can be obtained from table F for various values of Level of Significance (α) [18].
f. Analyzing water quality at each water quality monitoring station using the Pollution Index Method [19].
g. Determine the water quality status at each monitoring station according to water quality standards [20].
h. Determining water quality modeling at each monitoring station according to linear regression models, exponential regression models, logarithmic regression models, polynomial regression models, and multiple regression models [21].

2.4. The formulas used in this article

a. Trend test with Mann-Whitney test
The following is the correlation coefficient formula using the Mann and Whitney method:
Statistical parameter value calculation formula:

$$U_1 = N_1 \times N_2 + \left(\frac{N_1}{N_2}\right) \times (N_1 + 1) - R_m \quad (1)$$

$$U_2 = N_1 \times N_2 - U_1 \quad (2)$$

$$Z = \frac{\frac{U-(N_1 N_2)}{2}}{\left(\frac{1}{12}\{N_1 N_2 (N_1+N_2+1)\}\right)^{\frac{1}{12}}} \quad (3)$$

b. Variant stability test
The following is the formula for the variance stability test (F-Test):

$$F = \frac{N_1.{S_1}^2(N_2-1)}{N_2.{S_2}^2(N_1-1)} \quad (4)$$

c. Stationer test
The following is the formula for the stability test of the average value (T-Test):

$$\sigma = \left(\frac{N_1.{S_1}^2+N_2.{S_2}^2}{N_1+N_2-2}\right)^{\frac{1}{2}} \quad (5)$$

$$t = \frac{\overline{X_1}-\overline{X_2}}{\sigma\left(\frac{1}{N_1}+\frac{1}{N_2}\right)^{\frac{1}{2}}} \quad (6)$$

d. Fisher's test
In this study, the analysis of variance used the F test (Fisher's test)

$$F = \frac{(n-k).\sum_{i=1}^{k} n_1 (\overline{X\iota}-\bar{X})^2}{(n-k).\sum_{i=1}^{k}\sum_{j=1}^{j=nj}(\overline{X\jmath\iota}-\bar{X})^2} \quad (7)$$

Where;

U_1, U_2	=	Statistical parameter for each group
Rm	=	Maximum rating total value
N_1, N_2	=	Total data for each group
Z	=	Test coefficient
S_1, S_2	=	standard deviation of group 1 data, the standard deviation of group data 2
F	=	F test count value
t	=	t test count value
$\overline{X_1, X_2,}$	=	the average value of group 1 data, the average value of group 2 data

3. Result and Discussion

3.1. *Hydrological Test and Determination of Seasonal Division*

3.1.1. Double Mass Curve Consistency Test

To test the consistency of the data, one of them can use multiple mass curve analysis. This multiple mass curve analysis is for annual rainfall data from an area. Multiple mass curves are one of the graphical methods for testing the consistency and similarity of hydrological data types from a rainfall station [21]. In the consistency test, it is illustrated on line 45 on the scatter diagram. Determine if there is a change in the slope of the scatter diagram. Suppose the graph shows a point with a change in slope. In that case, it is necessary to correct the recording of rain data using a correction factor. The double mass curve test results show that the maximum annual daily rainfall for the seven stations is 1354 mm – 3785 mm, with an average of 2198. The following are the analysis results using the Multiple Mass Curve Test (Table 1).

Table 1. Hydrological analysis with double mass curve test

Year	Annual rainfall Data (mm)						
	St. Kalipare	St. Geofisika	St. Sumberpucung	St. Kepanjen	St. Ngajum	St. Karangsuko	St. Gondanglegi
2010	3017	3238	3049	3228	3265	3214	3225
2011	1621	1680	1551	1673	1716	1602	1572
2012	2117	2139	1983	2084	2145	2009	2052
2013	2599	2470	2677	2749	2742	2645	2550
2014	1543	1973	1681	1549	1625	1560	1354
2015	1879	1731	1972	1972	2041	1991	2031
2016	3092	3785	3231	3319	3272	3239	3323
2017	2627	2066	2356	2290	2345	2244	2240
2018	1514	1397	1613	1720	1598	1544	1671
2019	1677	1685	1809	1719	1697	1640	1646

3.1.2. Absence of Trend Test with Mann-Whitney Test

The Mann-Whitney correlation test tests two data groups to determine whether the data come from the same population. By using equation (1-3), it was found that the value of Z count. Based on the table of tc values for normal distribution [21], for a 5% confidence degree, the value of Zc = -1.96 is obtained because Z count < Z table. Therefore, the results obtained that the hypothesis was accepted. The measurement station data was data that came from the same population. Thus the rain station data comes from the same population (Table 2).

3.1.3. Stationer Test with Variant Stability Test

A stationary test is used to test the stability of the variance and the average of hydrological data. From the test results, it will be known whether the value of the data variance is homogeneous or not. At the degrees of freedom dk1 = n1 – 1 = 4 and dk2 = n2 – 1 = 4 and the degree of confidence is 5%, the f table is 6.39. Using equation (4), the calculated F value is smaller than the F table value = 6.39. Then the hypothesis is accepted (Table 3).

Table 2. Hydrological analysis with the Mann-Whitney Test

Mann Whitney Test	Rainfall Station						
	Kalipare	Geofisika	Sumber pucung	Kepanjen	Ngajum	Karangsuko	Gondanglegi
Rm	29	34	31	28	32	28	29
U_1	11	6	9	12	8	12	11
U_2	14	19	16	13	17	13	14
Z count	-0.31	-1.36	-0.73	-0.10	-0.94	-0.10	-0.31
Z table	1.96	1.96	1.96	1.96	1.96	1.96	1.96
Result	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted

Table 3 shows that the rain data at seven rain stations around the Sutami Reservoir are accepted, meaning the variance value is stable or homogeneous.

Table 3. Hydrological analysis with Variant Stability Test (F Test)

F Test	Rainfall Station						
	Kalipare	Geofisika	Sumberpucung	Kepanjen	Ngajum	Karangsuko	Gondanglegi
$n_1.S_1(n_2-1)$	4306664	9144898	8183346	13743466	10860026	12459010	15008674
$n_2.S_2(n_1-1)$	15548514	9878444	7332564	11037090	8480386	9272980	11732524
F count	0.28	0.93	1.12	1.25	1.28	1.34	1.28
F table	6.39	6.39	6.39	6.39	6.39	6.39	6.39
Result	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted

3.1.4. Stationer Test with Stability Test Average Value

By using equation (5-6), the results obtained for the degrees of freedom dk = N1 + N2 -2 = 5 + 5 – 2 = 8, and the degree of confidence 0.025 in the two-way test, the t-table value = 2.31. The value of t count is smaller than the t table value = 2.31. Then the hypothesis is accepted. It is found that the rainfall data at seven rain stations around the Sutami Reservoir are all accepted, which means the variance value is stable or homogeneous. (Table 4).

Table 4. Hydrological analysis with Average Value Stability Test (T-Test)

T-test	Rainfall Station						
	Kalipare	Geofisika	Sumberpucung	Kepanjen	Ngajum	Karangsuko	Gondanglegi
α	787.70	771.02	696.33	880.00	777.42	824.09	914.15
t	-0.16	0.86	-0.45	0.12	0.56	0.15	-0.40
t Table 5%	2.31	2.31	2.31	2.31	2.31	2.31	2.31
Result	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted

3.1.5. Determination of Season

Determination of the dry and wet seasons is based on the regional average rainfall, which is calculated using the arithmetic mean method. According to BMKG, the wet (W) year is the rainfall greater than 115% of the observed average. The dry year (D) is less than 85% of the observed average rainfall [17]. The following is the result of determining the distribution of seasons in the Sutami Reservoir area (Table 5).

Table 5. The analysis of the Seasons Determination

Year	Month/Rainfall (%)												Annual Rainfall
	Jan	Feb	March	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2010	86	105	101	122	75	65	48	34	107	87	147	66	87
2011	71	65	46	89	40	7	0	0	0	25	87	106	45
2012	114	99	111	70	50	3	3	0	0	20	59	150	57
2013	117	145	88	64	92	90	2	0	0	24	90	179	75
2014	98	58	67	52	41	44	1	0	0	0	73	156	50
2015	102	127	102	167	52	5	0	0	0	0	57	108	60
2016	114	164	101	117	92	75	36	26	95	114	154	105	99
2017	173	119	137	155	44	29	50	1	14	51	153	112	87
2018	137	150	127	75	27	58	9	0	18	2	126	126	71
2019	151	123	159	93	58	1	0	0	0	0	29	115	61
Average	116	116	104	100	57	37	17	6	24	32	97	122	
Result	W	W	W	W	D	D	D	D	D	D	W	W	

The calculation above shows that November – April is the wet month, and June–October is a dry month. This dry month determines water quality status because the research only focuses on the dry.

3.2. Water Quality Analysis

The quality of the reservoir water flow regime or the level of water pollution is defined by several physical, chemical, and biological-microbiological materials and various other unique indicators [22].

3.2.1. Water Quality Test

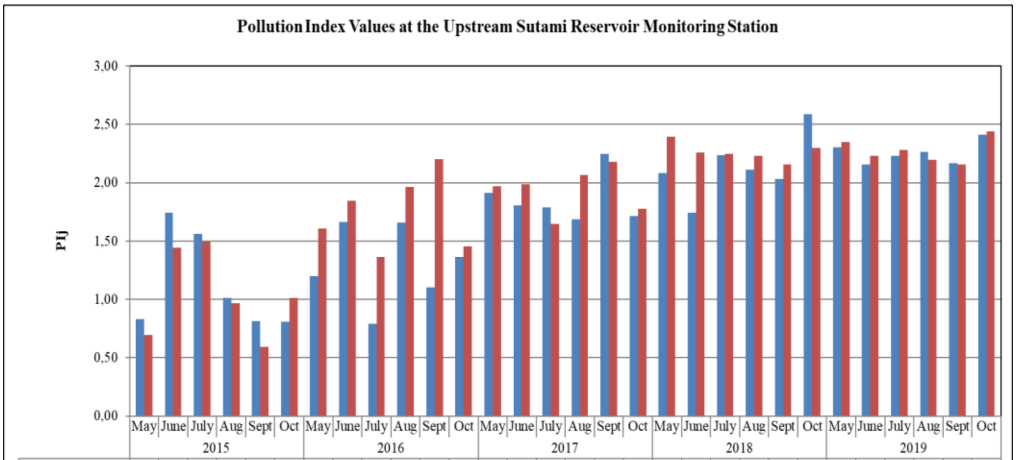
Testing of water quality data is carried out by testing the homogeneity of the data or commonly called analysis of variance. The homogeneity test of this data is necessary before determining the water quality status. The homogeneity test of this data is used to determine the uniformity of the data because it was taken from several points for six years, from 2015 to 2020. In this study, the analysis of variance used the F test (Fisher's test). Table 6 is an example of an F test that has been carried out at several depths. Because F count < F table, the data is homogeneous. The same is found in all ranges of years of observation and depth.

Table 6. Analysis of water quality Homogeneity Test Variance (F Test)

Monitoring Station	Parameter	F_{count}	F_{table}	Summary
Sutami Reservoir Depth I (0,3 m)	BOD	0.438	19.43	Homogenous
	COD	0.474	19.43	Homogenous
	DO	0.058	19.43	Homogenous
	NH_3-N	0.078	19.43	Homogenous
	TSS	2.932	19.43	Homogenous
	pH	0.574	19.43	Homogenous

3.2.2. Determination of Water Quality Status by Pollution Index Method

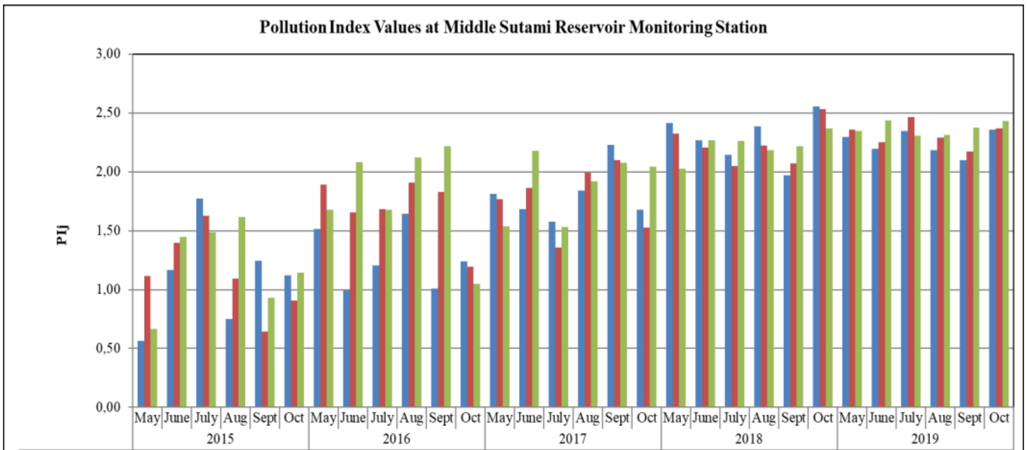
The analysis of determining the water quality status is carried out monthly with a class II water quality class. According to the Pollution Index method, the water quality index value of the Sutami Reservoir for the Upstream-Middle-Downstream Sutami Reservoir Monitoring Station from 2015 to 2019 are as follows (Figure 3-5).



	May	June	July	Aug	Sept	Oct	May	June	July	Aug	Sept	Oct	May	June	July	Aug	Sept	Oct	May	June	July	Aug	Sept	Oct	May	June	July	Aug	Sept	Oct
	2015						2016						2017						2018						2019					
1st depth (0.3 m)	0,83	1,74	1,56	1,01	0,81	0,81	1,20	1,66	0,79	1,66	1,10	1,36	1,91	1,80	1,79	1,68	2,25	1,71	2,08	1,74	2,24	2,11	2,03	2,59	2,30	2,16	2,23	2,26	2,17	2,41
2nd depth (4 m)	0,69	1,44	1,49	0,97	0,59	1,01	1,61	1,84	1,37	1,96	2,20	1,46	1,97	1,99	1,65	2,06	2,18	1,78	2,39	2,26	2,25	2,23	2,15	2,30	2,35	2,23	2,28	2,20	2,16	2,44

Figure 3. Pollution index values at the Upstream Sutami Reservoir Monitoring Station

Figure 3 shows the Pollution index values at the Upstream Sutami Reservoir Monitoring Station. The analysis was carried out at a depth of 0.3 m and 4. Sampling was taken from May-October, assuming it was in the dry season. Because the majority index value is 1.0 < Pij < 5.0, it can be categorized as lightly polluted.



	May	June	July	Aug	Sept	Oct	May	June	July	Aug	Sept	Oct	May	June	July	Aug	Sept	Oct	May	June	July	Aug	Sept	Oct	May	June	July	Aug	Sept	Oct
	2015						2016						2017						2018						2019					
1st depth (0.3 m)	0,56	1,17	1,78	0,75	1,24	1,12	1,51	0,99	1,20	1,64	1,01	1,24	1,81	1,69	1,58	1,84	2,23	1,68	2,42	2,27	2,14	2,38	1,97	2,55	2,29	2,20	2,35	2,18	2,10	2,36
2nd depth (5 m)	1,11	1,40	1,63	1,09	0,64	0,91	1,89	1,66	1,68	1,91	1,83	1,19	1,77	1,86	1,36	1,99	2,10	1,52	2,32	2,21	2,05	2,22	2,07	2,53	2,36	2,25	2,46	2,29	2,17	2,37
3rd depth (10 m)	0,66	1,45	1,49	1,62	0,93	1,14	1,68	2,08	1,68	2,12	2,21	1,05	1,54	2,18	1,53	1,92	2,07	2,04	2,02	2,26	2,26	2,18	2,22	2,37	2,35	2,43	2,31	2,31	2,38	2,43

Figure 4. Pollution index values at Middle Sutami Reservoir Monitoring Station

Figure 4 shows the Pollution index values at Middle Sutami Reservoir Monitoring Station. The analysis was carried out at three depths, namely 0.3 m, 5 m, and 10. It is because the depth of the reservoir in the middle is deeper than in the upstream. Sampling is still the same, taken in May-October, assuming it is in the dry season. Due to the majority index value being 1.0 < Pij < 5.0 can be categorized as lightly polluted.

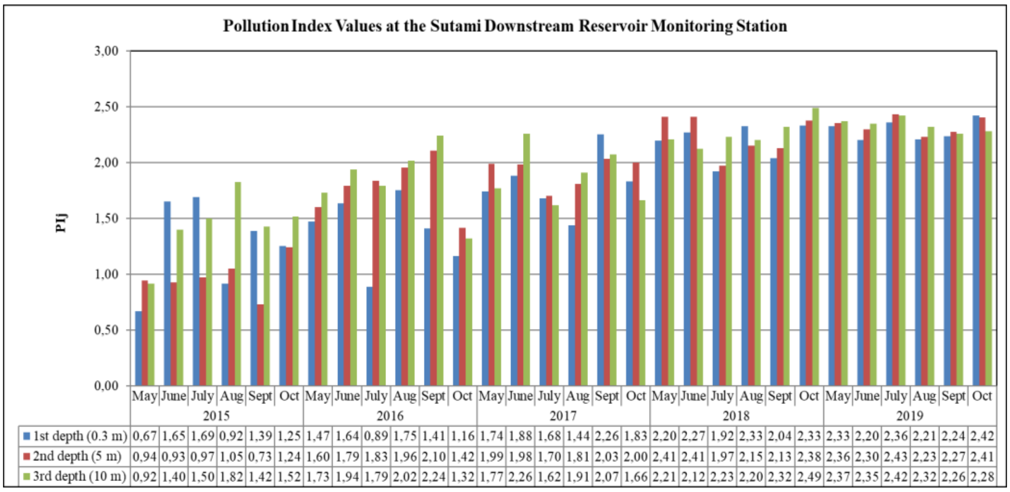


Figure 5. Pollution index values at the Sutami Downstream Reservoir Monitoring Station

Figure 5 shows the same results as Figures 3 and 4. The Sutami Downstream Reservoir Monitoring Station water is included in the lightly polluted category. Although currently, all observations are still in the lightly polluted category, it should be noted that the level of pollution is increasing from year to year. The pollution index in 2015 was around 0.9, but by the end of 2019, it rose to around 2.4. It needs attention from the authorities to prevent the pollution index from increasing.

From the results of determining the water quality status using the Pollution Index Method, the percentage of water pollution in the Sutami Reservoir is as follows (Table 7).

Tabel 7. Percentage of water quality status in 2015 to 2019 monitoring station

Class	Monitoring Station							
	Upper Sutami Reservoir		Middle Sutami Reservoir			Downstream Sutami Reservoir		
	0,3 m	4 m	0,3 m	5 m	10 m	0,3 m	5 m	10 m
Meets Quality Standards	13%	10%	10%	7%	7%	10%	13%	3%
Lightly Polluted	87%	90%	90%	93%	93%	90%	87%	97%
Conclusion	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted

The table above shows that the percentage of water that meets the quality standard is very small, ranging from 3%-13%, while lightly polluted is 87%-93%.

3.2.3. Mathematical Modelling of Water Quality Status with Regression Model

Determination of the water quality characteristics of the Sutami Reservoir consists of; determining the status of water quality using the Pollution Index Method, which is then carried out by mathematical modeling using a regression model; as well as determining the trophic status (Total-P parameter), which is used to determine the carrying capacity of the Total-P pollutant load in the Sutami Reservoir. Determination of water quality characteristics of the Sutami Reservoir for three monitoring point locations with each depth.

Modeling the water quality status is determined after determining the water quality status using the Pollution Index method. The modeling used is the linear regression model, polynomial regression model, logarithmic regression model, exponential regression model, and multiple regression model (power). The following is the result of analyzing the mathematical model of water quality status (Table 8-10 and Figure 6-7).

Table 8. Mathematical modeling of water quality status for Upstream Sutami Reservoir Monitoring Station

Mathematical Model	Upstream Monitoring Station			
	0.3 m		4 m	
Linear Regression	y =	$0.0497x + 0.9638$	y =	$0.0479x + 1.1074$
	R^2 =	0.6822	R^2 =	0.6693
Polynomial Regression	y =	$-0.0001x^2 + 0.0529x + 0.9464$	y =	$-0{,}002x^2 + 0{,}1089x + 0{,}7818$
	R^2 =	0.6824	R^2 =	0.7368
Exponential Regression	y =	$0.9976e^{0.032x}$	y =	$1{,}0809e^{0{,}0313x}$
	R^2 =	0.6133	R^2 =	0.5711
Logarithmic Regression	y =	$0.4587\ln(x) + 0.592$	y =	$0{,}507\ln(x) + 0{,}5881$
	R^2 =	0.5432	R^2 =	0.6996
Multiple Regression (power)	y =	$0.7687x^{0.3043}$	y =	$0{,}7443x^{0{,}3446}$
	R^2 =	0.5162	R^2 =	0.6479

From Table 8 above, it is found that the R^2 value that is the largest or close to 1 for the upstream Monitoring Station 1st depth (0.3 m) is a polynomial regression model with an R^2 value of 0.6423 and for the upstream Monitoring Station, 2nd depth (4 m) is a polynomial regression model with an R^2 value of 0.7368 so that the most suitable regression model with the variation of the PIj value of the Upper Sutami Reservoir is the polynomial regression model.

Table 9. Mathematical modeling of water quality status for Middle Sutami Reservoir Monitoring Station

Mathematical Model	Middle Monitoring Station					
	0.3 m		5 m		10 m	
Linear Regression	y =	$0{,}0535x + 0{,}9124$	y =	$0{,}0454x + 1{,}1249$	y =	$0{,}0443x + 1{,}2099$
	R^2 =	0.7204	R^2 =	0.6570	R^2 =	0.6382
Polynomial Regression	y =	$-0{,}0009x^2 + 0{,}0813x + 0{,}764$	y =	$-0{,}0005x^2 + 0{,}0595x + 1{,}0494$	y =	$-0{,}0009x^2 + 0{,}0736x + 1{,}0535$
	R^2 =	0.7326	R^2 =	0.6610	R^2 =	0.6556
Exponential Regression	y =	$0{,}95e^{0{,}0351x}$	y =	$1{,}1378e^{0{,}0277x}$	y =	$1{,}1958e^{0{,}027x}$
	R^2 =	0.6625	R^2 =	0.5616	R^2 =	0.5501
Logarithmic Regression	y =	$0{,}5278\ln(x) + 0{,}428$	y =	$0{,}4358\ln(x) + 0{,}7436$	y =	$0{,}4632\ln(x) + 0{,}7439$
	R^2 =	0.6546	R^2 =	0.5656	R^2 =	0.651
Multiple Regression (power)	y =	$0{,}6524x^{0{,}3699}$	y =	$0{,}8909x^{0{,}2709}$	y =	$0{,}8608x^{0{,}3004}$
	R^2 =	0.6850	R^2 =	0.5007	R^2 =	0.6346

Table 9 shows that the R^2 value is the largest or close to 1 for the middle monitoring station in the 1st depth (0.3 m), which is a polynomial regression model with an R^2 value of 0.7326, for the 2nd depth (5 m) it is a polynomial regression model with an R^2 value of 0.6570, and for 3rd depth (10 m) it is a polynomial regression model with an R^2 value of 0.6556 so that the most suitable regression model with variations in the PIj value of the Central Sutami Reservoir is the polynomial regression model.

Table 10. Mathematical modeling of water quality status for Downstream Sutami Reservoir Monitoring Station

Mathematical Model	Downstream Monitoring Station					
	0.3 m		5 m		10 m	
Linear Regression	y =	0,0463x + 1,0683	y =	0,0509x + 1,0633	y =	0,0364x + 1,3856
	R^2 =	0.6902	R^2 =	0.7585	R^2 =	0.6577
Polynomial Regression	y =	$-0,0001x^2 + 0,0499x + 1,0489$	y =	$-0,0021x^2 + 0,1165x + 0,7132$	y =	$-0,0008x^2 + 0,0623x + 1,2473$
	R^2 =	0.6905	R^2 =	0.8371	R^2 =	0.6785
Exponential Regression	y =	$1,0917e^{0,0288x}$	y =	$1,0732e^{0,0321x}$	y =	$1,3903e^{0,0203x}$
	R^2 =	0.6060	R^2 =	0.6933	R^2 =	0.6050
Logarithmic Regression	y =	0,4445ln(x) + 0,6789	y =	0,5421ln(x) + 0,5027	y =	0,3868ln(x) + 0,9868
	R^2 =	0.5950	R^2 =	0.8039	R^2 =	0.6940
Multiple Regression (power)	y =	$0,82x^{0,2944}$	y =	$0,7299x^{0,3546}$	y =	$1,0803x^{0,2278}$
	R^2 =	0.5909	R^2 =	0.7913	R^2 =	0.7109

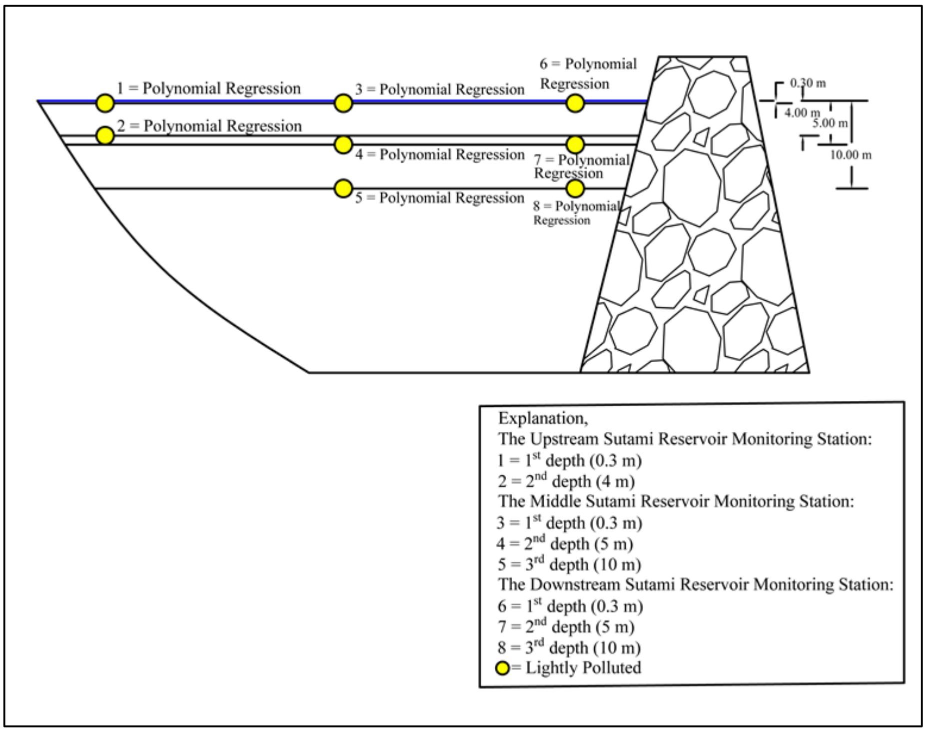


Figure 6. Depiction of the mathematical model in the Sutami Reservoir (side view)

Table 10 revealed that the R^2 value, which is the largest or close to 1 for the downstream Monitoring Station 1st depth (0.3 m), is a polynomial regression model with an R^2 value of 0.6905, for the 2nd depth (5 m) is a polynomial regression model with an R^2 value of 0.8371, and for 3rd depth (10 m) is a polynomial regression model with an R^2 value of 0.7109. So that the most suitable regression model for the variation of the PIj value of the Sutami Hilir Reservoir.

Obtained a regression model with the highest R^2 value at the upstream, middle, and downstream Sutami Reservoir Monitoring Stations for each depth (8 points of depth), namely the polynomial regression model. It means that the most suitable regression model for the variation of PIj data is the polynomial regression model. It shows that this polynomial regression model is in the form of a curved line that tends to increase over time and then flatten to decrease at the end of the period. It means that the trend of the level of pollution tends to continue to rise and starts to stabilize until it decreases at the end of the period studied.

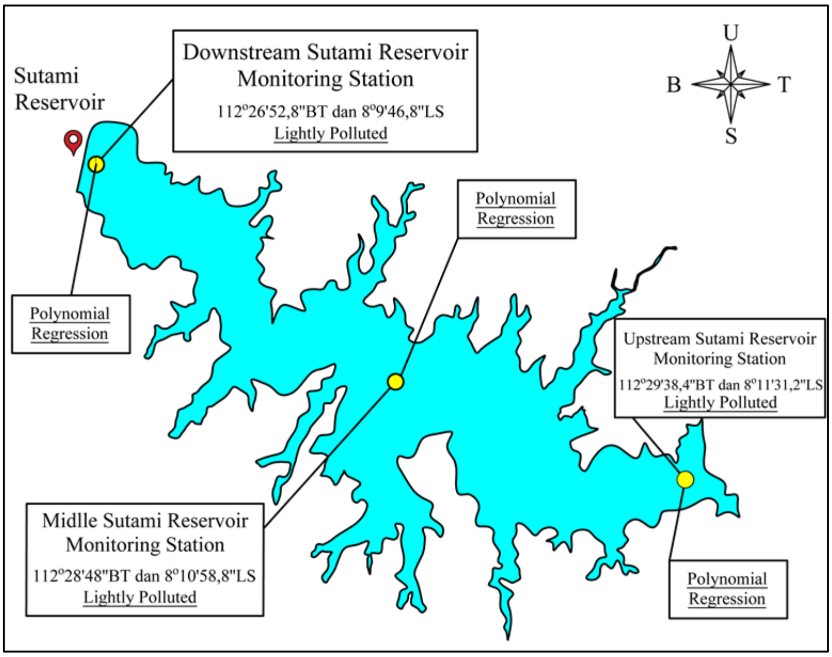


Figure 7. Depiction of the mathematical model in the Sutami Reservoir (top view)

Figure 7 summarizes the results of research that has been carried out, namely that at all sampling locations, the best mathematical model is polynomial regression, and the reservoir water quality condition is lightly polluted.

4. Conclusions

This research has succeeded in determining water quality status using the pollution index method and mathematical modeling. The levels of parameters BOD, COD, DO, and pH has exceeded the existing quality standard values. Meanwhile, the levels of TSS and NH3-N parameters have not exceeded the existing quality standard values. The status of water quality using the Pollution Index method is in the lightly polluted category. The value of the Total-P capacity that enters the Sutami Reservoir exceeds the maximum quality standard. The polynomial regression model is the most suitable mathematical model for the pollution index method data (PIj). This research can be used as a reference for the management to determine the steps in managing industrial and residential areas and limiting the use of pollutant materials.

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