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Analysis of The Influence of Land Use on Water Quality Pollution in The River Basin (DAS) Kali Pelayaran, Sidoarjo

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Abstract
Most rivers in Indonesia experience pollution due to waste disposal activities that are often uncontrolled in terms of both quantity and quality. Increased domestic activities, infrastructure development and land use around the watershed have had a significant impact on water quality in Pelayaran River. Pelayaran River with a length of 21 km is the source of raw material for drinking water processed by Taman Tirta Water Treatment Plant (IPA) in Sidoarjo Regency. This study aims to assess the condition of pollutant load in Pelayaran River, Sidoarjo. The research method used is by testing the status of river water quality using the pollution index, followed by simulating river water quality using Qual2kw with 3 scenarios, and calculating the capacity of the pollutant load. the water quality parameters analyzed are COD, BOD, TSS, and Total Nitrogen parameters. from the results of this study, it can be seen that the quality status of Kali Pelayaran and the capacity of the pollutant load. it is hoped that this research will be able to provide policy decisions in making water quality pollution control strategies.
Keywords: *land use, pollutant load carrying capacity, QUAL2Kw*

Abstrak
Sebagian besar sungai di Indonesia mengalami pencemaran karena aktifitas pembuangan limbah yang seringkali tidak terkendali baik dari segi kuantitas maupun kualitasnya. Peningkatan aktivitas domestik, pembangunan infrastruktur, dan penggunaan lahan di sekitar Daerah Aliran Sungai (DAS) telah berdampak signifikan terhadap kualitas air di Sungai Pelayaran. Kali Pelayaran dengan panjang 21 km menjadi sumber bahan baku air minum yang diolah Instalasi Pengolahan Air (IPA) Taman Tirta Kabupaten Sidoarjo. Penelitian ini bertujuan untuk mengkaji kondisi beban pencemar di Kali Pelayaran, Sidoarjo. Metode penelitian yang digunakan yaitu dengan melakukan pengujian status mutu air sungai menggunakan indeks pencemaran, dilanjutkan dengan simulasi kualitas air sungai menggunakan Qual2kw dengan 3 skenario, serta menghitung daya tampung beban pencemar. Parameter kualitas air yang dianalisis yaitu parameter COD, BOD, TSS, dan Total Nitrogen. Hasil penelitian ini dapat diketahui status mutu Kali pelayaran dan daya tampung beban pencemarnya. Diharapkan dengan adanya penelitian ini mampu memberikan keputusan kebijakan dalam membuat strategi pengendalian pencemaran kualitas air.
Kata Kunci: *daya tampung beban pencemar, penggunaan lahan, QUAL2Kw*

1. Introduction

Rivers have a crucial role as water providers people needs and support national development progress, therefore it is necessary to maintain water quality. Economic growth and urbanization cause an increase in water consumption, while the availability of clean water is decreasing due to poor quality. The poor quality of clean water is due to several factors, including increasing human population, expanding urban functions, and increasing disposal of industrial and agricultural waste. Changes in water quality in rivers are caused by waste generated from land use activities around the river basin (DAS). The decline in clean water quality is caused by several factors, including increasing population, expansion of urban areas, and increasing waste from industry and agriculture [1]. In research [2] it is stated that land use characterized by community activities, namely settlements, agriculture and industry, has contributed organic material thereby affecting water quality, where there is also a reduction in the use of forest land covering an area of 186 ha, residential land increasing by 35 ha, dry land increasing. 53 ha which is an important influence on reducing water quality.

Kali Pelayaran is a river with the source of pollution coming from the Mangetan Canal River branch which consists of residential, agricultural and industrial waste around the riverbanks. In research (Irfan M, 2023) which states that the shipping waters have been polluted and appear brown due to sources of pollution originating from industrial waste, residential areas, agricultural waste and flows from Brantas river tributaries. This proves that varying land use in the Kali Pelayaran watershed will automatically change the appearance of the river both in terms of physicality and the quality of the water itself. The problems above prove that human activities around the Pelayaran River have contributed to changes in the water quality of the Pelayaran River. Changes in water quality can be identified by monitoring water quality. Therefore, water quality monitoring can be used to answer specific problems related to river basin management.

This research, the water quality status of the Pelayaran River was analyzed using the Pollution Index (IP) method referring to the Decree of the Minister of Environment Number 115 of 2003 concerning Guidelines for Determining Water Quality Status. Then proceed with an analysis of land use relationships using the Pearson correlation test to see the dominant pollutant sources. The results of this research can be used to monitor developments in water quality for managing river flow areas as well as to inventory and determine the causes and effects of activities related to water quality.

2. Material and Methods

Location of Kali Pelayaran

Kali Pelayaran is located in Sidoarjo Regency which has a geographic location between 112°5' and 112°9' East Longitude and between 7°3' and 7°5' South Latitude with the northern boundary being Surabaya City and Gresik Regency, to the east there is the Madura Strait. , South is Pasuruan Regency, and West is Mojokerto Regency. The shipping river is a tributary of the Brantas River which has a length of 21 kilometers passing through 3 sub-districts, namely Taman sub-district, Krian sub-district and Baong Bendo sub-district, where the total number of villages passed is 10. These three sub-districts have a population until 2023, namely Balong Bendo sub-district 73,933 people, Taman District 200,405 people, Krian District 130,412 people, where the average annual population increase is 6.8% [4]. The research area is dominated by residential and agricultural land, where some residents work as farmers. **Figure 1** shows a map of the location of Kali Pelayaran.

Fig. 2: Map of Kali Pelayaran
Source: QGIS & Map RBI of East Java

Water sampling of Kali Pelayaran

Water sampling in rivers is based on SNI 6989.57:2008 concerning surface water sampling methods which are carried out twice based on season, namely the rainy season on March 24 2024 and the dry season on May 12 2024. Because the river discharge is less than 5 m3/s, the collection is the sample was taken at one point in the middle of the river at a depth of 0.5 times the depth of the river surface and carried out by grab sampling. Grab sample or momentary sample is a sampling method where the sample is taken directly from the body of water being observed. This sample only reflects the water conditions at the time the sampling was carried out [5]. There are 10 sampling points representing the upstream, middle and downstream rivers. Samples were taken using the purposive sampling method, which is a sampling procedure based on considerations made by the researcher. This consideration is based on access and sources of activities that are thought to have the potential to pollute water bodies. **Table 1** shows the coordinate points for water sampling.

Jurnal Serambi Engineering JSE Volume IX, No.3, Juli 2024 Hal 9947 - 9955 p-ISSN : 2528-3561 e-ISSN : 2541-1934

Tabel 1. Sampling Coordinates

Code Sample	Coordinate	Point Source	Non Point Source
T1	7°24'19.25"S 112°31'51.59"E	Residence	Canal Mangetan
T2	7°24'19.46"S 112°32'43.78"E		
T3	7°23'59.97"S 112°33'36.11"E		
T4	7°23'18.42"S 112°34'41.04"E	Residence	Agricultural
T5	7°22'22.64"S 112°35'23.68"E		
T6	7°22'12.88"S 112°36'40.36"E		
T7	7°21'43.09"S 112°39'17.54"E	Residence	Agricultural
T8	7°21'9.80"S 112°40'12.90"E		
T9	7°21'4.30"S 112°40'54.80"E		
T10	7°21'1.50"S 112°41'18.70"E		

Water analysis of Kali Pelayaran

In this research, the water quality parameters used are the key parameters contained in Minister of Environment and Forestry Regulation Number 01 of 2010 Water Pollution Control Procedures which consist of BOD, COD, TSS, and Ammonia. After carrying out laboratory tests, it can be continued with the calculation of the pollution index in accordance with the Decree of the Minister of Environment Number 115 of 2003 to determine the quality status of the Kali Pelayaran with the following equation.

$$IP_j = \sqrt{\frac{\left(\frac{C_i}{L_{ij}}\right)_M^2 + \left(\frac{C_i}{L_{ij}}\right)_R^2}{2}}$$

Explanation:
IPj : Pollution Index
Ci : Concentration of water quality parameters i
Lij : Concentration of water quality parameters I of listed in the water allocation standards j
M : Maksimum score
R : Average score

The pollution index obtained from the calculation results is then included in the classification of water quality status. Water quality status will explain whether the waters are good, lightly polluted, moderately polluted or heavily polluted. According to KepMenLH No. 115 of 2003, if the concentration of the parameter test results is divided by the concentration of the parameter in accordance with the quality standard (Ci/Lij) to give a value of more than 1, then the water quality status can be categorized as good but the category is lightly polluted and indicated as increasingly polluted. This statement can be supported if the average Ci/Lij value (Ci/Lij)R and/or maximum Ci/Lij value (Ci/Lij)M is higher, then the level of pollution of a water body will also be greater. In other words, the more parameters that exceed the quality standards and the concentration is high, the greater the Pollutant Index value and the worse the water quality will be [6]. The classification of water quality status is presented in the table, see **Table 2.**

Table 2: Status Water Quality

Indeks Pencemaran (IP)	Mutu Perairan
$0 \le Pij \le 1.0$	Baik
$1.0 < Pij \le 5.0$	Cemar Ringan
$5.0 < Pij \le 10$	Cemar Sedang
$Pij > 10$	Cemar Berat

Sumber: Kepmen LH No. 115/2003

Normality Test

The normality test assesses whether research data follows a normal distribution or not. Normally distributed data is a requirement in parametric statistics. In SPSS, there are two methods for testing normality based on the number of samples used. If the sample size is smaller than 50 then use the Shapiro-Wilk normality test, but if the sample data used is greater than 50 then you can use the Kolmogorov-Smirnov normality test. When the normality test has been carried out, the results that come out will be seen for their significance value to decide. If the significance value (sig) exceeds 0.05, the research data follows a normal distribution. Conversely, if the significance value is less than 0.05, the research data does not conform to a normal distribution. If the research data is normally distributed, parameter statistics can be carried out using the Pearson correlation test [7].

Pearson Correlation Test

Pearson correlation is a simple method involving one dependent variable and one independent variable. In this research study the independent variable is land use and the dependent variable is water quality parameters. This method produces a correlation coefficient to assess how strong the linear relationship is between the two variables [8]. The symbol for Pearson correlation is "ρ" if measured in a population, and "r" if measured in a sample. The correlation coefficient is a measure used to measure the level of relationship between variables. The correlation coefficient value ranges between -1 and 1, where the closer the "r" value is to 1, the stronger the relationship between these variables. Correlation is considered strong if the "r" value is greater than the "rsignificant" value, which is obtained from the table of degrees of freedom (df) against the level of confidence (α). rsignificant will be obtained from table 3. The following is the equation for calculating the "r" value:

$$r = \frac{\Sigma(x - x)(y - y)}{\sqrt{\Sigma(x - x)^2}\,\sqrt{\Sigma(y - y)^2}}$$

Explanation:
x: Concentration of water quality
x : Average Concentration of water quality
y: % land use
y: Average % land use
Determine value of df, can be known through the following equation:
$df = n - 2$

Table 3: Score of r significant

df	α = 0,10	α = 0,05	α = 0,025	α = 0,01
1	0,988	0,997	0,999	1,000
2	0,900	0,950	0,975	0,990
3	0,805	0,878	0,924	0,959
4	0,729	0,811	0,868	0,917
5	0,668	0,754	0,817	0,875
6	0,621	0,707	0,771	0,834
7	0,582	0,666	0,732	0,798
8	0,549	0,632	0,697	0,765
9	0,521	0,602	0,667	0,735
10	0,497	0,576	0,640	0,708
11	0,476	0,553	0,616	0,684
12	0,458	0,532	0,594	0,661
13	0,441	0,514	0,575	0,641
14	0,426	0,497	0,557	0,623
15	0,412	0,482	0,541	0,606

3. Results and Discussion

3.1. Kali Pelayaran Water Quality

Based on the findings of laboratory analysis for BOD, COD, TSS and Ammonia parameters from 10 points representing upstream to downstream of the Pelayaran River, the average concentration has exceeded the quality standard limits set in PP No. 22 of 2021. The laboratory analysis results can be seen in **Figure 2**. Based on the analysis findings, the quality status of Pelayaran River water quality can be determined. Assessment of the status of river water quality in this study uses one of the methods listed in the Decree of the Minister of Environment Number 115 of 2003, namely the Pollution Index method.

Jurnal Serambi Engineering JSE
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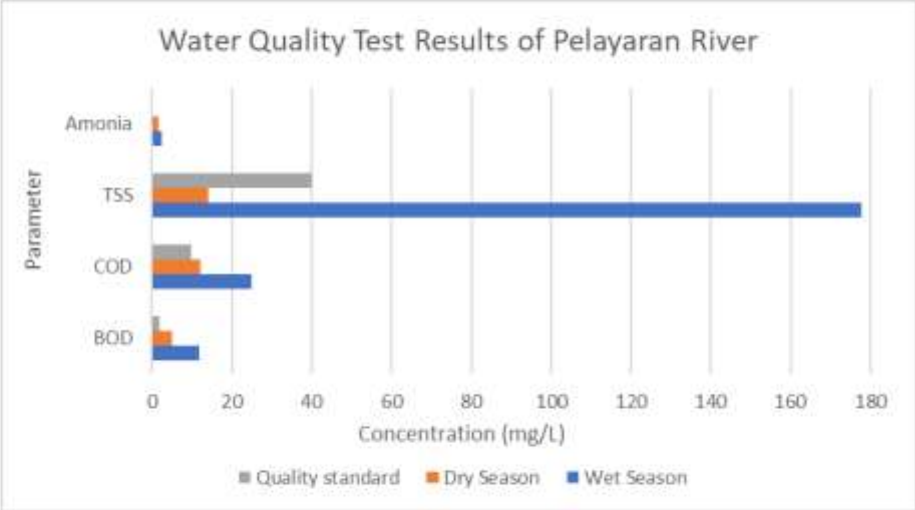


Fig. 2: Result of Laboratory Test
Source: Author's calculation result

Based on the calculated results and comparisons with the Class I Quality Standard of PP No. 22 of 2021 where Kali Pelayaran water is designated as drinking water raw water, it shows that Kali Pelayaran has a diverse pollutant index value in two seasons, namely in the rainy season in the range of 2.97 - 7.19, while the dry season is 1.86 - 5.02. So it can be seen that the status of the Pelayaran River pollutant index is on average moderately polluted during the rainy season and lightly polluted during the dry season. However, there are 2 points that have an unchanged quality status in both seasons, namely point 7 and point 10. Point 7 has a quality status of mild pollution in both wet and dry seasons, while point 10 has a quality status of moderate pollution during the wet and dry seasons. **Table 4** displays the outcomes of the quality status analysis of the Pelayaran River.

Table 4: Analysis of Kali Pelayaran

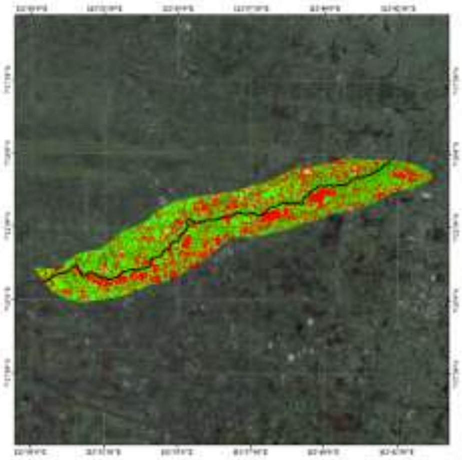
Sampling point	Distance from upstream (Km)	IP SCORE			
		Wet Season	Description	Dry Season	Description
1	0	5,32	moderately polluted	3,59	lightly polluted
2	1,84	5,76	moderately polluted	2,75	lightly polluted
3	3,6	5,20	moderately polluted	3.46	lightly polluted
4	6,18	5,50	moderately polluted	3	lightly polluted
5	8,56	7,19	moderately polluted	3,125	lightly polluted
6	10,99	5,79	moderately polluted	3.79	lightly polluted
7	15,99	2,97	**lightly polluted**	1,86	lightly polluted
8	18,14	6,17	moderately polluted	4,24	lightly polluted
9	19,45	6,08	moderately polluted	3,345	lightly polluted
10	20,2	6,06	moderately polluted	5.02	**moderately polluted**

Source: Author's calculation result

Based on the results of pollution index calculations in the rainy and dry seasons, the Kali Pelayaran is declared moderately polluted during the rainy season and lightly polluted during the dry season. This is caused by many influencing factors, namely during the rainy season with high rainfall carrying various dissolved substances and particles from the soil surface into rivers including pollutants such as agricultural and domestic waste. Meanwhile, river flow rates increase because incoming rainwater can transport more pollutants from surrounding areas into the river. High rainfall can cause greater water flow on the land surface, causing greater soil erosion which contains a lot of nutrients and carries mud, sedimentation and organic matter from the land surface into rivers and causes rivers to become polluted. This is confirmed by research [9] which states that high BOD and COD parameters exceed quality standards during the rainy season and discharge also fluctuates depending on rainfall and rainy days affecting the TSS concentration value.

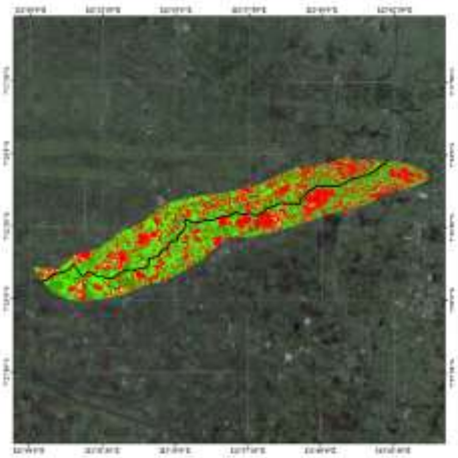
3.2. Classification of Land Use in the Kali Pelayaran Riverbanks

This research uses Landset 8 satellite imagery with a scale of 1:100,000 to create land use maps in the Kali Pelayaran watershed and river borders. The data used is temporal data for annual time periods, namely 2019, 2021 and 2024 with classification into 2 classes, namely buildings and agriculture to see land use around the Kali Pelayaran watershed. The map depicting land use within the Kali Pelayaran watershed presented temporally and spatially in **Fig 3, Fig 4** and **Fig 5**. Alterations in land use and land cover are related to causes originating from human activities and from nature itself to influence water quality in riverbanks [10].



(a)

Fig. 3: (a) DAS Kali Pelayaran 2019



(b)

Fig. 4: (b) DAS Kali Pelayaran 2021

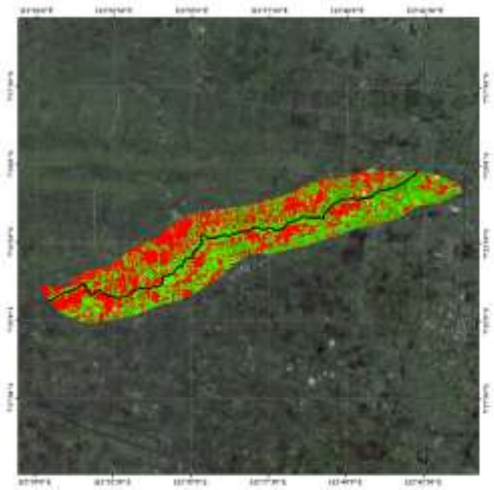


Fig. 5: DAS Kali Pelayaran 2024

Based on the picture above, there has been an increase of 6% every two years on average in the building category. This is because there is development of building land where there is a need for new infrastructure, housing or commercial facilities. Meanwhile, in the agricultural category from 2019 to 2024 there will be fluctuating changes. This happens because the empty land in the Kali Pelayaran watershed is categorized as agricultural. Thus, there are unstable changes from year to year. However, this fluctuating change is in line with the increase or decrease in building land and vegetation land. **Table 5** displays the temporal percentage of land use in the Kali Pelayaran riverbanks.

Table 5: Percentage of Land Cover of the Kali Pelayaran Riverbanks

Year	Residential land (%)	Agricultural land (%)
2019	34,85	36,67
2021	51,44	37,02
2024	95,72	30,71

Source: Author's calculation result

3.3. The Effect of Land Use on Water Quality

This study conducted a Pearson correlation test to evaluate the association between water quality pollution parameters and land use in the Kali Pelayaran riverbanks. Before carrying out the Pearson correlation test analysis, a data normality test was carried out to prove that the data used was distributed normally and parametric. The analysis was carried out using the Shapiro-Wilk normality test via SPSS software because the amount of data was less than 50. Based on the results of the Shapiro-Wilk normality test with a data amount of 10, the significance figure was more than 0.05, which means the data used was normally distributed. So, the correlation analysis examining the connection between land impact and water quality was carried out using a parametric test with Pearson correlation. According to [11], the Pearson correlation test is used when research data is distributed normally data with a sig value of more than 0.05 so that the data can be used for parametric tests. The normality test results are illustrated in **Figure 5**.

Tests of Normality

	Kolmogorov-Smirnov^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Konsentrasi Permukiman	.154	10	.200*	.923	10	.380
Konsentrasi Pertanian	.130	10	.200*	.947	10	.638

Fig. 5: Results of Normality Test
Source: Author's calculation result

After the normality test, because the research data is distributed normally, it can be continued with the Pearson correlation test to assess the impact of land use on each aspect of water quality pollution parameter. The significant R value in the research data is 0.878. So if there is a parameter with a Pearson correlation value that is above 0.878, then it is stated to have a close relationship with land use. The results of the Pearson correlation test can be seen in **Table 6**.

Table 6: Results of Pearson Correlation

Parameters	Residential	Agriculture
Suhu	0,646	-0,796
pH	0,005	0,212
TSS	**0,998**	0,379
BOD5	**0,999**	-0,935
COD	**0,989**	-0,938
Total N	**0,989**	-1,000

**R Significant -0,878 or 0,878*

Source: Author's calculation result

According to the findings from the Pearson correlation test, the correlation between TSS parameters and residential land has a Pearson correlation coefficient of 0.998 with a significance level of 0.042, so it can be said that residential land and TSS parameters have a perfect correlation with positive data. This can be due to the fact that residential land tends to have more intensive human activities compared to agricultural land, which triggers soil erosion and the movement of solid materials into waterways.

The same thing also happens to the BOD parameter for residential land use which has a Pearson correlation value of 0.999, which shows that the two have a very strong correlation. This is because residential land with high population density has the potential to produce large amounts of domestic waste. This waste contains organic materials such as food waste, detergents and other domestic waste which can worsen water quality by increasing BOD concentrations. The use of water for various purposes such as bathing, washing and cooking in households is the main source of this organic waste [12].

Meanwhile, the relationship between COD parameters and residential land use has a Pearson correlation value of 0.989, which means that COD parameters also have a very strong correlation with residential land rather than agricultural land. The main source that causes high COD is waste from households and industry which produces organic waste and is the main factor in increasing COD concentrations [13]. On the other hand, agricultural land tends to have fewer concentrated sources of organic pollutants. The use of fertilizers and pesticides is a typical problem in agriculture, but usually does not increase COD levels significantly because these substances tend to be more correlated with nitrate and phosphate parameters [14].

Finally, the total nitrogen parameter has a perfect or very close correlation with residential land with a Pearson correlation value of 0.989. Residential land is increasing every year followed by high population density resulting in residential land having more sources of nitrogen pollution, sources of nitrogen in household wastewater are food waste, soap and fertilizer [15]. In research [16], it is stated that residential waste contains around 40-60% protein. The protein found in household waste in water is a source of organic nitrogen along with urea. After that, this protein will be converted into ammonia and will ultimately turn into nitrites and nitrates in the oxidation process if there is sufficient oxygen. These parameters are included in total nitrogen

4. Conclusion

Kali Pelayaran has a quality status of light to moderate pollution with a pollution index in the rainy season in the range of 2.97 – 7.19 and in the dry season 1.86 – 5.02. The pollution of the Pelayaran River is closely related to the use of the surrounding land. Based on the results of the analysis using the Pearson correlation, the parameters BOD, COD, TSS, and Total Nitrogen have a very strong relationship with residential land use, where the Pearson correlation value for the BOD parameters is 0.999, COD is 0.989, TSS is 0.998, and total nitrogen is 0.989. So it is necessary to manage waste on residential land so that the waste entering the river is of good quality and does not cause pollution.

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