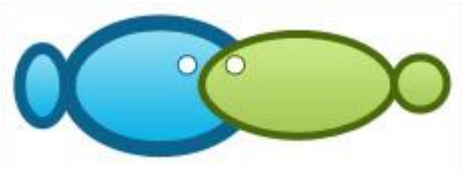

Analysis of water quality and primary productivity in Welang, Gembong, and Rejoso rivers, Pasuruan East Java, Indonesia

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Abstract. Welang, Gembong, and Rejoso are large rivers that flow in the Pasuruan area and empty into the Madura Strait. The high human activity in the area can cause both physical and chemical in the waters. The purpose of this study was to determine the condition of water quality and primary productivity in the Welang River, Gembong River, and Rejoso River, based on the abundance of periphyton. According to the results of this research, it can be concluded that the water quality in the Welang, Gembong, and Rejoso rivers has been moderate-to-severe pollution levels that exceeded the quality standards in the three rivers are: total suspended solids (TSS), alkalinity, and cadmium. Meanwhile, the primary productivity in these rivers is classified as oligotrophic.
Key Words: productivity, oligotrophic, periphyton, diversity, abundance.

Introduction. Surface water vulnerable to contamination various natural and anthropogenic stressors. Natural stresses include oxidation of mineral rocks, erosion, weathering of materials, and climate change, while anthropogenic factors include wastewater disposal with excessive nutrient input, use of agricultural chemicals, geomorphological changes, land use, and hydrological pressure. Another important pressure that enters aquatic ecosystems is the increase in domestic and industrial waste (Custodio et al 2021). The decline in water quality occurs due to human activities that do not care about the aquatic environment and do not heed the principles of sustainable development (Dawud et al 2016).

Rivers are sources of surface water that provide benefits to human life (Mardhia & Abdullah 2018). River quality to changes in land use and by waste due to agricultural, livestock farming, residential, and industrial activities resulting in pollution of river bodies. Evaluation of the occurrence of river pollution requires monitoring of water quality, can be carried out with physical, chemical, and biological parameters (Handinata & Muntalif 2017). According to (Kahirun et al 2019), the direct impact of river pollution can be observed in the reduced number of native fish, and changes in water color and odor.

The Pasuruan is an area with rapid industrial growth, causing high waste disposal in rivers that flow in Pasuruan (Wijayanti & Lestari 2017). Welang River, Gembong River, and Rejoso River are large rivers that flow in the Pasuruan area and into the Madura Strait. The water quality in the upstream part of the river is still relatively good, but in the middle, down to the lower reaches of the river, there is a decrease in water quality, correlated with the utilization of the areas along the river banks (Riwayadi 2016).

Changes in river water quality can be detected by means of biomonitoring, using biological indicators, like the periphyton. Periphyton represents a complex community consisting of autotrophic and heterotrophic microorganisms. and sticking to the aquatic

substrates, such as plants, wood, stones, so that they can quickly respond to changes in the aquatic environment (Justus et al 2021). Periphyton algae play an important role in the waters, namely as primary producers. As much as 69% of the total primary productivity in the waters is due to the periphyton. In addition, periphyton also acts as a nutrient or food for aquatic organisms, as a basis for environmental restoration, and also as an indicator of environmental conditions (Safitri et al 2019). The current study aimed to determine the condition of water quality and primary productivity in the Welang, Gembong, and Rejoso River based on the abundance of periphyton.

Material and Method

Research time and location. The research was carried out in March 2021 in the lower reaches of the Welang River, Gembong River, and Rejoso River, Pasuruan, East Java Province. Analysis of water quality parameters and identification of periphyton was carried out in the Laboratory of the Technical Implementation Unit of Freshwater Fishery Sand Source, Faculty of Fisheries and Marine Sciences, Universitas Brawijaya.

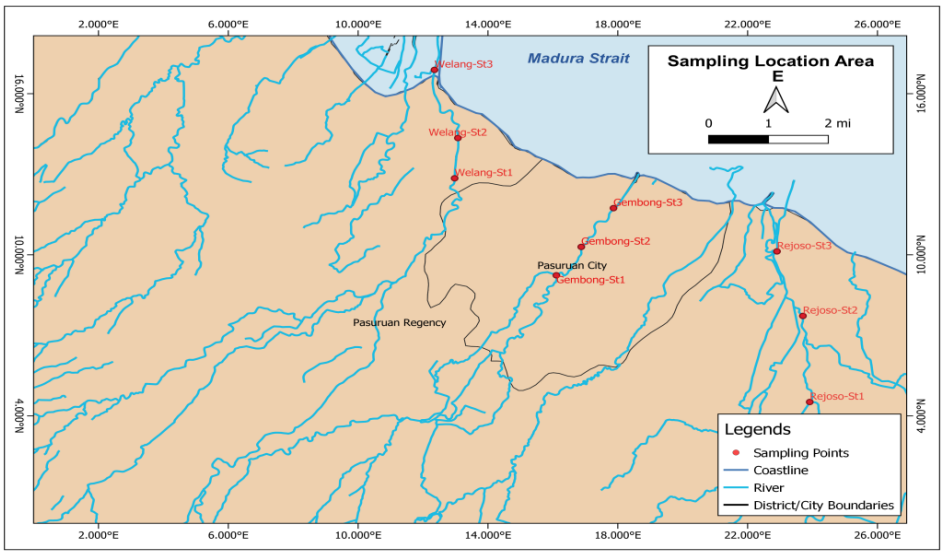

Figure 1. Research location map.

Research method. The research was conducted using a survey method with descriptive data analysis. The determination of observation stations was based on the purposive sampling method in terms of influence of the human activities around the sampling point. There are 3 points of sampling in each river. Samples of water quality and periphyton were collected at each station, in each river.

Research variables. The variables observed in this study were the abundance of periphyton in each river, the level of sensitivity to pollution and the physical and chemical components of the waters. The physical parameters consist of temperature, current, brightness, and total suspended solids (TSS). The chemical parameters include pH, dissolved oxygen (DO), nitrate, phosphate, alkalinity, total organic matter (TOM), total P, total N, and heavy metal, cadmium (Cd). The biological parameters were measurements of chlorophyll-a and periphyton abundance.

Data analysis

Water quality status. The STORET method shows the classification of parameters that have met or exceeded the water quality standard by referring to the Decree of the State Minister of the Environment Number 115 from 2003, concerning the guidelines for determining the status of water quality. The STORET method compares water quality data with standards that are adjusted to the class and designation of the Government Regulation Number 82 of 2001, concerning the water quality management and water

pollution control. Table 1 shows the indices assigned for determining the status of the water quality, based on the STORET method. According to Canter (1977), if the measurement results meet the water quality standard value (measurement result ≤ quality standard) then a score 0 is given. If the measurement result does not meet the water quality standard value (measurement result > water quality standard value) then it is given a score as in Table 1:

Table 1

Value of the water quality status, based on the STORET method

Number of samples	*Value*	*Parameter*		
		Physical	*Chemical*	*Biologic*
<10	Maximum	-1	-2	-3
	minimum	-1	-2	-3
	Average	-3	-6	-9
≥10	Maximum	-2	-4	-6
	minimum	-2	-4	-6
	Average	-6	-4	-18

(Source: Minister of Environment Decree No. 115 of 2003).

Results

Periphyton density. Periphyton densities in the lower reaches of the Welang, Gembong, and Rejoso rivers in Pasuruan are shown in Figure 2:

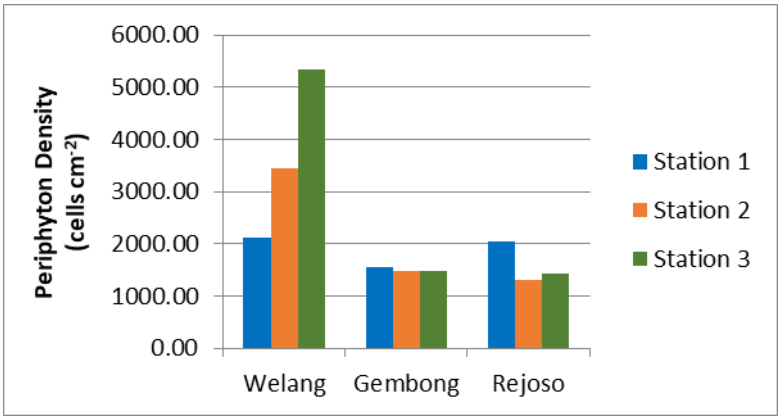

Figure 2. Periphyton density.

The average density of periphyton in the Welang River ranges from 2126.0–5340.40 cells cm^{-2}. Gembong River ranges from 1472.50 to 1556.50 cells cm^{-2}, while on the Rejoso River it ranges from 1303.68 to 2043.50 cells cm^{-2}. The highest periphyton density was found at station 3 on the Welang River and the lowest at station 2 on the Rejoso River.

Diversity index. The diversity index at the lower reaches of the Welang, Gembong, and Rejoso rivers can be seen in Table 2.

Table 2

Diversity index

Stations	*Welang*	*Gembong*	*Rejoso*
Station 1	1.91	2.05	0.81
Station 2	2.31	2.04	0.76
Station 3	2.41	2.04	0.94

The average diversity index on the Welang River ranges from 1.91 to 2.41, on the Gembong River it ranges from 2.04 to 2.05 and on the Rejoso River it ranges from 0.81 to 0.94. The average diversity index in the three rivers has a low value, with a low periphyton community stability, except at station 3 on the Welang River, where it has a moderate value. The diversity index value can be classified into three categories, namely: 0<H'<2.3, with a low stability of the periphyton community, 2.3<H'<6.9, with a moderate stability of the periphyton community, and H'>6.9 with a highly stable community (Agustin et al 2019).

Dominance index. The dominance index in the lower reaches of the Welang, Gembong, and Rejoso rivers can be seen in Table 3.

Table 3

Dominance index

Stations	*Welang*	*Gembong*	*Rejoso*
Station 1	0.19	0.16	0.60
Station 2	0.13	0.16	0.66
Station 3	0.11	0.15	0.54

The average dominance index on the Welang River ranges from 0.11 to 0.19, the Gembong River ranges from 0.15 to 0.16 and the Rejoso River ranges from 0.55 to 0.66. Based on the average dominance index, it was found that in the Welang and Gembong rivers there was no dominant species of, while in the Rejoso River there was a slightly dominant species in accordance with Agustin et al (2019) who stated that a dominance index value close to 1 suggests a dominance of certain.

Chlorophyll-a. The chlorophyll-a values downstream of the Welang, Gembong, and Rejoso rivers in Pasuruan are presented in Figure 3:

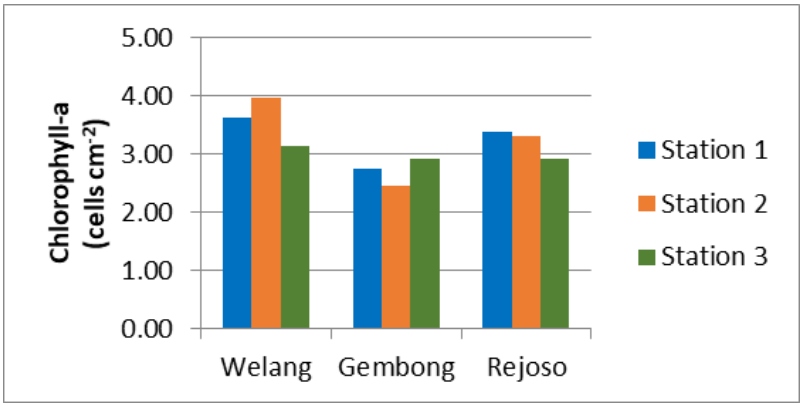

Figure 3. Chlorophyll-a (cells cm^{-2}).

The average chlorophyll-a in the Welang River ranged from 3.13 to 3.96 cells cm^{-2}, in the Gembong River it rangeds from 2.45 to 2.91 cells cm^{-2} and in the Rejoso River it ranged from 2.92 to 3.38 cells cm^{-2}. The highest chlorophyll-a was found at Station 2 of the Welang River and the lowest was found at Station 2 of Gembong River.

Aquatic fertility. The water fertility can be determined based on the Trophic Index (TRIX) method. Figure 4 shows the value of water fertility in the Welang, Gembong, and Rejoso rivers in Pasuruan:

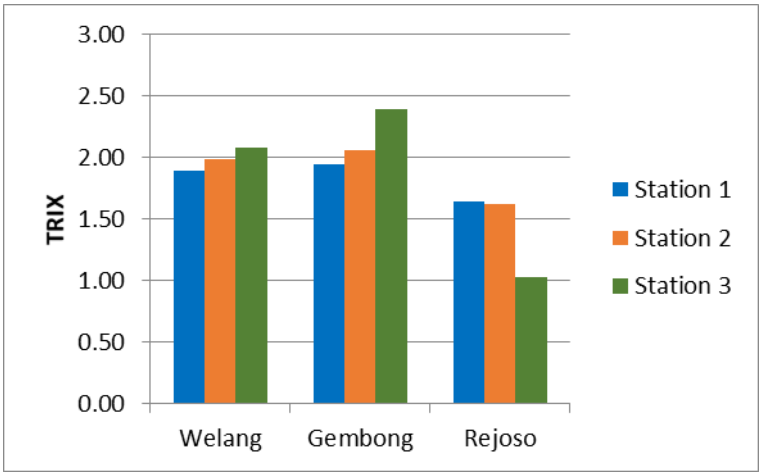

Figure 4. Aquatic fertility according to TRIX.

The average fertility of the waters in the Welang River ranges from 1.89 to 2.08, in the Gembong River it ranges from 1.95 to 2.39 and in the Rejoso River it ranges from 1.03 to 1.64. The highest fertility was found at Station 3 on the Gembong River and the lowest at Station 3 on the Rejoso River.

Water quality analysis

Temperature. The average temperature on the Welang, Gembong, and Rejoso rivers in Pasuruan is shown in Figure 5:

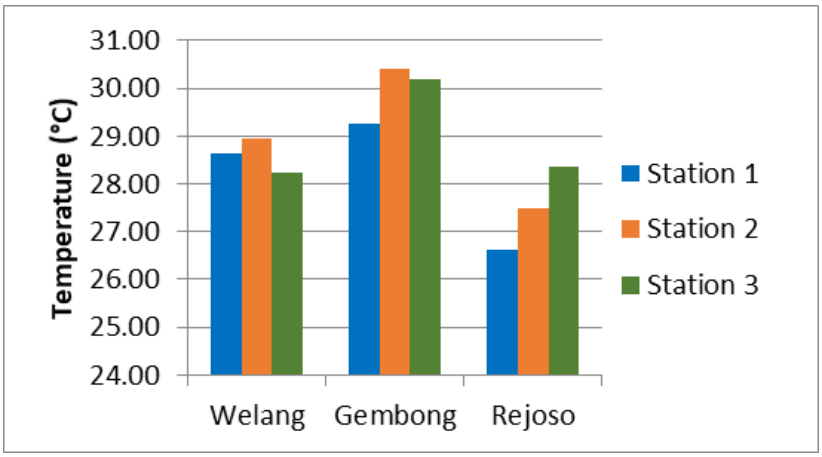

Figure 5. Temperature (°C).

The temperature in the lower reached of the Welang River ranges from 28.23 to 28.95°C, on the Gembong River it ranged from 29.25 to 30.40°C and on the Rejoso River it ranged from 26.63 to 28.35 °C. The highest temperature value was found at Station 2 on the Gembong River and the lowest at Station 1 on the Rejoso River.

Brightness. The brightness of the Welang, Gembong, and Rejoso rivers in Pasuruan is shown in Figure 6.

The average brightness of the Welang River ranges from 14.13 to 15.58 cm, on the Gembong River it ranges from 26.80 to 36.75 cm and on the Rejoso River it ranges from 21.05 to 21.83 cm. The highest brightness was found at Station 3 on the Gembong River and the lowest at Station 2 on the Welang River.

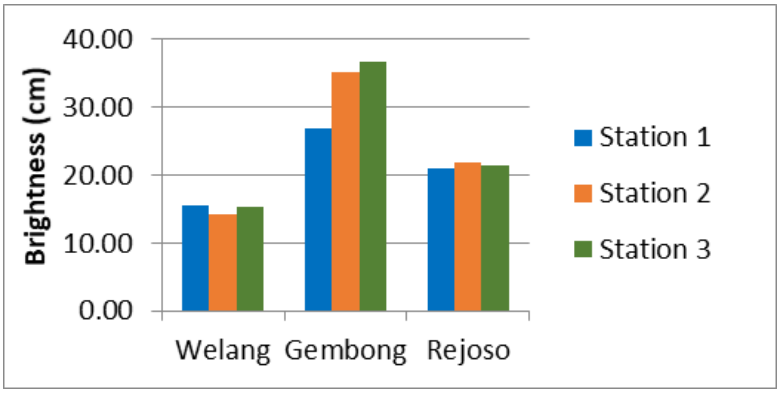

Figure 6. Brightness (cm).

Current speed. The current velocity values downstream of the Welang, Gembong and Rejoso rivers in Pasuruan are shown in Figure 7:

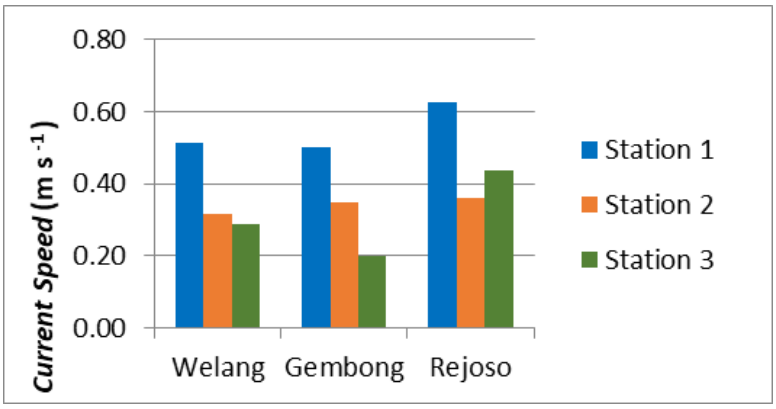

Figure 7. Current speed (m s^{-1}).

The average current velocity in the Welang River ranged from 0.29 to 0.52 ms^{-1}, in the Gembong River it ranged from 0.20-0.50 m s^{-1} and in the Rejoso River it ranged from 0.36 to 0.63 m s^{-1}. The highest current was found at station 1 on the Rejoso River and the lowest at station 3 on the Gembong River.

Total Suspended Solid (TSS). Total Suspended Solids (TSS) in the lower reaches of the Welang, Gembong, and Rejoso rivers in Pasuruan are shown in Figure 8:

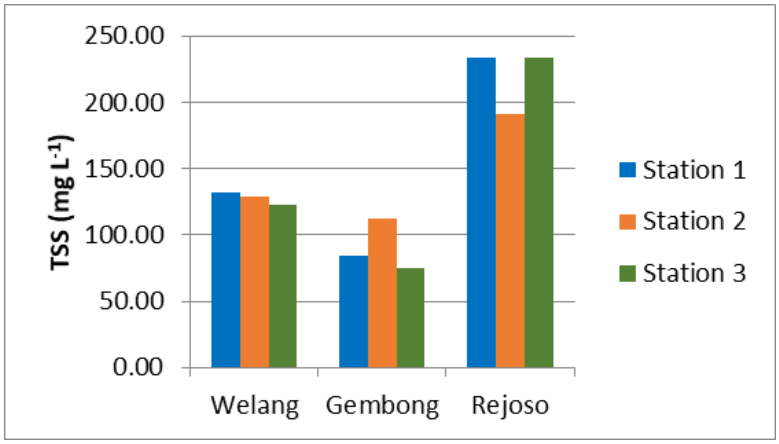

Figure 8. TSS (mg L^{-1}).

The average TSS in the lower reaches of the Welang River ranged from 122.98 to 132.25 mg L^{-1}, in the Gembong River it ranged from 75.13 to 111.90 mg L^{-1} and in the Rejoso

River it ranged from 191.48 to 233.65 mg L^{-1}. The highest TSS was found at stations 1 and 3 of the Rejoso River and the lowest is at station 3 of the Gembong River.

pH. The pH values downstream of the Welang, Gembong, and Rejoso rivers in Pasuruan are shown in Figure 9:

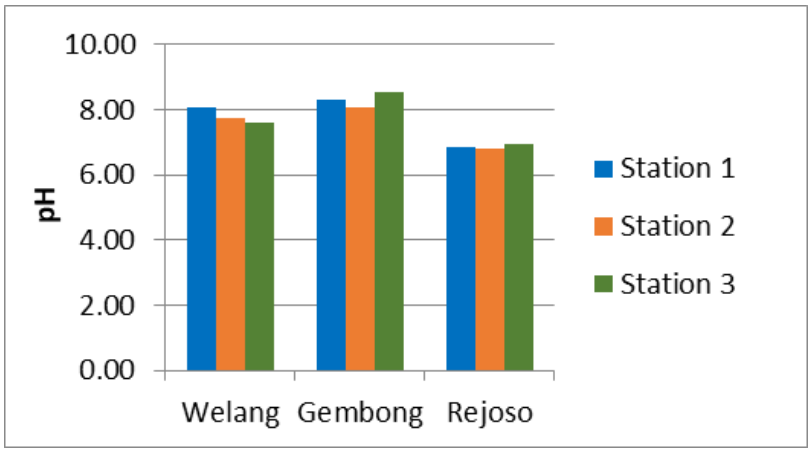

Figure 9. pH.

The average pH in the Welang River ranged from 7.59 to 8.05, in the Gembong River it ranged from 8.05 to 8.55 and on the Rejoso River it ranged from 6.80 to 6.93. The highest pH was found at station 3 on the Gembong River and the lowest at station 2 on the Rejoso River. Based on the results, the pH is still in good condition and normal to support the growth of biota, especially periphyton. According to (Agustin et al., 2019) the river's pH of 8 is good for living organisms. The optimum pH range for the life of Class Bacillariophyceae is 6.4–8.5 and their growth will be slowered if pH>9.

Dissolved oxygen. Dissolved oxygen values at the lower reaches of the Welang, Gembong, and Rejoso rivers in Pasuruan are shown in Figure 10:

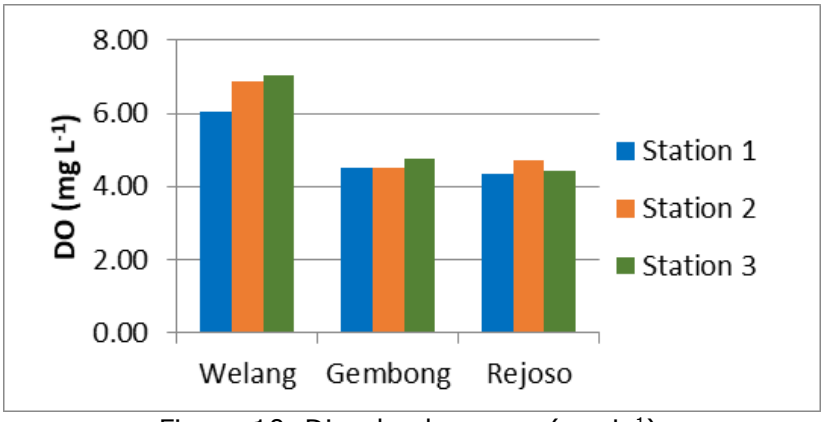

Figure 10. Dissolved oxygen (mg L^{-1}).

The average DO in the Welang River ranged from 6.07 to 7.04 mg L^{-1}, in the Gembong River it ranged from 4.50 to 4.78 mg L^{-1} and in the Rejoso River it ranged from 4.33 to 4.70 mg L^{-1}. The highest DO was found at Station 3 of the Welang River and the lowest at Station 1 of the Rejoso River.

Nitrates. Nitrates concentration values in the Welang, Gembong, and Rejoso rivers in Pasuruan are shown in Figure 11:

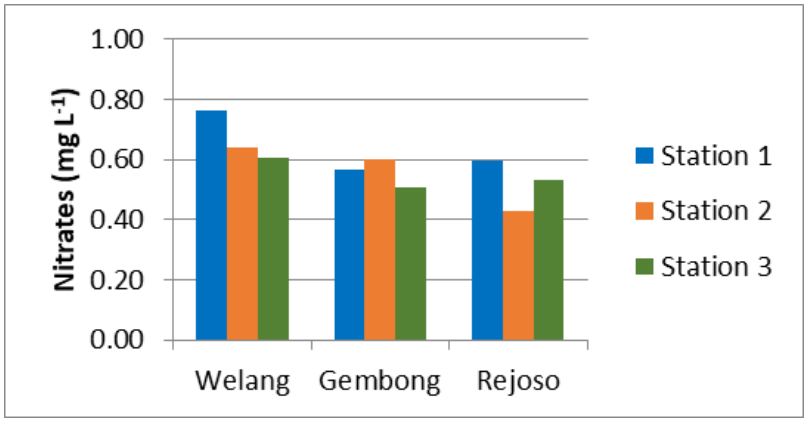

Figure 11. Nitrates (mg L^{-1}).

The average nitrate in the Welang River ranged from 0.61 to 0.76 mg L^{-1}, in the Gembong River it ranged from 0.51 to 0.60 mg L^{-1} and in the Rejoso River it ranged from 0.43 to 0.59 mg L^{-1}. The highest nitrate value was found at station 1 on the Welang River and the lowest at station 2 on the Rejoso River.

Orthophosphate. Orthophosphate concentration values in Welang, Gembong, and Rejoso Rivers in Pasuruan are shown in Figure 12:

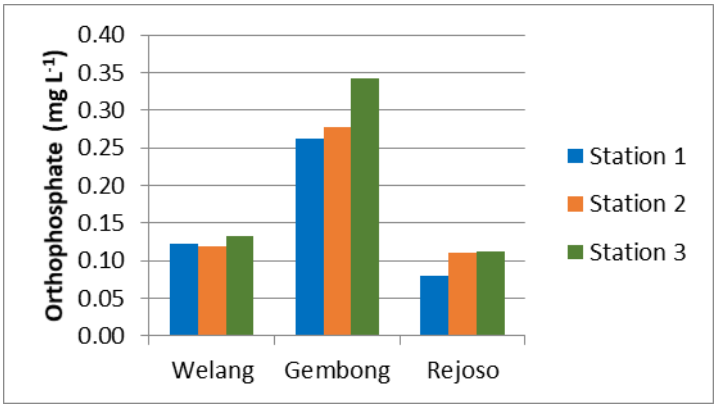

Figure 12. Orthophosphate (mg L^{-1}).

The average orthophosphate in the Welang River ranged from 0.12 to 0.13 mg L^{-1}, in the Gembong River it ranged from 0.26 to 0.34 mg L^{-1} and in the Rejoso River, it ranged from 0.08 to 0.11 mg L^{-1}. The highest orthophosphate was found at Station 3 on the Gembong River and the lowest at Station 1 on the Rejoso River.

Total Organic Matter (TOM). TOM concentration values on the Welang, Gembong, and Rejoso Rivers in Pasuruan are shown in Figure 13:

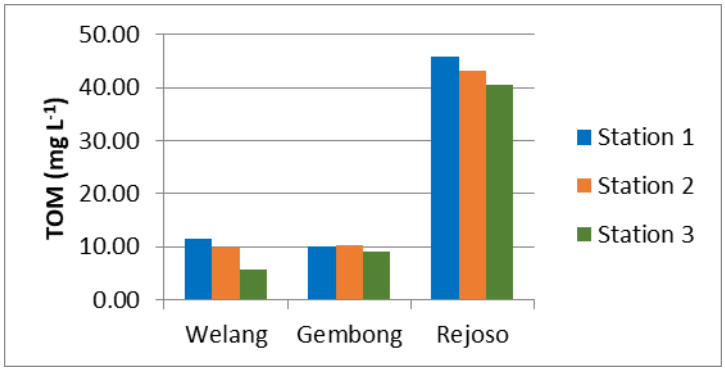

Figure 13. TOM (mg L^{-1}).

The average TOM in the Welang River ranged from 5.59 to 11.46 mg L^{-1}, in the Gembong River it ranged from 9.08 to 10.22 mg L^{-1} and in the Rejoso River it ranged from 40.58 to 45.87 mg L^{-1}. The highest TOM was found at station 1 on the Rejoso River and the lowest at station 3 on the Welang River.

Alkalinity. Alkalinity values downstream of the Welang, Gembong, and Rejoso rivers in Pasuruan are shown in Figure 14:

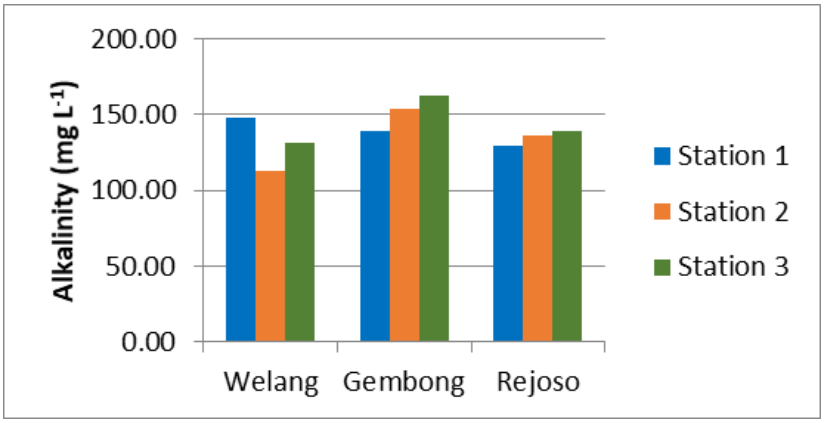

Figure 14. Alkalinity (mg L^{-1}).

The average alkalinity in the Welang River ranged from 112.93-148.28 mg L^{-1} in the Gembong River it ranged from 139.38 to 162.10 mg L^{-1} and in the Rejoso River it ranged from 129.11 to 138.62 mg L^{-1}. The highest alkalinity was found at Station 3 of the Gembong River and the lowest is at Station 2 of the Welang River.

Chemical Oxygen Demand (COD). COD values in the lower reaches of the Welang, Gembong, and Rejoso rivers in Pasuruan are shown in Figure 15:

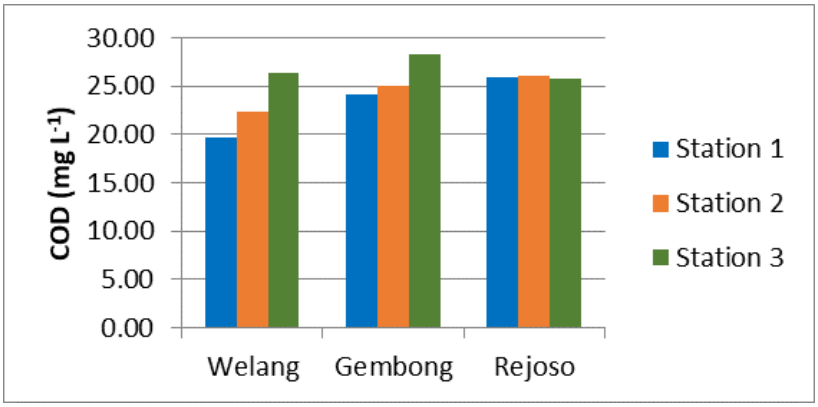

Figure 15. COD (mg L^{-1}).

The average COD in the lower reaches of the Welang River was of 19.65–26.30 mg L^{-1}, in the Gembong River it was of 24.10–28.25 mg L^{-1} and in the Rejoso River, it ranged from 25.74 to 26.01 mg L^{-1}. The highest COD Welang River. Based on the results, the average COD in the lower reaches of the Welang, Gembong, and Rejoso rivers is still optimal and has not exceeded the water quality standard. Andika et al (2020) stated that a good level of COD in the waters is 50 mg L^{-1}.

Total phosphate. Total phosphate (total P) in the lower reaches of the Welang, Gembong, and Rejoso Rivers in Pasuruan are shown in Figure 16:

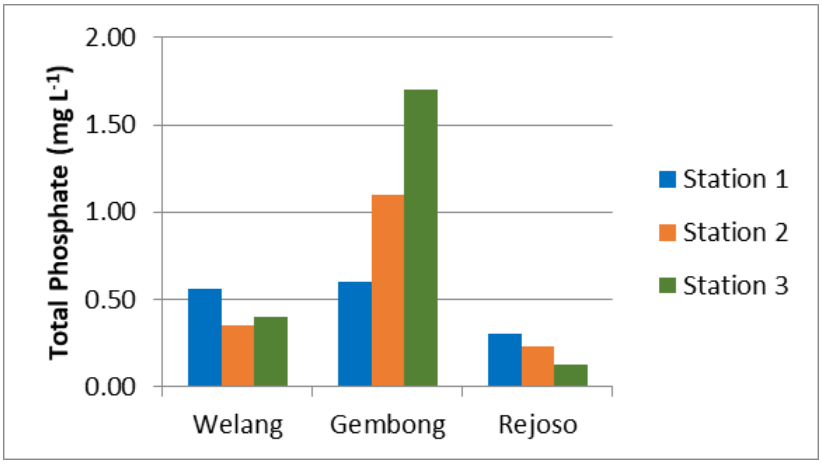

Figure 16. Total phosphate (mg L^{-1}).

The average total phosphate in the Welang River ranged from 0.35 to 0.56 mg L^{-1} in the Gembong River it ranged from 0.60 to 1.70 mg L^{-1} and in the Rejoso River it ranged from 0.13 to 0.31 mg L^{-1}. The highest total phosphate was found at Station 3 on the Gembong River and the lowest was at Station 3 on the Rejoso River.

Total nitrogen. Total nitrogen (total N) concentration values in the Welang, Gembong, and Rejoso rivers in Pasuruan are shown in Figure 17:

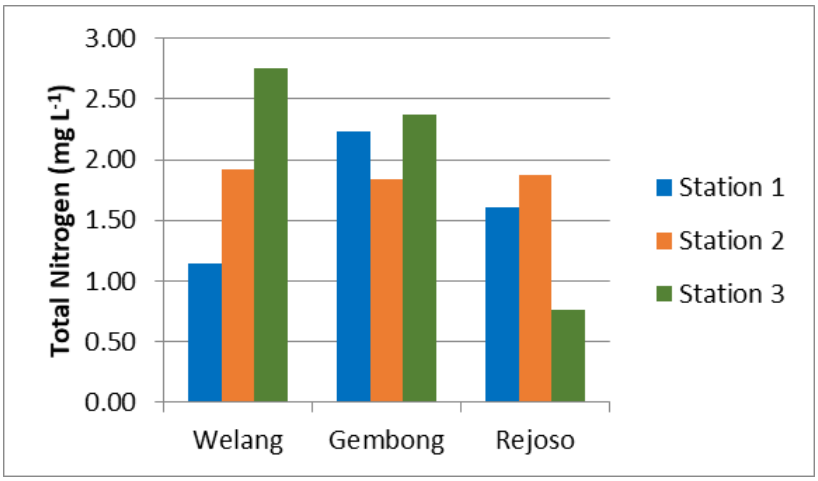

Figure 17. Total nitrogen (mg L^{-1}).

The average total nitrogen in the Welang River ranged from 1.15 to 2.75 mg L^{-1}, in the Gembong River it ranged from 1.84 to 2.38 mg $L^{-1}$and in the Rejoso River it ranged from 0.76 to 1.87 mg L^{-1}. The highest total nitrogen was found at station 3 on the Welang River and the lowest at station 3 on the Rejoso River. The total nitrogen in the lower reaches of the Welang, Gembong, and Rejoso rivers still meets the water quality standards. Based on Government Regulation Number 22 of 2021, the quality threshold of Total Nitrogen for a class III river designation is 20 mg L^{-1}.

Cadmium. Cadmium (Cd) concentration values in Welang, Gembong, and Rejoso Rivers in Pasuruan are shown in Figure 18. The average Cd in the Welang River ranges from 0.00 to 0.10 mg L^{-1}, in the Gembong River it ranged from 0.15 to 0.28 mg L^{-1} and in the Rejoso River it ranged from 0.09 to 0.15 mg L^{-1}. The highest Cd value was found at Station 1 on the Gembong River and the lowest at Stations 1 and 2 on the Welang River. Based on the average Cd values found in the Gembong and Rejoso rivers, Cd concentration has exceeded the value of 0.01, which is the permissible Cd value in the waters (Usman et al 2015).

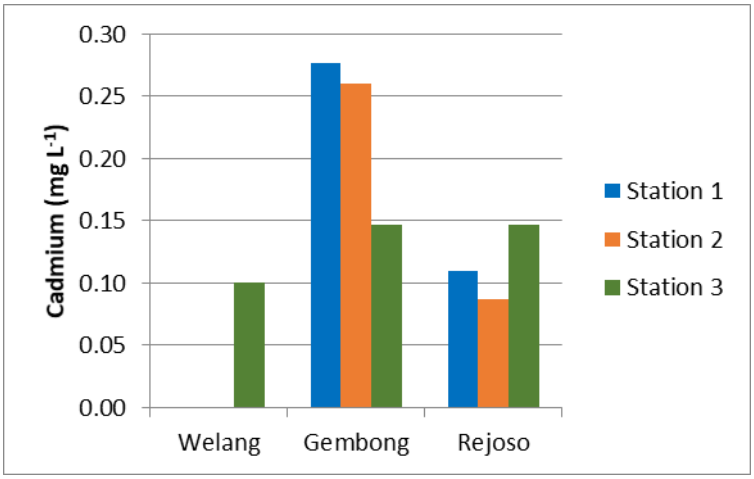

Figure 18. Cadmium (mg L^{-1}).

Analysis of river water quality status. The following are the results of the analysis of water quality status based on the STORET method in the lower reaches of the Welang, Gembong, and Rejoso rivers.

Table 4

Analysis of river water quality status

Location	*Station*	*Score total*	*Category*	*Pollution status*
Welang River	1	-28	Currently	Moderately polluted
	2	-26	Currently	Moderately polluted
	3	-46	Bad	Heavily polluted
Gembong River	1	-48	Bad	Heavily polluted
	2	-68	Bad	Heavily polluted
	3	-62	Bad	Heavily polluted
Rejoso River	1	-60	Bad	Heavily polluted
	2	-62	Bad	Heavily polluted
	3	-60	Bad	Heavily polluted

The results of the classification of the quality of the waters downstream of the Welang, Gembong, and Rejoso Rivers showed that the Welang River stations 1 and 2 were moderately polluted, while station 3 was heavily polluted. Gembong and Rejoso rivers have been included in the bad category, with heavily polluted water conditions. By the Decree of the Minister of Environment Number 115 of 2003 a score of 0 indicates a water status meeting the quality standards, a score of -1 to -10 is indicates lightly polluted waters, a score of -11 to -30 indicates moderately polluted waters and a score >-31 indicates heavily polluted waters.

Discussions. In accordance with Agustin et al (2019), there are 3 classes of waters, based on the periphyton density, namely: (1) oligotrophic waters, that have a low fertility level, with a periphyton density range of 0–2,000 cells cm^{-2}, (2) mesotrophic waters, that have a moderate fertility level, with a periphyton density range of 2,000–15,000 cells cm^{-2}, and (3) eutrophic waters, that have a high fertility rate, with a periphyton density >15,000 cells cm^{-2}.

Based on the values of chlorophyll-a, the lower reaches of the Welang, Gembong, and Rejoso rivers are classified as meso-oligotrophic waters, this is because of the average value of chlorophyll-a ranges from 2 to 5 mg L^{-1}. The content of chlorophyll-a which ranges from 0–2 mg L^{-1} is classified as oligotrophic, 2–5 mg L^{-1} is classified as meso-oligotrophic, 5–20 mg L^{-1} is classified as mesotrophic, 20–50 mg L^{-1} is classified as eutrophic and >50 mg L^{-1} is classified as hypertrophic (Wijayanto et al 2015).

From the calculation of fertility levels based on the TRIX index, it results that the downstream waters of the Welang, Gembong, and Rejoso rivers can be classified as oligotrophic, with low fertility levels. According to Linus et al (2016), TRIX levels ranging from 0-4 are specific for oligotrophic waters, 4-5 for mesotrophic, 5-6 are for eutrophic and 6-10 for hypertrophic waters.

The results of this research show that the temperature of the waters downstream of the Welang, Gembong, and Rejoso rivers is in the normal range and is good for the life of aquatic biota, according to Warma (2015), stating that the optimum temperature range for phytoplankton growth in waters is 20-30°C, while the optimal temperature range for fish life in tropical waters is 28-32°C. At a temperature of 18–25°C fish are still able to survive, but experience a decrease in appetite. Meanwhile, below this temperature, fish will die in tropical waters, due to cold. According to Yuniarno et al (2015), algae from the phylum Chlorophyta and diatoms will grow well within a temperature range of 30–35°C and 20–30°C, respectively, while the phylum Cyanophyta can tolerate a higher temperature range than Chlorophyta and diatoms.

Based on the average brightness, the Welang and Rejoso rivers have a low brightness level, while the Gembong River has an optimal brightness level for fresh waters, in line with Arsad et al (2019), who stated that the range of water brightness for fresh water is 25-40 cm, which includes productive waters. A low brightness is due to the lack of light penetration into the water body, usually caused by the high turbidity value (Saputra et al 2018).

The currents in the lower reaches of the Welang, Gembong, and Rejoso rivers have an average to fast current. According to Andriansyah et al (2014), the category of "medium current rivers" has current speeds ranging from 0.25 to 0.50 ms^{-1}. Only certain species that are strongly attached enough to survive the current. The average TSS value in the lower reaches of the Welang, Gembong, and Rejoso rivers is high and exceeds the class III PP no 22 of 2021 quality standard, which is 100 mg L^{-1}. The high TSS is influenced by the materials inflowing from the land, which are carried downstream by river flow, increasing the water turbidity due to the suspended matter (Winnarsih et al 2016). Based on the results, the pH is normal, able to support the growth of biota, especially periphyton. According to Agustin et al (2019), the river's pH of 8 is good for living organisms. The optimum pH range for the Bacillariophyceae class is 6.4–8.5 and their growth will slow down when the pH>9. DO levels in the lower reaches of the Welang, Gembong, and Rejoso rivers are classified as optimal and meet the class III of the quality standard based on Government Regulation Number 22 of 2021, with a minimum limit value of 3 mg L^{-1}. Yuniarno et al (2015) stated that aquatic organisms usually require oxygen concentrations in the range of 5-8 mg L^{-1}. The nitrate value in the downstream waters of the Welang, Gembong, and Rejoso rivers is optimal and meets the water quality standards. Algae can grow optimally at a nitrate content of 0.009–3.5 mg L^{-1} (Isnaeni et al 2015). The value of orthophosphate is normal and appropriate for periphyton growth. Orthophosphate contents of less than 0.004 mg L^{-1} will be a limiting factor for the microalgae growth, while orthophosphate levels of more than 1 mg L^{-1} can cause an algal population explosion or bloom (Arsad et al 2019).

TOM levels in the lower reaches of the Welang and Gembong rivers still meet the water quality standards. However, in the Rejoso River, the TOM value is very high and exceeds 30 mg L^{-1}, the value established by the PP No. 22 for the Year 2021. According to Sembiring et al (2012), a safe concentration of TOM is 30 mg L^{-1}. Based on the results, the average alkalinity in the lower reaches of the Welang, Gembong, and Rejoso rivers exceeds the class III water quality standard. The quality standard value for class III alkalinity according to the PP No. 22 of 2021 is 75 mg L^{-1}. A too high alkalinity is not appropriate for the aquatic organisms because, causing a high hardness value or high sodium content in waters (Husen 2016). Based on the results, the average COD in the lower reaches of the Welang, Gembong, and Rejoso rivers is still optimal and has not exceeded the water quality standard. This is in accordance with the statement of Andika et al (2020): a good level of COD in the waters is 50 mg L^{-1}. The value of total P in the Welang and Rejoso rivers is still below the maximum value established by the quality standard, but at the Gembong River's stations 2 and 3 it has exceeded the class III water

quality standard. According to Ma'rufatin & Dewanti (2020), the maximum total phosphate in class III rivers is 1 mg L^{-1}.

The polluted condition is indicated by several physical and chemical parameters whose values are not allowed by quality standards. In the Welang River, the parameters that exceed the quality standards are TSS and alkalinity. In the Gembong River, temperature, TSS, alkalinity, cadmium, and total P exceeded the thresholds. In the Rejoso River, the parameters that exceed the quality standard are TSS, alkalinity, cadmium, and TOM. Thus, the water quality in the three rivers in not appropriate for a class III water designation, negatively affecting the aquatic biota and the surrounding community. Water management efforts are needed for the three rivers, to restore the water quality.

Conclusions. Based on the results of the study, the average water quality status in the lower reaches of the Welang, Gembong, and Rejoso Rivers, based on the STORET method, is classified as bad, with the category "heavily polluted", according to the scoring results obtained at each station in each river. Parameters that exceed the class III quality standards are TSS, alkalinity, total P, TOM, and Cd. The value of primary productivity downstream of the Welang, Gembong, and Rejoso rivers, based on the Trophic Index method, is classified as oligotrophic, with low fertility levels, as indicated by the low values of periphyton abundance and chlorophyll-a levels in the river.

Conflict of interest. The authors declare no conflict of interest.

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