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Actual Status Assessment and Prediction of the Musi River Water Quality, Palembang, South Sumatra, Indonesia

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ABSTRACT

Water pollution in rivers is still a crucial problem for the countries that use river water as the primary water source. This study aimed to determine the water quality of the Musi river and the content of heavy metals in water, sediment and mussels as well as to predict the water quality of the Musi river in the next five years. The water samples were taken from 18 stations (sampling points) from upstream to downstream to be checked physically, chemically and biologically. Prediction of the river water quality was made using the QUAL2Kw software. The research results show that the Musi River water is categorized as lightly polluted with concentrations of TSS and DO that have passed the threshold. The heavy metals in river water, such as Pb and Cr have also passed the quality standard. The Fe, Mn, and Zn concentrations are pretty high in the sediment. In turn, in mussels, the metals measured were Fe, Cu, and Zn. The prediction results reveal that several values of the river quality parameters will pass the threshold value with the same pattern tendency from each station.

Keywords: heavy metals, pollution index, quality status, water pollution, sedimentation.

INTRODUCTION

Rivers are one of the primary sources of fresh water for the survival of humans and other living things (Adilah and Nadia, 2020). In its utilization, large rivers also function as transportation routes, and even some industries are located on the banks of the river. Transportation activities affect vegetation arrangement, which can have implications for erosion and abrasion that form sediments upstream, middle and downstream rivers (Beltaos and Burrell, 2021; Gabbud and Lane, 2016). This can lead to siltation and concentration of pollutants. Activities in the river also have a severe impact on the dissolved oxygen depletion.

Human activities, such as household waste disposal, industrial activities, and agriculture have had an impact on decreasing the river water quality. The decrease in water quality will reduce the usability, productivity, carrying capacity and capacity of water resources, reducing the wealth of natural resources. The addition of large quantities of waste material from upstream to downstream of the river will continuously result in the river being unable to recover (Bai et al., 2022). In the end, there was a disturbance in the balance of the concentration of the river's chemical, physical, and biological factors.

There are at least four major rivers in the middle of Palembang City, namely the Musi River, Komering River, Ogan River and

Keramasan River, all of which empty into the Musi River (Pradono et al., 2019). The Musi River is a source of drinking water, bathing, washing, transportation facilities, irrigating rice fields, livestock needs, and a place to keep fish and recreation. Additionally, the Musi River is often used as a place to dispose of liquid waste by industry. This behavior causes rivers to be vulnerable to pollution.

Several industries along the Musi River are rubber processing, wood processing, fertilizers, ceramics, detergents, oil, gas, cold storage, electroplating, soft drinks, and fabric dyeing. In addition to these industries, there are also stockpiles and ship barges. Most industries do not have an optimal Wastewater Treatment Plant (WWTP). In addition, the Musi River is also a shipping lane for various types of ships. The topography of the Palembang City area shows that the people who live on the banks of the Musi River are still dense (Putri et al., 2021). This contributes to the generation of domestic waste into the waters of the Musi River.

Throughout the author's search, the research that examines the river water quality in detail complete with future predictions is scarce, especially in the Musi River. This work is the first to thoroughly assess the water quality in the Musi River can predict the water quality for the next five years. The heavy metal content in water, sediment and mussels was also investigated.

MATERIALS AND METHOD

The location of study

The Musi River, with a length of 21.35 km from upstream (Pulo Kerto) to downstream (Sei Lais), is divided into 17 segments resulting in 18 sampling stations. Segmentation of rivers is based on input from tributaries, turns, changes in river dimensions and output from the river to the tributaries (Figure 1). Water sampling and analysis referred to the Indonesian national standard (SNI) and followed the work by Rusdiyanto et al. (2021).

Sampling method

Sampling of water, sediment and mussels in the Musi River, Palembang was divided into 18 stations. At each station, the water samples were taken to measure temperature and tested for levels of total suspended solids (TSS), total dissolve solid (TDS), dissolved oxygen (DO), pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), phosphate, nitrate, ammonium, and *Escherichia coli* levels. The results of the sample analysis were then compared with the quality standards that have been set for each parameter. The data from the analysis became the basis for predicting the water quality of the Musi River. Moreover, the content of heavy metals in water, sediment and mussels was analyzed.

River water quality prediction

The simulation process to predict the river water quality is carried out using QUAL2Kw software by utilizing the existing data from analyzing water quality and pollutant sources in the Musi River. The simulation was carried out to obtain projections for the next five years (2022–2026). The five-year span refers to Indonesian government regulation No. 82 of 2001, which states that

Figure 1. Maps of sampling location

the minimum capacity is determined once every five years. The domestic sector generated diffuse sources with the population along the Musi River 5 years earlier. The population for the next five years was calculated according to equation 1.

$$P_n = P_0 (1 + (r.n)) \quad (1)$$

where: P_n and P_0 were the total populations after the next n years and in the initial year, while r and n were the ratios of population growth and the time period in years.

The domestic waste emission factors for the BOD, COD and TSS parameters were obtained by multiplying the formula to calculate the pollution load from the household following equation 2.

$$\text{PBP} = \text{total population} \times \text{emission factors} \times \text{equivalent ratio} \times \alpha \quad (2)$$

PBP is a potential pollution load, while the emission factors (generation load) for BOD, COD, and TSS are 40, 55, and 39 g/person/day, respectively. The equivalent ratios for those used for urban, suburban, and rural areas are 1.0, 0.8125, and 0.625, respectively. Delivery load α = 1, used for areas located between 0 to 100 m from the river. The value of α = 0.85 for the locations between 100–500 m from the river. The value of α = 0.3 for the locations greater than 500 m from the river.

Pollution index

The pollution index (PI) is intended to show the level of pollution (Decree of the Minister of the Environment No. 115 of 2003) for class II. The criteria were determined based on scores, namely good ($0 \leq Pij \leq 1.0$), lightly polluted ($1.0 < Pij \leq 5.0$), moderately polluted $5.0 < Pij \leq 10.0$), and heavily polluted ($Pij \geq 10$).

RESULTS AND DISCUSSION

River water characteristics

The Musi river water temperature measured at 18 stations is in the range of 27–30°C (Figure 2). The normal water temperature is 25°C, with the minimum water quality standard threshold being 22°C and the maximum temperature being 28°C. Several sampling points have passed the maximum quality standard from the measurement results. This temperature is suitable for the tropics and is suitable for the living conditions of microorganisms such as eubacteria, fungi and protists. However, the higher the temperature in the water, the lower the dissolved oxygen content; thereby, the ability of aquatic organisms to survive is reduced. This applies to stations 1–2, 14–18) with a temperature of 29–30°C. Water temperature is influenced by vegetation or the cover of water bodies. If the vegetation that covers the body of water is low, it will make the temperature high (Samal et al., 2019). On the basis of the predictions for the next five years, it is known that the water temperature of the Musi River is in the range of 28.95–29.10°C. Several sampling points were previously below the quality standard, and in the next five years they will exceed the quality standard.

The pH value indicates the level of acidity in the river waters. The pH value of the Musi river water is shown in Figure 3. The results of

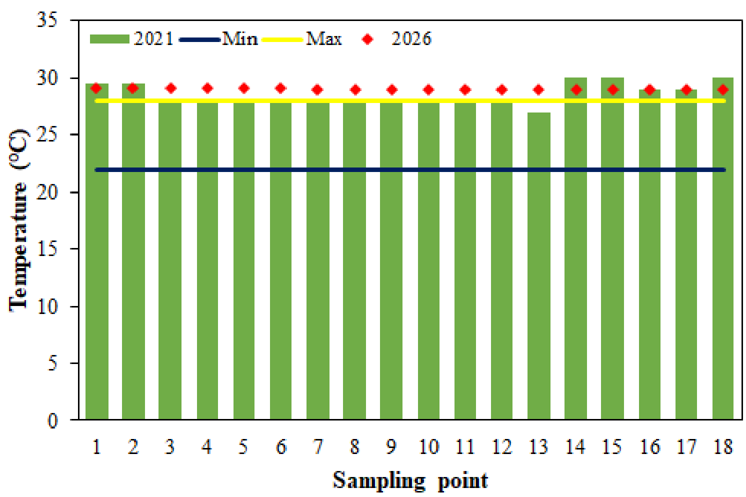

Figure 2. Water temperature of the Musi river among the sampling points

measuring pH or the degree of acidity at the measurement point have an average value of 6.5. This shows that the pH at the research site tends to be acidic, but point 14 has the highest pH value of 8. This shows that the pH at point 14 tends to be alkaline. All of these sampling points still meet the minimum and maximum quality standards. On the basis of the water quality standards, the pH value is good for growing and cultivating freshwater biota and irrigating plants. Most freshwater biotas are sensitive to changes in pH and prefer a pH between 6.5–8.5 (Anyanwu et al., 2019). Furthermore, biochemical processes such as nitrification are affected by the pH value. From the measurement results, at station 14, the pH value is higher, but it is still possible to survive biota in the river. It is still within the maximum quality standards. The pH of river water has slightly increased with a similar pattern at each station for the next five years. However, the pH remains below the quality standard.

Total suspended solids (TSS) are suspended material (diameter > 1 m) retained on a milli pore sieve with a pore diameter of 0.45 m (Mailisa et al., 2020). TSS consists of silt, fine sand, and microorganisms, mainly caused by soil erosion carried into rivers (Patandung et al., 2021; Wibowo et al., 2021). An increase in TSS causes an increase in cloudiness and reduces the sunlight entering the river. The results of the TSS analysis in the Musi River are shown in Figure 4. High TSS content occurs at the location at station 3, with a value of 84 mg/L. The TSS content has exceeded the threshold value of 50 mg/L. The variability of TSS in the Musi River is affected by the interaction of residential and industrial waste, water sediments, changes in salinity and transportation activities in the river, making it quite difficult to predict. Soil particles are transported due to rainwater runoff along with other impurities that enter the waters (Baensch-Baltruschat et al., 2021).

It is predicted that in the next five years, TSS will still pass the quality standard. The concentration of TSS also has a strong correlation with Cu, As, Fe and Ni metals. Heavy metals are carried along with organic or sediment loads. Suspended sediments carry metals into channels via surface runoff. Surface sediments carry heavy metals from anthropogenic sources into the river water (Bhaskar and Dixit, 2013; Liang et al., 2020).

BOD describes the organic matter levels. Organic matter is oxidized to CO_2 and H_2O by aerobic microbes (Abdel-gawad et al., 2017). These organic materials include fats, proteins, starch, glucose, aldehydes, and esters. The results of BOD measurements in the Musi River waters at 18 points are shown in Figure 5. The lowest BOD value is 0.6 mg/L at station 13, while the highest is at station 1 at 2.12 mg/L. Overall, the BOD value of the Musi River still meets the class II quality standard, although two stations have passed the quality standard. The low amount of organic matter in the Musi River causes the BOD value to be below the threshold. However, the prediction results show that in 2026 the BOD concentration will be slightly above the quality standard.

To be chemically oxidized, the organic matter requires a certain amount of oxygen, known as chemical oxygen demand (COD). Water pollution can also be measured through the COD

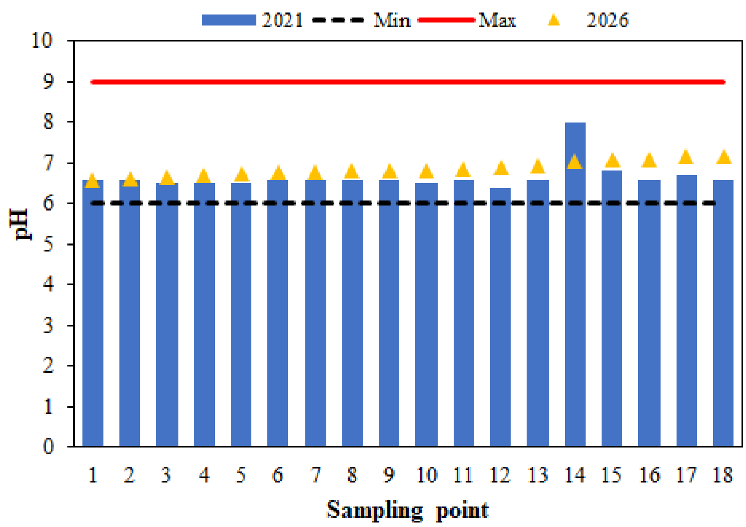

Figure 3. The pH value of the Musi River

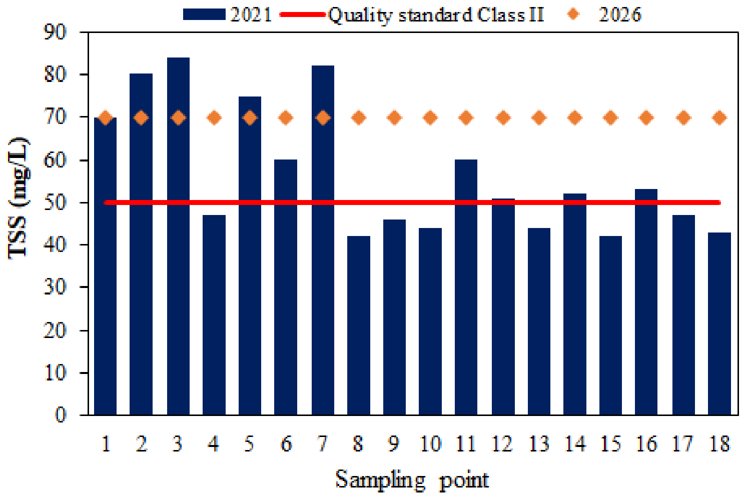

Figure 4. Total suspended solid content in the Musi River

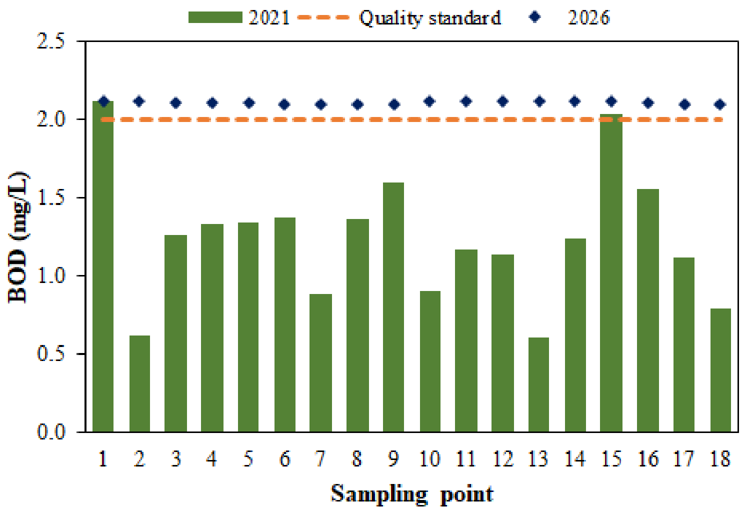

Figure 5. BOD content in the waters of the Musi River

value (Kumar et al., 2019). The results of COD measurements in the waters of the Musi River are presented in Figure 6. The COD measurements at the measurement point show the highest value of 65 mg/L at point 10. On the basis of the quality standard of Indonesian Government Regulation no. 22 of 2021, the value of the class II quality standard for COD is 25 mg/L. Therefore, it can be concluded that stations 9 and 10 have exceeded the quality standard. This is caused by waste in the body of water. Household, agricultural, and industrial waste are all examples of the waste that can impact the high value of COD concentration, with household and industrial waste producing the most waste (Wang et al., 2020).

The DO measurement results in the Musi River are presented in Figure 7. The dissolved oxygen levels also fluctuated at each sampling point. Dissolved oxygen is affected by temperature. The greater the temperature, the lower the dissolved oxygen content (Null et al., 2017). The DO measurement results at the measurement point show an average value of 7–8 mg/L. It can be concluded that the dissolved oxygen at all sampling points has passed the quality standard. DO has a suggested quality guideline of 6 mg/L. The excess of precipitation into the river causes this circumstance. The oxygen concentration of water rises as temperature falls and falls as salinity rises (Ponce-Palafox et al., 2019). Furthermore, it was suggested that oxygen is a significant indication of water quality since dissolved oxygen is involved in the oxidation and reduction of organic and inorganic components. Temperature influences the solubility of oxygen in water at a given pressure. Another factor that affects the solubility

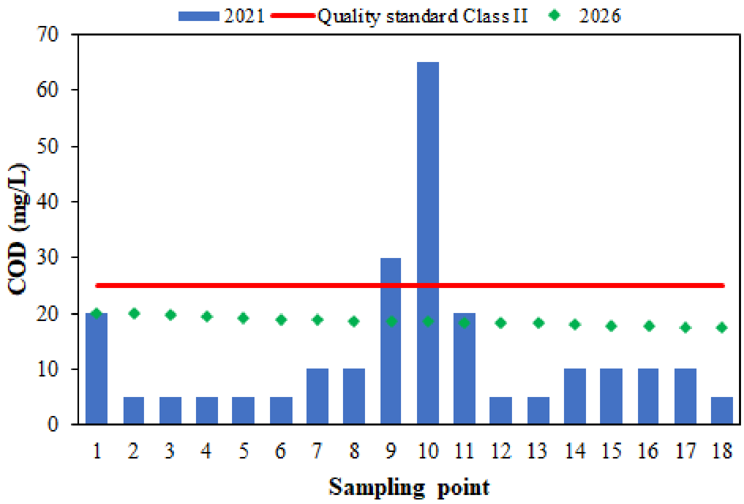

Figure 6. COD concentration in the Musi River

of oxygen is turbulence and the surface area of water that is open to the atmosphere (Piatka et al., 2021). Moreover, the Musi River is included in the category of a large river with a swift current.

The results of the nitrate measurement at the measurement station showed the lowest value of <0.01 mg/L at point 5, while the highest value was 0.2 mg/L at point 1 (Figure 8). All 18 stations still meet the quality standard for the nitrate concentration class (10 mg/L), despite the predicted concentration of nitrate. The phosphate concentration varies at each station in the Musi River (Figure 9) which is influenced by the pollution level and the area of the river. The concentration of phosphate is controlled by the pollution load from human activities and agricultural and industrial sectors (Wojtkowska and Bojanowski, 2018). Using products for washing and non-reduced industrial effluents causes foamy water and reduces oxygen uptake. However, the survey results show that many still use the river for bathing, washing, and toileting.

The ammonia concentration values in the Musi River ranged from 0.022 to 7.134 mg/L (Figure 10). The concentration of the ammonia value should not exceed the ammonia parameter value of 0.2 mg/L. The prediction results indicate a potential increase in ammonia to 8.715 mg/L. This high concentration of ammonia was found at station 14, where there is a fertilizer industry that uses ammonia as raw material.

Heavy metal content in Musi River water

Heavy metals can be found in nature or as by-products of human operations, such as industry and mining. Iron, for example, is frequently found

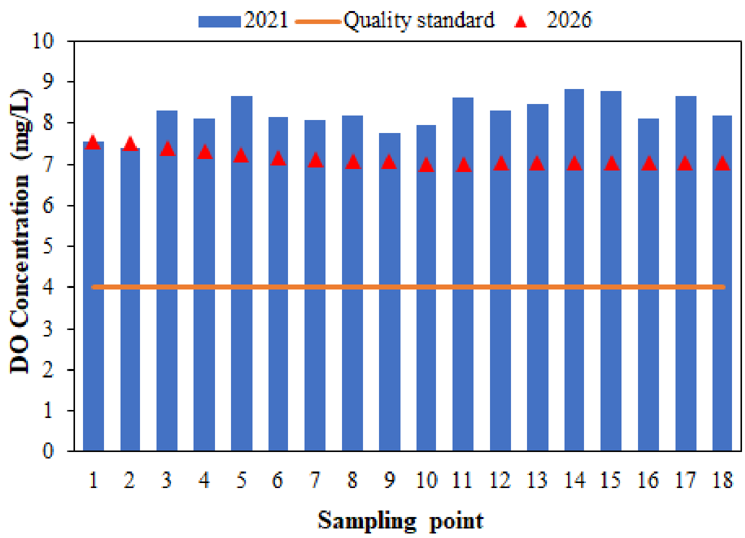

Figure 7. DO concentration in the Musi River

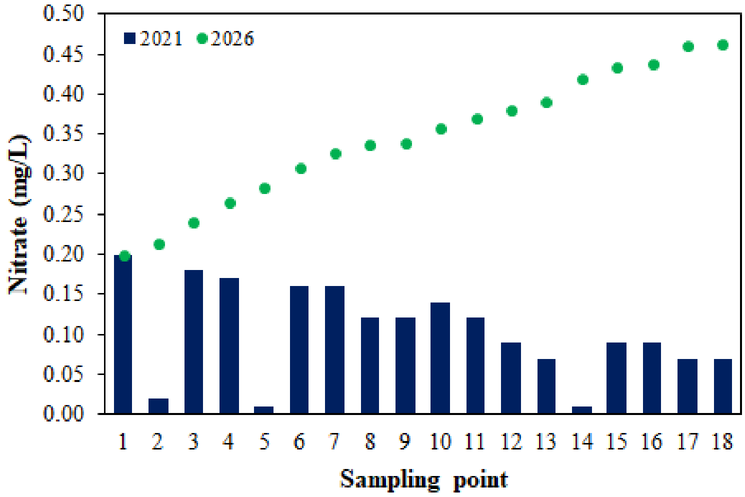

Figure 8. Nitrate concentration in the Musi River

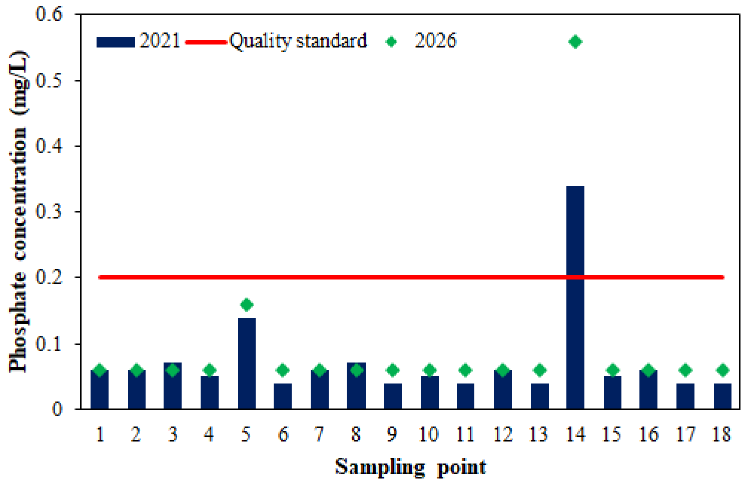

Figure 9. Phosphate concentration in the Musi River

in aquifers or soils in volcanic areas as part of the natural element cycle (Syakti et al., 2015). The heavy metal content of the Musi river water at 18 sampling stations was investigated (Table 1). From the measurement results, the highest iron content was 1.337 mg/L at station 9. Overall, all stations still met the quality standard for the iron content.

The highest cadmium content was found at station 6 at 0.011 mg/L and has exceeded the threshold (0.010 mg/L). This may be due to the transport and enrichment of metals from nearby streams to the mainstream. Cadmium is below the detection limit in river water and suspended sediments but is present in very small concentrations in bottom sediments. The long residence time of the bottom sediments can provide an appropriate platform for the metal to bind to it.

The measurement results of hexavalent chromium VI at the measurement point have the lowest value of 0.038 mg/L at station 10. At the same time, the highest value is 0.101 mg/L at station 7 with densely populated areas on the banks of the river. Thus, all sampling points other than station 1 have exceeded the river water quality standard threshold. Chromium is strongly attached to the soil surface and is thus absent in river water due to its poor dissolution ability. The sources of Cr in the study area can be caused by iron shale and weathering of intrusive rocks, water transportation, and residential and industrial waste. In the upstream part of the river, Cr is present in higher concentrations in the bottom sediment, which is gradually concentrated in the suspended sediment along its downstream, probably due to its finer grain size than the bottom sediment, which provides a wider specific surface area for scavenging metals resulting in enrichment by surface adsorption and ion attraction.

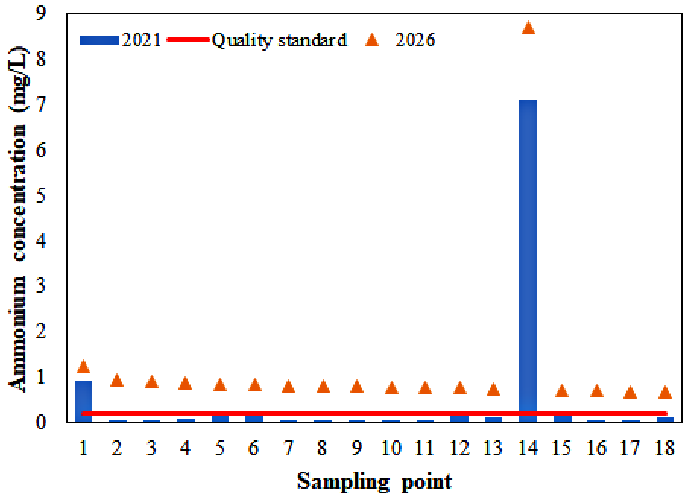

Figure 10. Ammonium concentration in the Musi River

On the basis of the research results, the highest concentration of Pb (0.29 mg/L) was found at station 20. All sampling points except stations 1 and 2 exceeded the threshold value. The zinc measurement results at the measurement point have the lowest value of <0.003 mg/L from station 2 to station 20, and the highest value is 0.011 mg/L at station 1. However, the results show that 18 concentrations of heavy zinc metal still meet the quality standard. The same was found for the CN^-, Mn, As, and Se concentrations.

The analysis of the *E. Coli* content in the Musi river water at all points showed that the *E. Coli* content >1600/100 mL. This demonstrates that the river water includes a high concentration of organic materials, which serves as a source of microbial life. The amount of pathogenic bacteria in water will grow if the organic matter level of the water is high enough to serve as a home and source of life for microorganisms. Because the population is very dense on the outskirts, it has the potential to pollute the Musi River.

Heavy metal content in sediments and mussels

The heavy metal content in the measured sediments is shown in Table 2. The heavy metal content of the sediment samples is dominated by

Table 1. Heavy metal content of the Musi river water

Sampling point	Fe (mg/kg)	Cd (mg/kg)	Cr HV (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	CN^- (mg/kg)	Mn (mg/kg)	As (mg/kg)	Se (mg/kg)
1	0.462	0.0065	0.049	0.013	0.011	0.001	0.077	<0.008	<0.0036
2	0.610	0.0065	0.066	0.026	<0.003	0.003	0.068	<0.008	<0.0036
3	0.858	<0.003	0.082	0.039	<0.003	0.003	0.066	<0.008	<0.0036
4	0.799	<0.007	0.087	0.052	<0.003	0.003	0.059	<0.008	<0.0036
5	0.607	0.003	0.093	0.118	<0.003	0.002	0.174	<0.008	<0.0036
6	0.675	0.011	0.080	0.105	<0.003	0.003	0.040	<0.008	<0.0036
7	0.778	0.008	0.101	0.131	<0.003	0.004	0.056	<0.008	<0.0036
8	0.994	<0.003	0.068	0.131	<0.003	0.002	0.074	<0.008	<0.0036
9	1.337	0.004	0.083	0.184	<0.003	0.002	0.032	<0.008	<0.0036
10	1.183	<0.003	0.069	0.184	<0.003	0.002	0.057	<0.008	<0.0036
11	1.296	0.008	0.067	0.236	<0.003	0.002	0.058	<0.008	<0.0036
12	1.204	0.003	0.073	0.197	<0.003	0.003	0.054	<0.008	<0.0036
13	1.086	0.006	0.055	0.223	<0.003	0.003	0.075	<0.008	<0.0036
14	1.189	<0.003	0.064	0.118	<0.003	0.003	0.066	<0.008	<0.0036
15	0.873	0.006	0.071	0.092	<0.003	0.003	0.062	<0.008	<0.0036
16	0.935	0.007	0.074	0.290	<0.003	0.002	0.061	<0.008	<0.0036
17	0.973	0.005	0.069	0.039	<0.003	0.004	0.027	<0.008	<0.0036
18	1.086	<0.003	0.059	0.052	<0.003	0.003	0.072	<0.008	<0.0036
Quality standard	-	0.010	0.050	0.030	0.050	0.020	-	0.05	0.05

Fe, Mn, Zn, and Pb. Heavy metals have persistence, environmental toxicity, and bioaccumulation in aquatic ecosystems (Jordanova et al., 2018). Heavy metals usually quickly settle into sediments after entering rivers (Shyleshchandran et al., 2018). Heavy metals are more concentrated in sediments than in water bodies of river systems (Liu et al., 2018). River sediments serve as reservoirs for heavy metals. This results in increased concentrations in sediments, compared to river systems. If the hydrodynamic conditions change or the physicochemical equilibrium changes, the metals present in the sediment can be released back into the water, causing secondary pollution (Hill et al., 2013). Therefore, where sediment acts as a secondary source for heavy metals, there is the potential to use sediment as an effective environmental medium for monitoring and evaluating the magnitude and source of heavy metal pollution in the aquatic environment (Cui et al., 2019).

Mussels are also used as an indicator of environmental pollution. The results of the metal content test in mussels are summarized in Table 3. Of the 18 stations, mussels were found in only two stations. In this study, the concentrations of Fe, Cu, and Ni in mussels were measured. Copper (Cu) is very dangerous if dissolved levels in the human body are high enough or exceed the permissible threshold. The main cause why heavy metals are dangerous pollutants is because heavy metals cannot be destroyed by living organisms in the environment and accumulate in the environment, mainly settling on the bottom of the water to form complex compounds with organic and inorganic materials through absorption (Ode et al., 2022; Saravanan et al., 2021; Sharma et al., 2021). As with mussels, mussels have been used extensively to monitor pollution in the aquatic environment (Azizi et al., 2018; Oliveira et al., 2016). Heavy metals accumulate in aquatic organisms at concentrations many times higher than in water, and can biomagnify in the food chain to the levels that cause physiological harm to humans as consumers (EL-Shenawy et al., 2016).

Heavy metals tend to accumulate in human organs and nervous systems and interfere with their normal functions. In recent years, nickel (Ni), copper (Cu), and zinc (Zn) have caused health problems. In addition, cardiovascular disease, kidney-related problems, neurocognitive diseases, and cancer are associated with trace metals such as cadmium (Cd) and chromium (Cr). Pb is known to slow down the physical and mental growth in infants (Rahmanian et al., 2015).

Table 3. Heavy metal content in a mussel of the Musi River

Sampling point	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Ni (mg/kg)
1	0.0021	1.8061	1.5146	0.028
2	0.0038	0.0534	1.2286	0.0312

Table 2. Heavy metal content in the sediments of the Musi River

Sampling point	Fe (mg/kg)	Cd (mg/kg)	Cr HV (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	CN- (mg/kg)	Mn (mg/kg)	As (mg/kg)	Se (mg/kg)
1	18254.6	0.0065	< 2.5	2.49	261.44	< 0.2	251.22	0.36	2.71
2	19277.9	0.0065	2.81	15.02	153.59	< 0.2	218.94	0.6	4.69
3	12317.07	<0.003	< 2.5	2.88	110.3	< 0.2	146.36	0.32	4.89
4	60853.3	<0.007	6.42	23.46	102.14	< 0.2	20.98	1.01	7.42
5	10896.09	0.003	< 2.5	5.08	92.38	< 0.2	35.89	0.94	9.36
6	23238.66	0.011	< 2.5	11.34	196.02	<.0.2	87.02	0.93	5.56
7	21878.21	0.008	3.83	14.37	138.48	<.0.2	289.48	0.82	9.69
8	13940.4	<0.003	< 2.5	4.56	128.26	<.0.2	199.32	0.78	8.3
9	12509.52	0.004	< 2.5	8.89	91.51	< 0.2	18.43	0.73	4.28
10	16312.88	<0.003	23.55	2.84	224.34	< 0.2	126.97	0.55	4.16
11	23819.42	0.008	7.48	8.87	141.37	< 0.2	331.32	0.94	8.81
12	20785	0.003	7.48	3.01	135.54	0.4	336.57	0.96	7.83
13	21863.76	0.006	2.64	2.88	166.56	< 0.2	310.23	0.94	7.85
14	20840.3	<0.003	5.42	2.59	218.38	< 0.2	142.64	0.99	2.03
15	3275.95	0.006	< 2.5	7.31	167.74	< 0.2	242.98	1.02	3.44
16	19261.82	0.005	< 2.5	9.6	367.9	< 0.2	161.01	9.6	7.54
17	115.31	<0.003	5.75	4.52	157.47	0.3	183.07	0.88	7.94
18	19221.83	0.007	3.25	4.47	146.05	< 0.2	203.15	0.59	3.11

Pollution index result

Water quality management referring to the pollution index (PI), can provide the suggestions for assessing water quality and taking the action to improve the water quality when there is a decrease in quality due to the occurrence of pollutants. On the basis of the pollution index analysis, the Musi River classification was obtained at each station (Table 4). The Musi River water quality is different at each station. However, there are two types of quality from 18 stations: good (Station of 4–6, 8–9, 11–13, 16–17) and lightly polluted (Station of 1–3, 7, 10, 14–15, and 18). The PI at stations categorized as good ranged from 0.53–0.98, while for the lightly polluted category, it ranged from 1.05 to 4.45. At the stations classified as good, the water quality may still support the life of fish and other aquatic creatures in the river. Values were obtained from all parameters and three samplings. In general, the condition of water quality in the upper reaches of the Musi River based on the pollution index can be classified as lightly polluted.

Table 4. Quality status of the Musi River in different sampling points

Sampling point	Pollution index	Quality status
1	2.25	Lightly polluted
2	1.05	Lightly polluted
3	1.09	Lightly polluted
4	0.54	Good
5	0.98	Good
6	0.74	Good
7	1.07	Lightly polluted
8	0.53	Good
9	0.75	Good
10	1.57	Lightly polluted
11	0.73	Good
12	0.57	Good
13	0.47	Good
14	4.45	Lightly polluted
15	1.09	Lightly polluted
16	0.85	Good
17	0.84	Good
18	1.08	Lightly polluted

CONCLUSIONS

The actual assessment of the Musi River is classified as lightly polluted based on the sampling station. Several parameters, such as TSS and DO have exceeded the specified quality standard values. The Musi River water also contains the heavy metals that have passed the threshold values, namely Pb and Cr. Meanwhile, high Fe, Mn, and Zn contents were found in the sediments. In mussels, the Fe, Cu, Zn, and Ni contents were found. Pollution comes not only from community activities along the river, but also from industry and runoff from agricultural activities. The results of this investigation can be a reference for the relevant government to take steps and policies to overcome the pollution in the Musi River.

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