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Analysis of metal pollution index in waters in the central Java area, Indonesia

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Abstract: Central Java is one of the regions in Indonesia with a lot of water resources that must be appropriately managed. In addition, metal content in water bodies in Central Java must now be assessed to prevent health impacts that may be measurable. One of the methods to analyze the management of water bodies is the water quality index method. This study aimed to examine the water quality index due to metal contamination in water bodies in Central Java. Metal measurements were carried out using the AAS (Atomic Absorption Spectrophotometry) method. The value of the water quality index using the water quality index method for waters in Central Java in 2015-2018 was categorized to mild to moderately polluted, and only 2 locations were measured as heavily polluted. Two areas that are included in the heavily polluted category were the waters of Bulakan and Bojonegoro in 2016. To determine the cause of why the water quality index value being classified as moderately polluted and lightly polluted, we must look at the metal parameters that contribute the most to the index value. These parameters can be initial information on the pollutant source that causes pollution.

Keywords: metal pollution; water quality; water quality index; pollution index; central java

INTRODUCTION

Pollutants in the aquatic environment generally come from the deposition of substances resulting from human activities (Bashir *et al*., 2020; Häder *et al*., 2020). Due to population growth and increased resource consumption, industrial development will increase the severity of pollution of natural resources. Pollutants that enter the waters result from pesticides, fertilizers, domestic and industrial waste (liquid waste), transportation, and deposition from the air (Helmy *et al*., 2022; Sarwono *et al*., 2022; Suryawan *et al*., 2021). Naturally, heavy metals that enter the aquatic system can come from weathering of soil, rocks, and human activities, such as industrial and residential waste discharged into water bodies (Akhtar *et al*., 2021; Vardhan *et al*., 2019; Yan *et al*., 2018).

Many rivers in Indonesia have been polluted and are no longer suitable for consumption for various needs (Belinawati *et al*., 2018; Suriadikusumah *et al*., 2021). Even river water from within the forest area is suspected of having been contaminated with a lot of pollutant substances. The problems above become the main challenges towards good quality water, so there is a need for efforts to protect public health. The occurrence of a change in the waters will impact the organisms that live in it. The presence of heavy metals in waters is acutely toxic to the life of aquatic biota, which indirectly affects human health. This is related to the properties of heavy metals that cannot degrade so that they accumulate in the aquatic environment (Zhang *et al*., 2014), and therefore can accumulate in aquatic biotas such as shellfish and fish as well as in sediments.

Heavy metal pollution in water bodies in Central Java is currently very concerning (Susanti *et al*., 2020; Tjahjono *et al*., 2017). The entry of pollutants may reduce the potential biological resources. Pollution by industrial materials containing hazardous materials, such as mercury (Hg), Cadmium (Cd), lead (Pb) tends to increase cases of poisoning and public health problems. The main cause of heavy metals being hazardous pollutants, namely that they cannot be destroyed (non-degradable) by living organisms in the environment and accumulates in the environment, especially settling on the bottom of the water to form complex compounds with organic and inorganic

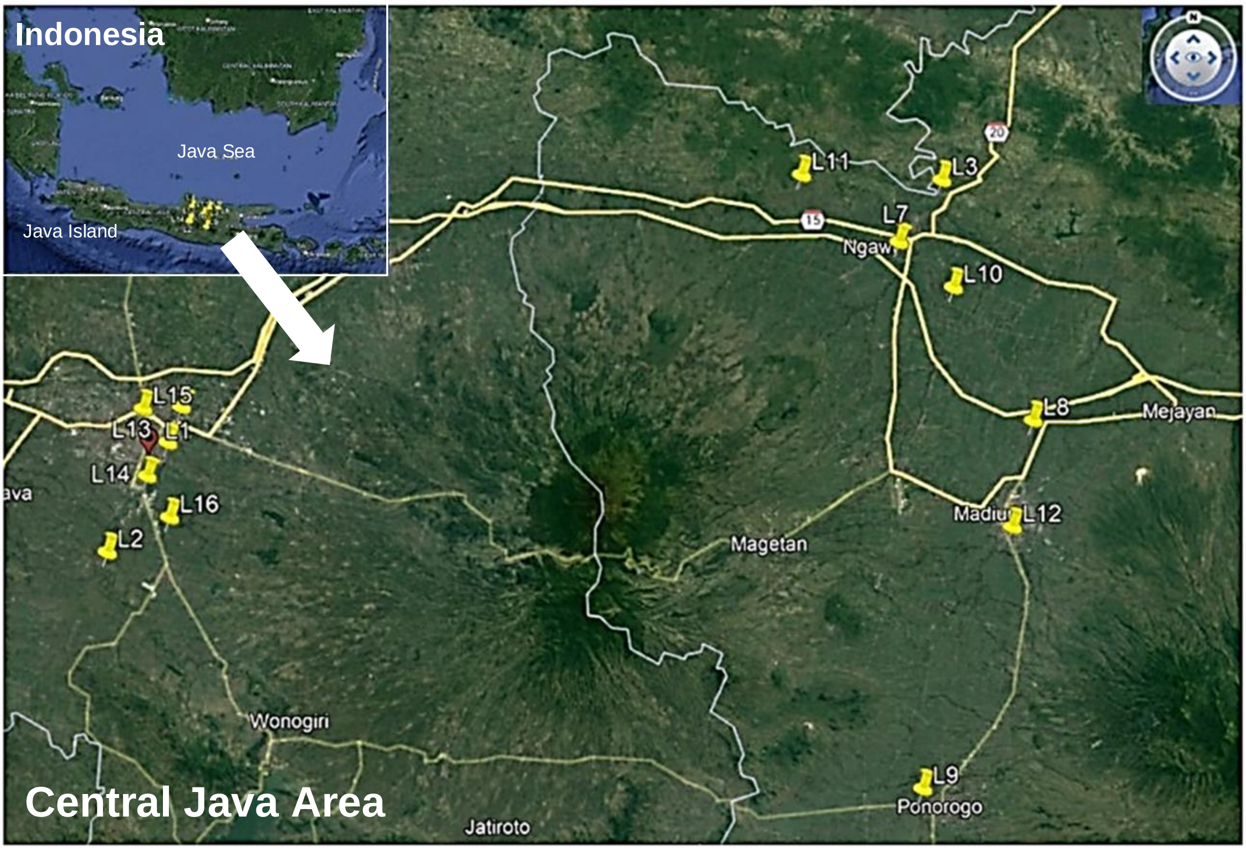

Figure 1. Water sampling locations whitin the central Java, Java Island, Indonesia

materials by adsorption and combination. Aquatic biota that lives in waters polluted with heavy metals can accumulate these heavy metals in their body tissues. The higher the metal content in the waters, the higher the heavy metal content accumulates in the animal's body (Azizi *et al.*, 2018).

Table 1. Sampling Locations

No	Name of village as sampling location	Code
1	Jebres	L1
2	Bulakan	L2
3	Napel	L3
4	Kajangan	L4
5	Cepu	L5
6	Bojonegoro	L6
7	Beran	L7
8	Lebak Kayu	L8
9	PingirSari	L9
10	Mangunharjo	L10
11	Cengklik	L11
12	Demangan	L12
13	Semanggi	L13
14	Bacem, Sukoharjo	L14
15	Embanmati	L15
16	Peren	L16

The water quality index aims to present a value representing water quality (Abbasnia *et al.*, 2019; Septiariva and Suryawan, 2021). Indonesia has two commonly used water quality index methods: the Pollution Index method and the Storet method. Both methods provide freedom in determining the type and number of parameters used and the use of local water quality standards. The difference lies in the data requirements. The Pollution Index method is taken from one monitoring, while the Storet method requires data from several monitoring results. This study aimed to study the water quality index caused by metal contamination in water bodies in Central Java.

MATERIALS AND METHODS

The data used in this study are secondary data from local governments. The location of the sampling points consists of 16 points (Figure 1; Table 1). Sample analysis was carried out in Surakarta municipal government laboratory. Water quality data used for this study was from 2015 to 2018.

The metal content examined in this study were Fe, Mn, Pb, Cu, Cr^{6+}, and Ni. Grab sampling used for one-time manual sampling that is carried out by

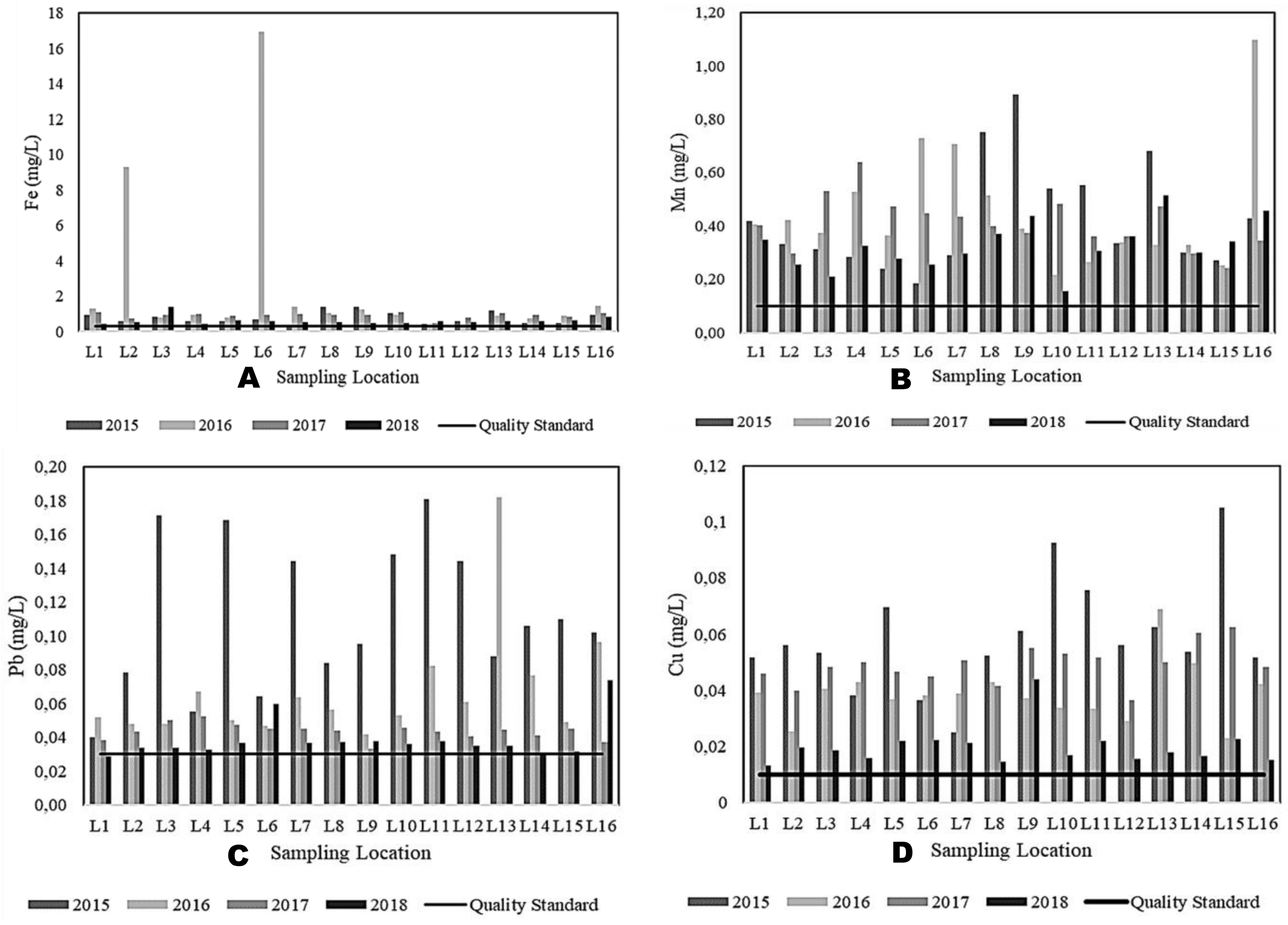

Figure 2. Concentration of Fe (A), Mn (B), Pb (C), and Cu (D) in the water body of the study areas

sampling first, then further analysis was carried out in laboratory. Water Sample of 1 L was put into a glass bottle and was given a few drops of HNO_3 to pH < 2. This treatment was to prevent the metal from oxidizing, settling, or settling on the wall or bottom of the container. The water samples were then placed in an icebox and stored in a refrigerator in the laboratory. Prior to the analysis, the sample was removed from the refrigerator and allowed to return to room temperature (20 – 25 °C), shaken, and then prepared for analysis by using AAS (Atomic Absorption Spectrophotometry).

Quality standards for water was based on Indonesian Government Regulation No. 82 of 2001 for class I (Pemerintah Republik Indonesia, 2001) water quality and USPA National Recommended Water Quality Criteria 2004 (only for Ni parameters). The pollution index was used to determine the pollution level relative to permitted water quality parameters. Evaluation of pollution index values was done as the following:

$0 < WQI \leq 1.0$ = meets quality standards
$1.0 < WQI \leq 5.0$ = lightly polluted
$5.0 < WQI \leq 10.0$ = moderately polluted
$WQI > 10.0$ = heavily polluted

RESULTS AND DISCUSSIONS

Figure 2A shows the content of Fe metal in the study area. Fe is an essential metal that in certain quantities is needed by living organisms, but it can cause toxic effects in excess amounts. High content of Fe metal will have an impact on human health, including poisoning (vomiting), intestinal damage, premature aging to sudden death, arthritis, congenital disabilities, bleeding gums, cancer, kidney cirrhosis, constipation, diabetes, diarrhea, dizziness, fatigue, hepatitis, hypertension, insomnia (Ismiyati *et al*., 2021; Supriyantini and Endrawati, 2015).

Fe and Mn in water can cause turbidity, corrosion, and hardness. Fe and Mn also cause a yellowish color in laundry and plumbing equipment (Zhang *et al*., 2020). The technologies commonly used to remove Fe and Mn include membrane technology, adsorption, ion exchange, and precipitation. Figure 2B shows Mn content at the study sites. The permissible content of manganese in water used for domestic purposes is below 0.05 mg/L.

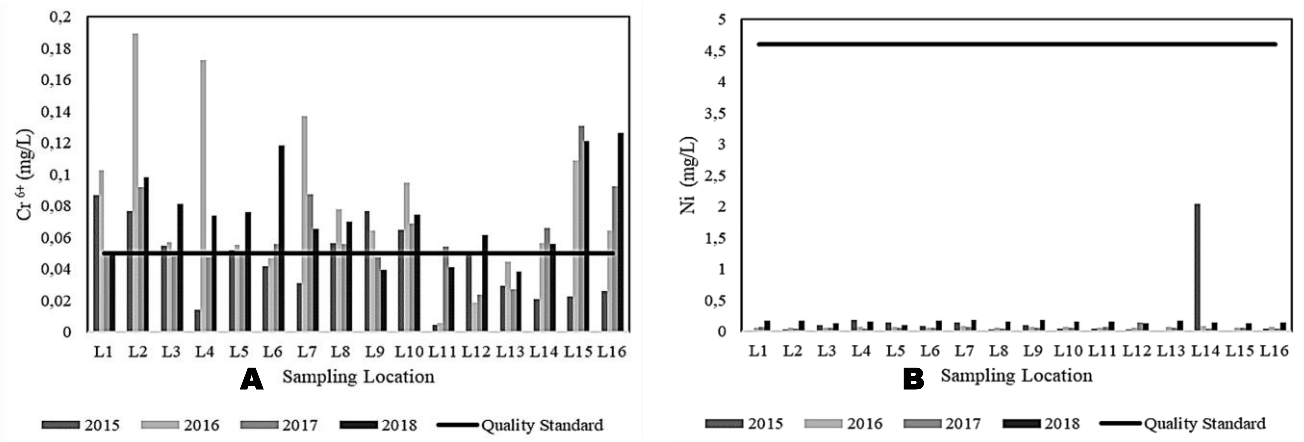

Figure 3. Concentration of Cr^{6+} (A) and Ni (B) in the water body of the study areas

The presence of heavy metals in sediments is considered pollution if the concentration exceeds the specified threshold. Heavy metals enter water bodies and settle in sediments through three stages: rainfall, adsorption, and absorption by aquatic organisms (Apritama *et al*., 2020; Saravanan *et al*., 2021). Heavy metals in the aquatic environment will be adsorbed by particles and then accumulate in the sediment (Brennecke *et al*., 2016). Heavy metals have the property of binding other particles and organic matter and then settling to the bottom of the water and uniting with other sediment particles.

Figure 2C shows Pb concentration in the water bodies. Pb is harmful to the environment because it is very toxic, has bioaccumulative properties in the aquatic biota if its presence exceeds the threshold, and both sediment and biota remain contaminated for a long time (Mulia and Nurfajriani, 2017). The high toxicity of heavy metals encourages efforts to solve the problem of heavy metal pollution in an environmentally friendly manner. However, Lead can cause children's intellectual and brain development disorders, nervous system disorders, kidney damage, loss of consciousness, and even death (Lech, 2002).

Heavy metal pollutants with high toxicity other than Pb is Copper (Cu) and Chromium (Cr). Concentration of Cu in the water bodies at the study area is shown on Figure 2D. Pollution of Cu metal is generally in the form of Cu^{2+} ions and Cr metal is in the form of Cr^{3+} ions and Cr^{6+} ions (Nayak *et al*., 2020). Where both are present in high concentrations

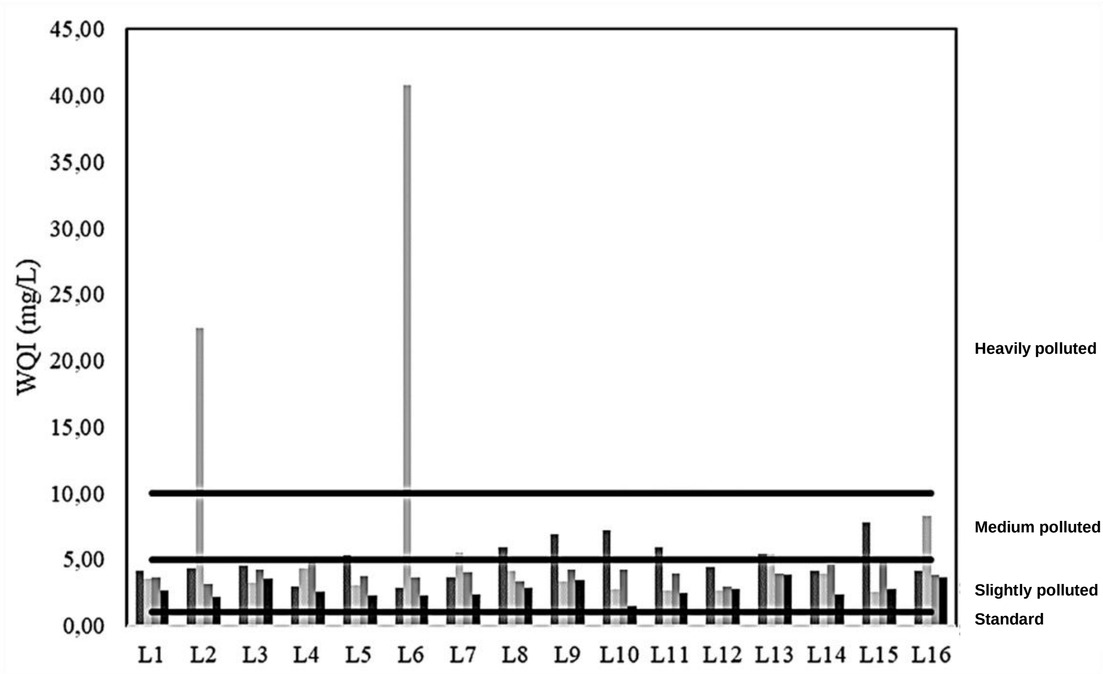

Figure 4. Water Quality Index (WQI) values in the study areas

in aquatic environments, it is very dangerous due to the nature of the toxicity and accumulation of these metals in the food chain and their persistence in aquatic environments.

Figure 3A shows concentration of Cr^{6+} in the water bodies at the study area. Cr^{6+} is one type of contaminant that is carcinogenic (He and Li, 2020; Wang *et al*., 2021). The toxicity of Cr^{6+} is due to its solubility and high mobility in the environment (Zewail and Yousef, 2014). Besides being carcinogenic, Cr^{6+} is very toxic and corrosive (Li *et al*., 2017). It can cause immune system disorders, ulceration of the mucous membranes of the nose and skin, liver and kidney disorders, and even death.

The nickel concentration in the waters in this study is still below the quality standard (Figure 3B). Nickel contamination in gills causes degeneration and hyperplasia of the epithelial surface, gill filament hypertrophy, secondary lamellae distortion, fusion, and secondary lamellae edema, but prolonged exposure causes cell death (Athikesavan *et al*., 2006).

The value of the water quality index using the pollution index method for waters in Central Java ranges from lightly to moderately polluted. Only two points were categorized heavily polluted, the values at L2 and L6 in 2016 (Figure 4).

CONCLUSION

The value of the water quality index using the pollution index method for the water body varied from slightly to heavily polluted. In general, it can be said that the water body has been polluted because most of the index values are in the light to the moderately polluted category by metals.

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