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Water Quality Indices for Assessing Heavy Metal Pollution in Winongo River and Gajahwong River Yogyakarta-Indonesia

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Abstract

Winongo and Gajahwong Rivers traverse three regions: Sleman Regency, Yogyakarta City, and Bantul Regency. Both rivers' water quality was assessed using two water quality indices specified for detecting only the heavy metal presence, namely Heavy Metal Pollution Index (HPI) and Pollution Index (PI). Details on river water quality were a series of monitoring data from 2017 until 2020 that comprised eleven parameters: pH, BOD, COD, NH_3N, TSS, Total Coli, oil and grease, Fe, Cu, Cd, Cr, and Pb. The results indicate that the heavy metal contents of Winongo and Gajahwong Rivers meet the class II water quality standard. Non-metal parameters, namely COD and TSS, are present in small amounts and below the upper thresholds. The HPI values of Winongo and Gajahwong Rivers were 3.15 and 2.29, respectively, or categorized as 'excellent'. Similarly, based on the PI values (0.78 and 0.72, respectively), both rivers' water quality fell into the category of 'good'.

Keywords: water quality, HPI, PI, Gajahwong River, Winongo River

Abstrak

Sungai Winongo dan Sungai Gajahwong melintasi tiga wilayah yaitu Kabupaten Sleman, Kota Yogyakarta dan Kabupaten Sleman. Penilaian kualitas air kedua sungai tersebut menggunakan indeks kualitas air yaitu Indeks Pencemaran Logam Berat (HPI) dan Indeks Pencemar (PI) dihususkan untuk logam berat. Data kualitas air sungai adalah data series pemantauan tahun 2017-2020, terdiri dari 11 parameter kualitas air. Parameter tersebut adalah pH, BOD, COD, NH_3N, TSS, Total Coli, minyak lemak, Fe, Cu, Cd, Cr, dan Pb. Hasil penelitian ini menunjukkan bahwa semua parameter logam berat memenuhi baku mutu sungai kelas II untuk Sungai Gajahwong dan Winongo. Parameter lainnya hanya COD dan TSS yang berada di bawah baku mutu sungai kelas II. Indeks HPI Sungai Winongo 3,15 dan HPI Sungai Gajahwong 2,29; keduanya mempunyai kategori sangat baik. Indeks PI Sungai Winongo 0.78 dan PI Sungai Gajahwong 0,72, keduanya mempunyai kategori baik.

Kata kunci : Kualitas Air, HPI, PI, Sungai Gajahwong, Sungai Winongo

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1. Introduction

Urban rivers are streams that run through the centers of cities and serve as passageways for river water, forming elements of urban landscapes and serving as ecological spaces (Lee, et al, 2022). Winongo and Gajahwong, the Opak River's tributaries, traverses three administration units: Sleman Regency, Yogyakarta City, and Bantul Regency. Human activities along the streams are persistently growing, thus increasing the amount of waste entering the river systems and affecting the water quality. Because many people rely on rivers as a clean water source, it should have a well-maintained quality (Ratnaningsih et al., 2018). For this reason, water quality assessment is imperative in order to determine which water sources are suitable for fulfilling the needs of human life and other living organisms (Ratnaningsih et al., 2016). Many methods can be used to assess water quality status, on of them is Water Quality Index (WQI) (Abbasi & Abbasi, 2012).

The number of research cases for easy understanding of river water quality and scientific evaluation of water quality through various water quality indices (WQIs). Lee, et al. (2022), has been developed the advanced water quality management methods applicable to urban rivers (S-WQI).

One of the methods widely used in assessing the water quality status of rivers in Indonesia is the Pollutant Index (PI) (KLHK, 2018), which is frequently juxtaposed with other methods like the Storet. PI has been extensively reviewed in Saraswati et al. (2014), Effendi (2016), and Ratnaningsih et al. (2018). Saraswati et al. (2014) explain that the CCME is more sensitive in responding to WQI dynamics at every monitoring site and has more universal applications outside the country of its developer than PI and Storet. Effendi (2016) used PI for rapid water pollution assessment, while Ratnaningsih et al. (2018) developed WQI as an alternative to water quality assessment in the Ciliwung River.

Apart from PI, this research also used the Heavy Metal Pollution Index (HPI) developed specifically for heavy metal parameters (Prasad & Bose, 2001; Edet & Offiong, 2002; Giri & Singh, 2014; Abdel-Satar et al., 2017). Prasad & Bose (2001) used HPI to assess the water quality of nine springs and eight bodies of surface water near a limestone mine in Sirmour, an Indian state in the outer Himalayas, and found that heavy metals, namely copper, cadmium, iron, chromium, manganese, lead, and zinc, were far below the established quality standards. In addition to HPI, Edet & Offiong (2002) used two other methods, namely the contamination index (Cd) and heavy metal evaluation index (HEI), to monitor heavy metal content in the Akpabuyo-Odukpani area, Lower Cross River Basin (southeastern Nigeria). Giri & Singh (2014) specifically used HPI to assess Al, As, Ba, Cr, Co, Cu, Fe, Mn, Ni, Se, V, and Zn pollution in the Subarnarekha River, India. Abdel-Satar et al. (2017) studied WQI, HPI, and Cd primarily for assessing the severity of heavy metal pollution in the Nile River, Egypt. The HPI and Cd showed poor to marginal heavy metal pollution, while the WQI varied from marginal to good for nutrient and heavy metal contents.

The purpose of this study is to compare the calculation of the HPI and PI for assessing metal parameters, primarily in the Gajahwong and Winongo rivers. Both methods are also applied to assess non-metal parameters in order to obtain a complete picture of the water quality condition of the rivers. Domestic activities generate the most pollutants in the Winongo and Gajahwong Rivers, including liquid waste containing heavy metals from the use of detergents (Suoth & Nazir, 2016). The used detergent characteristics determine the heavy metal content in domestic wastewater (Jenkis & Russell, 1994). According to Soylak et al. (2013), samples of detergents in household waste contain cadmium, copper, chromium, cobalt, iron, lead, manganese, nickel, and zinc. Inorganic compounds are also a source of heavy metal (Effendi, 2003). These compounds can be metals and heavy metals.

2. Methods

The research was conducted in Gajahwong and Winongo, two large rivers traversing Yogyakarta City. Eight samples were collected from each river to represent its upper to lower reaches (**Figure 1**). The two rivers were selected because the Environment and Forestry Service (*Dinas Lingkungan Hidup dan Kehutanan*, DLHK) of the Special Region of Yogyakarta (SRY) keeps track of their water quality annually and, therefore, they have complete time-series yearly data and a consistent list of tested parameters, especially for heavy metals. The DLHK SRY provides secondary data measured three times a year at predetermined water quality monitoring points from 2017 until 2020. Parameters measured are limited to the available data for the short-term monitoring. For future research opportunities, long term data set with complete parameters can better represent actual water quality conditions.

The river water quality analysis compared the secondary data with the class II water quality standards described in the SRY Governor's Regulation No. 20 of 2008, including BOD, COD, NH_3N, TSS, total coli, oil and grease, and heavy metals. In this research, the analysis focused on heavy metal parameters: iron (Fe), copper (Cu), cadmium (Cd), chromium (Cr), and lead (Pb) and intended to identify the effect of heavy metal pollution on the water quality status of the Winongo and Gajahwong Rivers using pollution index (PI) and heavy metal pollution index (HPI). PI can determine pollution level relative to predetermined water quality standards (Saraswati et al., 2014), and it has been widely used for water quality evaluation and monitoring on a river or watershed scale (Susanti & Wahyuningrum, 2020). PI is mathematically formulated as follows (Dwivedi & Pathak, 2007):

$$PI_j = \sqrt{\frac{(C_i/L_{ij})_M^2 + (C_i/L_{ij})_R^2}{2}} \quad (1)$$

Where *PIj* is the Pollution Index for the purpose *j*, *Ci* is the concentration of the water quality parameter *i*, *Lij* is the water quality standard *j*, *M* is the maximum, and *R* is the mean value. PI values were then grouped into four classes, namely good (0≤PI≤1.0), slightly polluted (1.0<PI≤5.0), moderately polluted (5.0<PI≤10), and heavily polluted (P>10.0).

HPI is a water quality index designed particularly for determining water quality status based on heavy metal contents. HPI is defined as (Prasad et al., 2001):

$$\mathrm{HPI} = \frac{\sum_{i=1}^{n} \mathrm{WiQi}}{\sum_{i=1}^{n} \mathrm{Wi}} \quad (2)$$

Where *Wi* is the unit weight (*1/Si*), *Qi* is the *i*-th sub-index parameter, *i* is the water quality parameter, and *n* is the number of parameters measured. Referring to a study by Bora & Goswani (2017), HPI values were then grouped into five categories, namely 0-25 (very good), 26-50 (good), 51-75 (poor), 76-100 (very poor), >100 (not suitable for drinking water). These categories are also in line with Shankar (2018), which defines 100 value of HPI as a critical value. The next step was to compare the PI and HPI values.

3. Results and Discussion

Water Quality of Winongo and Gajahwong River

Heavy Metal

Figure 2a shows the mean levels of iron (Zn) in 2017–2020. Iron contents in Gajahwong and Winongo Rivers fluctuated from point S1 through S8. The iron concentrations varied from 0.115 to 0.312 mg/L in the former and from 0.138 to 0.290 mg/L in the latter. These figures are still below the upper threshold for iron content in class II water.

Figure 2b shows that copper (Cu) concentrations from point S1 to S8 had an increasing trend. These concentrations were in the range of 0.0152–0.0227 mg/L in Gajahwong and 0.016–0.021 mg/L in Winongo. In Gajahwong, copper levels at S1–S5 were below the upper threshold for Cu in class II water, but the ones at S6–S8 had exceeded it. Meanwhile, in Winongo, the copper content was within its permissible presence in class II water, except for S7.

Figure 2c shows that cadmium contents fluctuated between 0.0046 and 0.0086 mg/L in Gajahwong and between 0.004 and 0.015 mg/L in Winongo. However, there was an increasing trend from S1 through S8. The cadmium level at point S7 in Gajahwong had exceeded its allowable presence in class II water. Meanwhile, the cadmium levels at all monitoring points in Winongo met the class II water quality standard.

Figure 2d presents fluctuating chromium (Cr) levels in 2017–2020. They increased from point S1 through the middle of the catchment but continuously decreased until point S8. The chromium concentrations were in the range of 0.008–0.0163 mg/L in Gajahwong and 0.006–0.036 mg/L in Winongo. The class II water quality standard for this parameter was met at all sampling points.

Figure 2e depicts the lead (Pb) contents in 2017–2020. It also shows an increasing trend from point S1 through S8 in the two rivers, although less significant. Pb levels varied from 0.0203 to 0.0385 mg/L in Gajahwong and from 0.025 to 0.039 mg/L in Winongo. Like chromium, these concentrations were below the upper threshold for Pb parameter in the class II water quality standard.

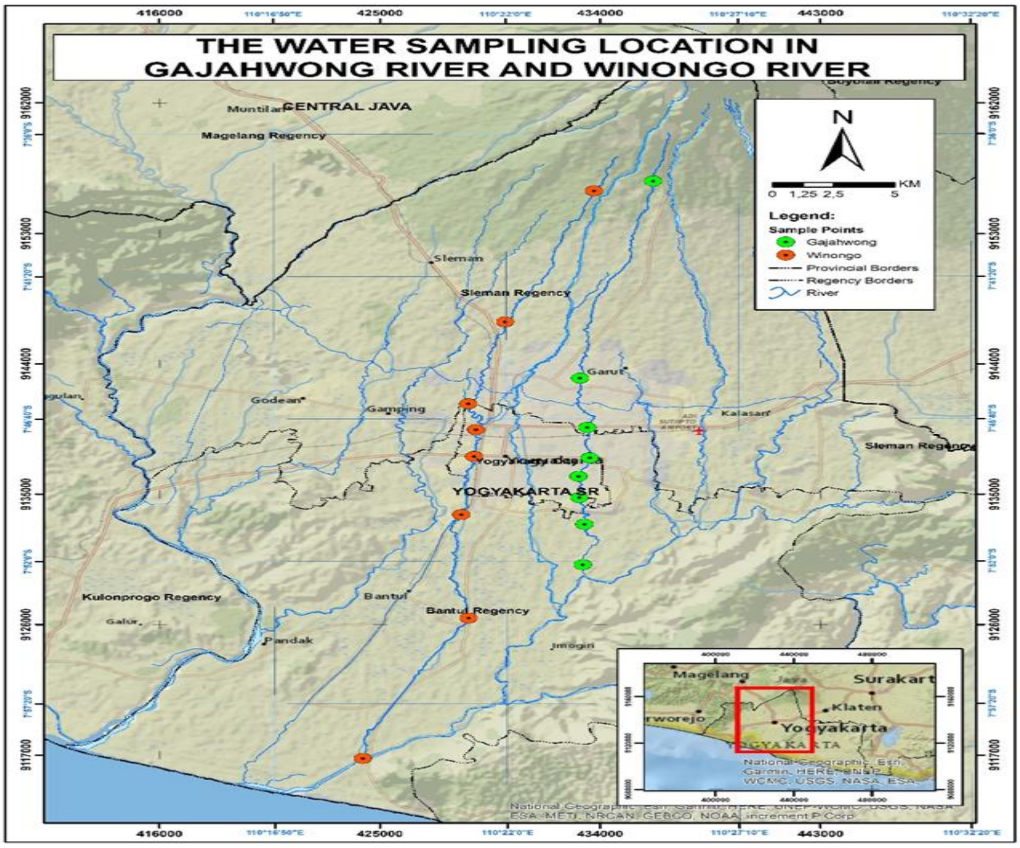

Figure 1. Locations of Water Sampling Points along the Gajahwong and Winongo Rivers

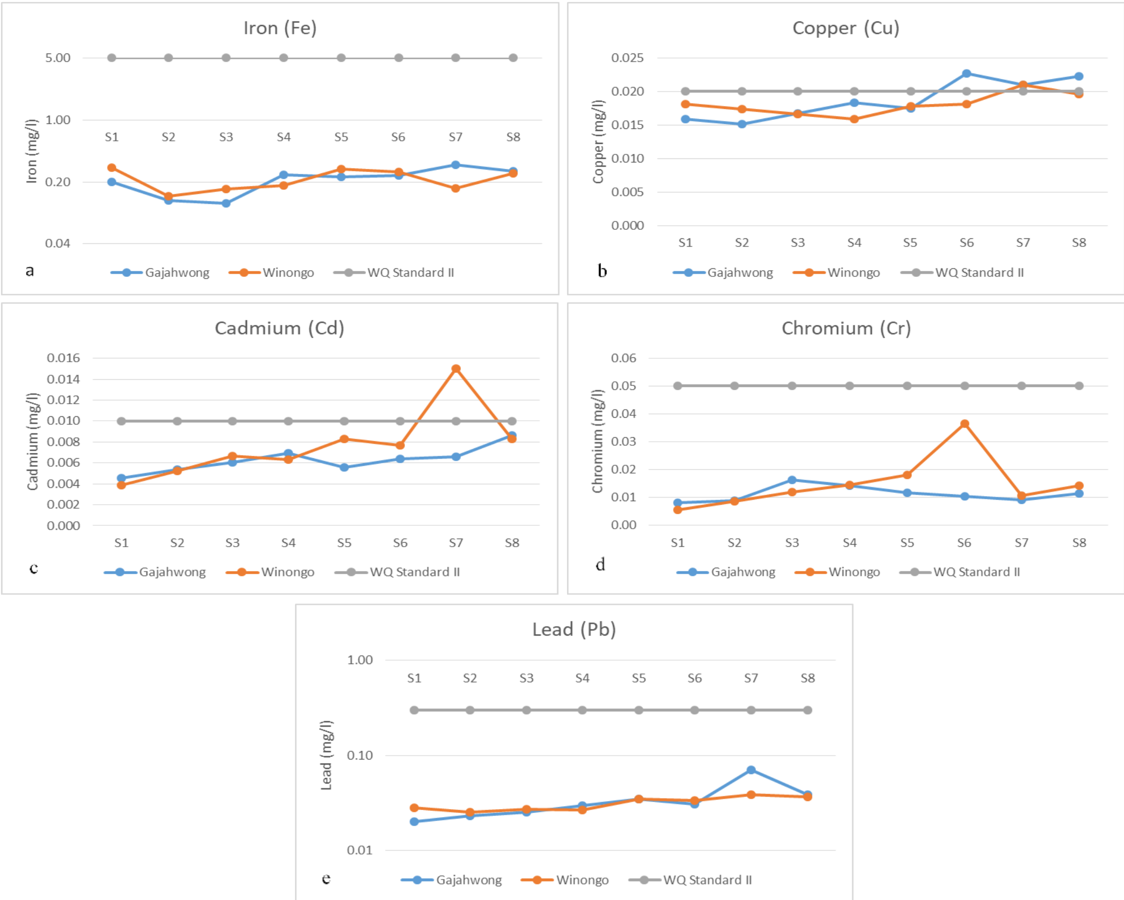

Figure. 2. Water Quality Graphs for Heavy Metal Parameters in Winongo and Gajahwong River

Non-Metal

In water quality analysis, the non-metal parameters indicate the presence or absence of domestic waste in a water body. They include BOD, COD, NH_3N, TSS, total coli, and oil and grease. **Figure 3a** presents the mean BOD levels in 2017–2020, which varied from 3.07 to 4.63 mg/L in Gajahwong and from 4.403 to 5.248 mg/L in Winongo. At these levels, BOD in both rivers had exceeded its upper threshold for class II water quality, i.e., 3 mg/L. **Figure 3b** shows COD levels in the range of 11.40–17.15 mg/L in Gajahwong and 13.243–16.942 mg/L in Winongo. In contrast to BOD, the COD levels were below the upper threshold, 25 mg/L. These results indicate that the amount of oxygen used in biological processes is higher than in chemical processes.

As seen in **Figure 3c,** the average NH_3N levels in 2017–2020 fluctuated between 0.036 and 0.878 mg/L in Gajahwong and between 0.042 and 0.482 mg/L in Winongo. The presence of this non-metal parameter started to increase at point S2 but then decreased at point S6. NH_3N contents in Gajahwong, primarily at points S3, S5, and S6, had exceeded the class II water quality standard. On the contrary, all sampling points in Winongo met the standard for this parameter.

Figure 3d presents the mean Total Suspended Solids (TSS) in 2017–2020, which varied from 19.08 to 27.26 mg/L in Gajahwong and from14.85 to 32.225 mg/L in Winongo. Even though the TSS levels at all sampling points in both rivers fluctuated, they were below the upper threshold of permissible TSS in class II water quality, i.e., 50 mg/L.

Figure 3e shows that the total coli in 2017–2020 was 19108.3–1333551667 JPT/100mL in Gajahwong and 10226.67–152798.33 JPT/100mL in Winongo. Total coli showed an increasing trend from point S1 until S8 and had exceeded their allowable presence in class II water, 5000 JPT/100mL.

In 2017–2020, the presence of oil and grease (**Figure 3f**) varied from 1183.3 to 2333.3 μg/L in Gajahwong and from 1333.3 to 4400 μg/L in Winongo. These concentrations fluctuated from point S1 until S8. Based on the class II water quality standard, they had exceeded the upper threshold, 1000 μg/L.

The results showed that in general, the parameters exceed the standard. Those are BOD, Total Coliform, Oil, and Grease. Those parameters indicate domestic waste. Winongo River and Gajahwong River are urban rivers which the main load input comes from domestic waste. he wastewater and waste handlingsystem so far has been considered ineffective to control water pollution in the rivers (Saraswati et al., 2019)

Figure. 3. Water Quality Graphs for Non-Metal Parameters in Winongo and Gajahwong River

Based on the heavy metal and non-metal pollutant loads, it is apparent that Winongo has better water quality than Gajahwong. For heavy metal parameters, the copper (Cu) standard is exceeded in Gajahwong (points S6 and S8), while the allowable presence of cadmium (Cd) is exceeded in Winongo (S7). Besides, there are more non-metal parameters above their acceptable concentrations in Gajahwong than in Winongo. The upper thresholds of BOD, total coli, and oil and grease are exceeded in both rivers, but the water of Gajahwong also contains excessive NH_3N. This state of water quality represents the surrounding human activities and pollutant loads entering the streams.

Heavy Metal Pollution Index (HPI) of Winongo dan Gajahwong Rivers

Table 1 presents the HPI values of the Gajahwong River. The HPI values at points S1–S8 were 1.42, 1.68, 3.40, 2.98, 2.39, 2.06, 2.05 and 2.38. Ranging between 1.68 and 3.40, each of the observation points fell into the category ‘excellent’ (0-25).

Point S1 had the lowest HPI, 1.42, which is consistent with the prevailing vegetation cover in the upper reaches of the Gajahwong River. S3 had the highest HPI, 3.40, because settlements and many supporting facilities dominate the land use surrounding this point, and, as a result, many human activities act as sources of pollution. This point is also located at the city center of Yogyakarta, which is densely populated and occupied by many economic activities from within and near the area.

HPI decreased to 2.06 and 2.05 at points S6 and S7, which lie in a transitional zone between urban (Yogyakarta City) and rural areas (Bantul Regency). On average, the HPI of Gajahwong was 2.29, indicating very good water quality. This index value also confirms that no heavy metal parameters are present in high amounts and, thus, do not pollute the river water.

Table 2. shows the HPI values of the Winongo River. The HPI values at points S1–S8 were 0.89, 1.59, 2.37, 3.01, 3.89, 8.21, 2.20, and 3.04. Like the Gajahwong River, the water quality status of the Winongo River is ‘Excellent’ (0-25). Point S1 had the lowest HPI, 0.89, because, in the upper reaches, not many human activities generate and dispose of waste into the river.

Points S2-S6 at the city center had higher HPI, with the highest being 8.21 at S6. This finding is consistent with an increase in human activities downstream. HPI decreased to 2.30 at S7 but increased to 3.04 at point S8. On average, the HPI of Winongo was 3.15, indicating very good water quality and no heavy metal pollutions.

Pollution Index (PI) of Winongo and Gajahwong Rivers

Table 3 presents the results of the PI calculations for the Gajahwong River. PI at points S1-S8 ranged between 0.58 and 0.94, with an average of 0.72. Point S2 had the lowest PI, 0.58, while point S8 downstream had the highest, 0.94. PI increased starting from point S2 to S8, which is believed to be the result of growing human activities. Nevertheless, the PI values at all monitoring points were below 1. This figure means that, based on heavy metal parameters, the river water quality falls in the category 'good'. There is no significant difference between the PI values of Winongo and Gajahwong Rivers. **Table 4** shows that the PI values of the Winongo River varied from 0.62 to 1.41. Of the eight monitoring points, only one (S7) had a PI value of above 1, indicating light pollution. PI decreased from S1 (0.68) through S4 (0.62), increased from S5 (0.71) until S7 (1.41), and then dropped to 0.76 at S8. In other words, the PI values fluctuated from the upper until the lower reaches of the Winongo River owing to the variations in the pollutant loads introduced at each monitoring point. On average, the PI value was 0.78, indicating a 'good' water quality status based on the metal contents.

Table 1. HPI values of Gajahwong River

Sampling Points	Locations	Coordinates	HPI	Status
S1	Tanen Bridge, Hargobinangun, Pakem, Sleman	S 7° 37' 46.1" ; E 110° 25' 16.6"	1.42	Excellent
S2	Pelang Bridge, Condongcatur, Sleman	S 07° 45' 8.8" ; E 110° 23' 38.6"	1.68	Excellent
S3	IAIN Bridge, Caturtunggal, Sleman	S 07° 46' 59.8" ; E 110° 23' 47.9"	3.40	Excellent
S4	Muja-Muju Bridge, Umbulharjo, Yogyakarta	S 07° 48' 8.1" ; E 110° 23' 51.2"	2.98	Excellent
S5	Peleman Bridge, Rejowinangun, Kotagede, Yogyakarta	S 07° 48' 49.8'' ; E 110° 23' 36.2''	2.39	Excellent
S6	Tegalgendu Bridge, Kotagede, Yogyakarta	S 07° 49' 37.3'' ; E 110° 23' 37''	2.06	Excellent
S7	Grojogan Bridge, Wirokerten, Banguntapan, Bantul	S 07° 50' 37.4'' ; E 110° 23' 43.9''	2.05	Excellent
S8	Kanggotan Bridge, Wonokromo, Pleret, Bantul	S 07° 52' 8.3'' ; E 110° 23' 41.5''	2.38	Excellent
Average (S1-S8)			**2.29**	**Excellent**

Source: Data processing, 2020 (secondary data source: DLHK DIY 2017–2020)

Table 2. HPI values of Winongo River

Sampling Points	Locations	Coordinates	HPI	Status
S1	Purwobinangun Bridge, Pakem, Sleman	S 07° 38' 746" ; E 110° 23' 125"	0.89	Excellent
S2	Jl. PJKA Bridge, Denggung, Sumberadi, Mlati, Sleman (Sate Kuda)	S 07° 43' 499" ; E 110° 21' 696"	1.59	Excellent
S3	Jatimulyo Bridge, Kracak, Yogyakarta	S 07° 46' 616" ; E 110° 21' 410"	2.37	Excellent
S4	Jlagran Bridge, Bumijo, Yogyakarta	S 07° 47' 379" ; E 110° 21' 410"	3.01	Excellent
S5	Tamansari Bridge, Wirobrajan, Yogyakarta	S 07^0 48' 494" ; E 110^0 21' 221"	3.89	Excellent
S6	Dongkelan Bridge, Kasihan, Bantul	S 07° 50' 431" ; E 110° 20' 911"	8.21	Excellent
S7	Bakulan Bridge, Jetis, Bantul	S 07° 54' 814" ; E 110° 20' 812"	2.20	Excellent
S8	Gading Bridge, Kretek, Bantul	S 07^0 58' 819" ; E 110^0 18' 831"	3.04	Excellent
Average (S1-S8)			**3.15**	**Excellent**

Source: Data processing, 2020 (secondary data source: DLHK DIY 2017–2020)

Comparison between the HPI and PI Values of Winongo and Gajahwong Rivers

The analysis results of the HPI and PI values were generally similar (**Figure 4**). The HPI values of the Gajahwong River were in the range of 1.42-3.40, with an average of 2.29. Meanwhile, the HPI values of the Winongo River varied from 0.89 to 8.21, with an average of 3.15. These variations and mean values are within the range of 'excellent' water quality status (0-25). Furthermore, the two rivers' HPI values were far above the lower bound of the numerical range. The PI values of the Gajahwong River varied from 0.58 to 0.94, with an average of 0.72. Meanwhile, the PI values of the Winongo River fluctuated between 0.62 and 1.41, with an average of 0.78. Based on these figures, the two rivers' water quality status is generally classified as 'good'. S7 is the only monitoring point whose PI value indicates light pollution.

Table 3. PI values of Gajahwong River

Sampling Points	Locations	Coordinates	PI	Status
S1	Tanen Bridge, Hargobinangun, Pakem, Sleman	S 7° 37' 46.1" ; E 110° 25' 16.6"	0.60	Good
S2	Pelang Bridge, Condongcatur, Sleman	S 07° 45' 8.8" ; E 110° 23' 38.6"	0.58	Good
S3	IAIN Bridge, Caturtunggal, Sleman	S 07° 46' 59.8" ; E 110° 23' 47.9"	0.65	Good
S4	Muja-Muju Bridge, Umbulharjo, Yogyakarta	S 07° 48' 8.1" ; E 110° 23' 51.2"	0.71	Good
S5	Peleman Bridge, Rejowinangun, Kotagede, Yogyakarta	S 07° 48' 49.8'' ; E 110° 23' 36.2''	0.71	Good
S6	Tegalgendu Bridge, Kotagede, Yogyakarta	S 07° 49' 37.3'' ; E 110° 23' 37''	0.71	Good
S7	Grojogan Bridge, Wirokerten, Banguntapan, Bantul	S 07° 50' 37.4'' ; E 110° 23' 43.9''	0.84	Good
S8	Kanggotan Bridge, Wonokromo, Pleret, Bantul	S 07° 52' 8.3'' ; E 110° 23' 41.5''	0.94	Good
Average (S1-S8)			**0.72**	**Good**

Source: Data processing, 2020 (secondary data source: DLHK DIY 2017–2020)

Table 4. PI values of Winongo River

Sampling Points	Locations	Coordinates	PI	Status
S1	Purwobinangun Bridge, Pakem, Sleman	S 07° 38' 746" ; E 110° 23' 125"	0.68	Good
S2	Jl. PJKA Bridge, Denggung, Sumberadi, Mlati, Sleman (Sate Kuda)	S 07° 43' 499" ; E 110° 21' 696"	0.66	Good
S3	Jatimulyo Bridge, Kracak, Yogyakarta	S 07° 46' 616" ; E 110° 21' 410"	0.64	Good
S4	Jlagran Bridge, Bumijo, Yogyakarta	S 07° 47' 379" ; E 110° 21' 410"	0.62	Good
S5	Tamansari Bridge, Wirobrajan, Yogyakarta	S 07^0 48' 494" ; E 110^0 21' 221"	0.71	Good
S6	Dongkelan Bridge, Kasihan, Bantul	S 07° 50' 431" ; E 110° 20' 911"	0.74	Good
S7	Bakulan Bridge, Jetis, Bantul	S 07° 54' 814" ; E 110° 20' 812"	1.41	Slightly Polluted
S8	Gading Bridge, Kretek, Bantul	S 07^0 58' 819" ; E 110^0 18' 831"	0.76	Good
Average (S1-S8)			**0.78**	**Good**

Source: Data processing, 2020 (secondary data source: DLHK DIY 2017–2020)

High HPI and PI values at S6, S7, and S8 are attributable to high Cu and Cd concentrations. In the Winongo River, the Cu and Cd levels at point S7 had exceeded the class II water quality standard. Meanwhile, in the Gajahwong River, the Cu contents at points S6 and S8 were above the allowable presence in class II water. Along the Winongo River, S6 had the highest HPI, while S7 had the highest PI. In the Gajahwong River, the highest HPI and PI values were identified at S3 and S8, respectively. Domestic and industrial activities are believed to contribute to the majority of pollutant loads in both rivers. Settlements and textile industries are the two sources of pollutants at point S6 in Winongo River. Meanwhile, nearby point S9 in Gajahwong River, there are dense settlements and many silver industries.

According to Shankar (2018), HPI is an effective method for assessing and ascertaining heavy metal concentrations. In his research, the mean HPI value of Cr, Fe, Pb, Cu, Ni, and Cd is 146.32, exceeding the critical number (100). For this reason, the observed groundwater is unsuitable for drinking, and it is believed to be attributable to urban, industrial, and agricultural activities. In the case of Winongo and Gajahwong Rivers, the HPI values are far below 100, mainly because the heavy metal concentrations present in both rivers meet the class II water quality standard. Abdel-Satar et al. (2017) explain that human activities are the primary cause of the high HPI value or, in other words, heavy metal pollution in the Nile River. Moreover, Bora & Guswani (2017) emphasize that human interventions are responsible for the water quality decline in the Kolong River. Eldaw et al. (2020) developed new methods to avoid the drawbacks of the heavy metal pollution index commonly used in water quality assessment. They evaluate heavy metal pollution using the NEI (negative evaluating index) and PEI (positive evaluating index). Decreased NEI and PEI values reflect an improvement in water quality. NEI indicates that heavy metals' contribution does not exceed the desired threshold values, whereas PEI is the opposite.

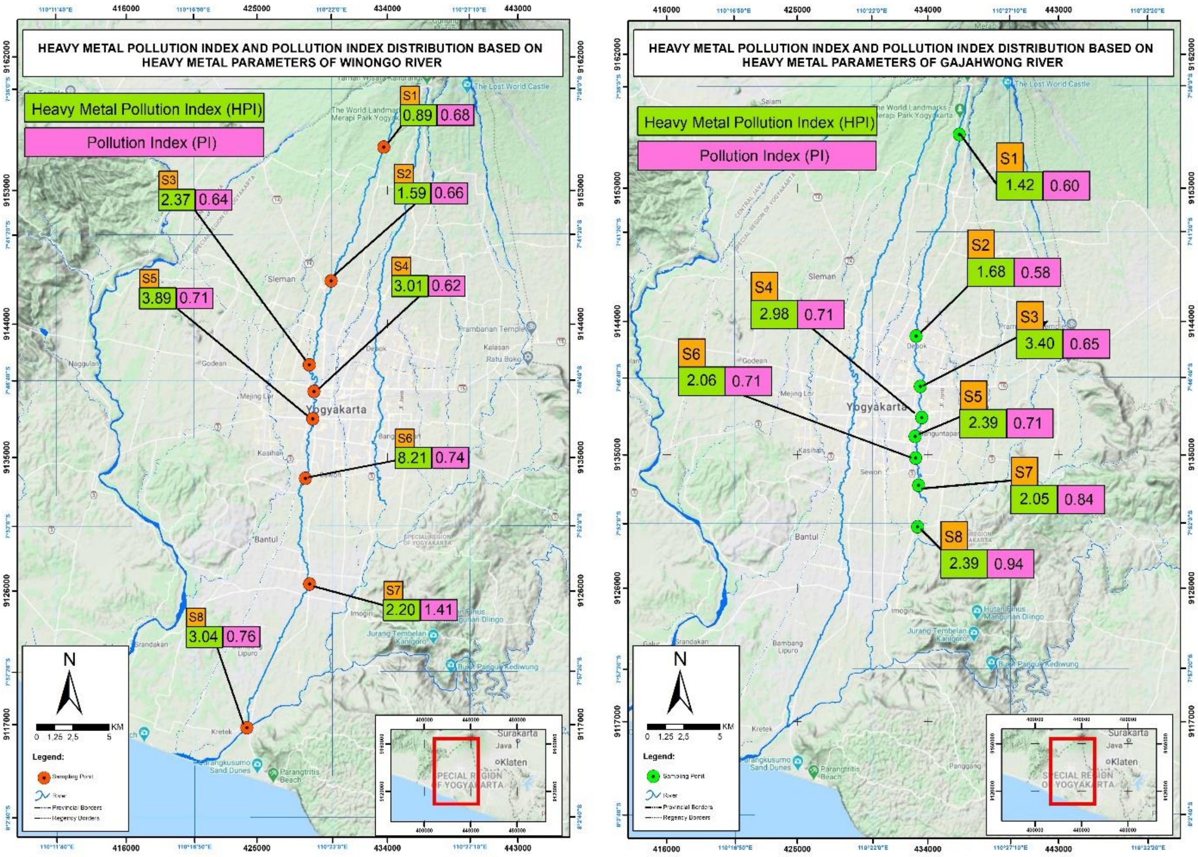

Figure 4. Distribution Points of the HPI and PI Values of Gajahwong River (a) and Winongo River (b)

Saraswati et al. (2014) explain that the PI does not incorporate sub-index scoring (subjective scores) for every parameter measured. The most significant aspect of the PI calculation is that the parameters are assessed based on the largest ratio of their concentrations to the quality standard. The water quality assessment using 17 parameters resulted in 'heavily polluted'. The PI sensitivity test used 6, 9, and 15 parameters exceeding the class I water quality standard. In the case of the Gajahwong River, it revealed that water quality assessment using 6, 9, and 15 parameters resulted in 'slightly polluted'. It can be concluded that even though the PI calculation draws on only a few or many parameters that exceed the predefined threshold, the water quality status observed does not change. This is also evident from the analysis results for Gajahwong and Winongo Rivers, which show that although 1-2 parameters exceed the water quality standard, the resulting status is categorized as 'good'. These results are consistent with a study by Effendi (2016), in which the PI values of Cihideung River, Ciapus River, and PPLH Lake indicate 'good' water quality.

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