COMPARATIVE ANALYSIS BETWEEN WPI AND WQI AS A WATER QUALITY INDICATOR IN RAMBUT RIVER, INDONESIA

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ABSTRACT

The increase of anthropogenic activites around the river bank possessed a great risk towards the water quality of the river. The wastewater which was discharged into river was not always treated properly. This condition could trigger a worsening pollution on the river. In Indonesia itself, there were 343 rivers which were found to have a worse water quality from time to time and remain unsolved until now. Meanwhile, there was Rambut River, located in the Tegal and Pemalang city border, which was at a risk of being polluted by the anthropogenic activities, e.g., agricultural and residential area. In this research, two different indicators were used a comparative analysis to determine how was the water quality in Rambut River, such as Water Pollution Index (WPI) and Water Quality Index (WQI). Both indicators showed similar results where the water quality in the upstream was better than the downstream. One sampling points in the most upstream part of the river was considered as clean or in good condition, while the others were lightly polluted. The results also showed that the sampling point which has the highest population density and dominated by agricultural and residential area were showing the worst water quality.

Keyword: water quality index, water pollution index, river quality, rambut river.

INTRODUCTION

Water quality assessment aims to give valuable informations on the actual condition of water bodies and assist the authorized stakeholders to plan various development and revitalization actions(Son *et al.*, 2020). Indonesia becomes one of the countries which possess a serious problem on the water bodies, specifically the river, whereit is allcommonly in a heavily polluted level (Honingh *et al.*, 2020; Kido *et al.*, 2008; Sikder *et al.*, 2015). In 2015 and 2016, there were 17 out of 417 heavily polluted rivers which the quality is stagnant throughout the years. Additionally, there were 343 rivers with a worse river quality from time to time (BPS, 2017). There were also 4 heavy polluted rivers found in the Central Java province, such as Bengawan Solo, Cisanggarung, Citanduy, and Progo. It was possible that the smaller rivers which flow near them will also be polluted and most of them were located in the Tegal and Pemalang city border. This condition is terrible for the development of drinking water source, tourism, and other purposes (Adrian *et al.*, 2020; Krisanti *et al.*, 2020; Muin & Nandiasa, 2019; Roosmini *et al.*, 2018; Sulaeman *et al.*, 2020).

One of the rivers in the Tegal and Pemalang city border is the Rambut River. Up until now, there is no analysis or assessment of the quality of this river yet. It has a total area of 166.1 squared kilometer and the total length of 63,975 kilometer. It flows across 10 different sub-districts which are inhabited by 722,034 people in total (Sugiarto *et al.*, 2020). This river is upstreamed in Tegal and downstreamed in Pemalang, making it to be a geographical border for both cities. These two cities have a high rate of population growth which directly affecting the dependency of the people towards the river. The increasing anthropogenic activity can lead to the increase of river pollution. Therefore, water quality assessment in Rambut River is crucial to investigate the real condition of the river and to decide the river managementstrategy (Efiana *et al.*, 2019; Faradiba *et al.*, 2019). Most of the area in Rambut River is used to discharge various types of wastewater without any proper treatment. It means that the river still become the end zone of solid waste, grey water, and sometimes, black water (Ling *et al.*, 2012; Ullah *et al.*, 2013).

There are two commonly used indicators to evaluate the river quality in Indonesia, such as Water Pollution Index (WPI) and Water Quality Index (WQI). WPI is an indicator developed by Nemerow(1971) andis mainly used by the Ministry of Environment and Forestry of Indonesiasince 2003. This indicator takes a look on the outcome probabilities of different pollutant sources, e.g., physical, chemical, and biological, that might enter the river(Brankov *et al.*, 2012; Effendi, 2016). Another indicator that is also widely used in Indonesia is Storet, but it has a weakness of not assessing the biological and non-biological pollutants proportionally(Endreny & Jennings, 1999; Rintaka *et al.*, 2019). Meanwhile, WQI is a water quality indicatorwhich aims to simplify the water quality assessments which have been used so far(Brown *et al.*, 1970; Horton, 1965; Miller *et al.*, 1986). Erasing the complexity and keeping the method to be simple is the main reason on the initiation of WQI. This way, the knowledge and understanding of river quality can be also obtained by the common people which has no water-related expertise.

This article aims to assess the water quality in Rambut River by comparing WPI and WQI standards.

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Hopefully, the results of the comparative analysis could be use to define the best implementation in Rambut River. The river quality was analysed by checking on the available criteria from both indicators. Since there were no publications about this kind of research yet, this article clearly has good novelty and urgency values, especially to identify the river condition in a highly populated place in Indonesia and Central Java.

METHODS

This research was conducted for four months in several places along Rambut River area. Rambut River is located at 7o13'50" - 6o52'15" S and 109o6'8" - 106o18'55" E and flows through ten sub-districts in the Pemalang and Tegal area, e.g., Warureja, Pemalang, Bantarbolang, Kedungbanteng, Randudongkal, Jatinegara, Warungpring, Bojong, Moga, and Pulosari. This river is upstreamed in the Bojong sub-district, Tegal from a water spring called Balekambang. The northern part of the Rambut watershed is bordered by the Java Sea, the eastern part is bordered by the Waluh watershed, the southern part is bordered by the Bogowonto watershed, and the western part is bordered by the Gung watershed, Cacaban watershed, and Konang Jimat watershed the initiation of WQI. This way, the knowledge and understanding of river quality can be also obtained by the common people which has no water-related expertise.

This article aims to assess the water quality in Rambut River by comparing WPI and WQI standards. Hopefully, the results of the comparative analysis could be use to define the best implementation in Rambut River. The river quality was analysed by checking on the available criteria from both indicators. Since there were no publications about this kind of research yet, this article clearly has good novelty and urgency values, especially to identify the river condition in a highly populated place in Indonesia and Central Java.

Table-1. Sampling location and coordinate.

Point	Sampling location	Coordinate
1	Kajenengan village, Bojong subdistrict, Tegal. Located at an altitude of ±520 meter above sea level	7° 6' 44.37" S and 109° 13' 23.76" E
2	Jatinegara village, Jatinegara subdistrict, Tegal. Located at an altitude of ±246 meter above sea level	7° 4' 4.17" S and 109° 15' 4.69" E
3	Kedungjati village, Warureja subdistrict, Tegal. Located at an altitude of ±45 meter above sea level	6° 59' 18.25" S and 109° 18' 31.45" E
4	Sukareja village, Warureja subdistrict, Tegal. Located at an altitude of ±13 meter above sea level	6° 55' 11.9" S and 109° 19' 48.51" E
5	Kedungkelor village, Warureja subdistrict, Tegal. Located at an altitude of ±7 meter above sea level	6° 52' 20.17" S and 109° 20' 35.70" E

The water from Rambut River was collected from five different points (Table-1) by considering the landuse, topography, administrative border, and physical condition of the river. These different factors had an influence towards the anthropogenic activity around river and later would affect the pollution load (Sugiarto *et al*., 2020).This research used grab sampling method to collect the water sample from Rambut River. It means that the water characteristic would not be collected and assessed continuosly during the time period. The water sample was collected on the exact river depth, which was 0.5 times of the Rambut River depth in the middle area (from each different sampling location).

Table-2. Contamination index classification of WPI.

Pij value	Contamination index
$0 \leq Pij \leq 1$	Meets standard
$1 \leq Pij \leq 5$	Light pollution
$5 \leq Pij \leq 10$	Moderate pollution
$Pij \geq 10$	Heavy pollution

The sampling collection tools were including clean buckets equipped with a rope, sterile jerrycans (5 litre), and sterile sampling bottles (500 ml). Moreover, in order to assess pH, dissolved oxygen (DO), temperature, and total suspended solid (TSS) directly in the sampling site, a water quality checker (WQC) measurement tool was used. It can be used by just inserting the probe into the water sample. Besides that, other measurements of turbidity, DO, and pH were also conducted again in the lab by using turbidimeter, DO meter, and pH meter, respectively.

The formula used for this research was as follows:

$$Pij = \sqrt{\frac{(\frac{Ci}{Lij})^2 M + (\frac{Ci}{Lij})^2 R}{2}} \quad (1)$$

Pij : Pollution index for designation j
Ci : Variable concentration i
Lij : Standard permitted for variable i
M : Maximum
R : Average

The collected water samples should be preserved right after it was being collected. The preservation method used in this research was by putting the water sample into a cooling box (4^{o}C). Several water quality parameters which would be assessed further in the laboratory were including pH, totaldissolved solid (TDS), TSS, biological oxygen demand (BOD), chemical oxygen demand (COD), DO, detergent, cadmium (Cd), chromium (Cr), nitrate (NO_3^-), nitrite (NO_2^-), phosphate (PO_4^{3-}), zinc (Zn), Cyanide (CN^-), Lead (Pb), Copper (Cu), and fecal coliform. The index is expressed as a Pollution Index of pollution which is used to determine the level of pollution relative to the allowable water quality parameters (Nemerow, 1971). The contamination index (IP) is defined for a provision, and can then be developed for some provisions for all of a water body or part of a river. There were several different level of contamination index in the WPI method based on the calculated value (Table-2).
The formula used for this research was as follows:

$WQI = \frac{\Sigma [\frac{Ci}{Pli}]}{n}$WQI : Water Quality Index
Ci : Variable concentration i
Pli : Standard permitted for variable
n : Number of variables

The Water Quality Index (WQI) method is a method used to assess mandatory parameters in determining water quality to meet drinking water needs (Lathamani *et al*., 2014). According to Davaa (2011) the use of WQI was originally proposed by Horton (1965) and Brown (1970). Since then, many different methods from WQI have been developed. The Ministry of Nature and Environment (MNE) of Mongolia has developed WQI to simplify the complex water quality data used in this study. There were several different classifications of water quality in the WQI method based on the calculated value (Table-3).

RESULTS AND DISCUSSIONS

Understanding the water quality of Rambut River was important, since it was functioned for various purposes, e.g., fisheries, agriculture, recreation, etc. The most commonly used water quality standard which was used in Indonesia is the PP No. 82/2001 about water quality management and water pollution control. In order to expect a safely used river water, the class II standard (section 55) was chosen to be compared with the existing condition (Table-4). It aimed to see if the Rambut River was severely polluted or not, before implementing the WPI and WQI indicator. It turned out that each of the sampling point showed different water quality results. Among the different parameters which were observed, there were some which exceeded the class II standard, such as TDS, TSS, nitrite, and fecal coliform. However, it was mostly the point 5 only.

The highest TDS and TSS results were shown in the point 5 with 27,600 mg/L and 252 mg/L, respectively. These numbers were actuallly surpassed the limits of class II for TDS (<1,000 mg/L) and TSS (<50 mg/L). The high value of TDS in point 5 was probably caused by the existence of household wastewater and fertilizer runoff from the agricultural area. Point 5 was dominantly surrounded by agricultural area (88.5%) and residential area (7.05%). These findings were in line with some research which stated that the existence of residential area had a relation with the increase of TDS value (Kumar & Kumar, 2013; Lee & Song, 2007; Vijay *et al*., 2011). A greater landuse proportion of residential area tend to increase the TDS value in a logarithmic scale (Izzati *et al*., 2018; Thirumalini & Joseph, 2009). Moreover, the presence of TDS in water was casued both naturally and from anthropogenic activities (Montaseri *et al*., 2018; Rusydi, 2018).

Table-3. Water quality indicator of WQI.

WQI value	Water quality classification	
	Class	Level
WQI ≤ 0.30	1	Very clean
0.31 ≤ WQI ≤ 0.89	2	Clean
0.90 ≤ WQI ≤ 2.49	3	Light pollution
2.50 ≤ WQI ≤ 3.99	4	Medium pollution
4.00 ≤ WQI ≤ 5.99	5	Heavy pollution
WQI ≥ 6.00	6	Dirty

Meanwhile, the increase of TSS value in point 5 was most likely to be caused by the sediments which were carried out by the soil erosion and surface runoff into the river during the rain. Furthermore, the decaying organisms, like plants and animals, could also had a role on the TSS increase because of the organic matters presence during the decaying and degrading process. Moreover, the agricultural area, which was mostly consisted of paddy fields, was dominating the area surronding point 5. This condition allowed for a higher chance of landslides and soil erosion because of land clearing around the river. The high value of TSS in river could reduce the water quality through less light absorption (Bilotta & Brazier, 2008; Rono, 2017; Rossi *et al*., 2006). The suspended solids in the water could prevent the sunlight from entering the water, decreasing the ability to bind the oxygen which was important for aquatic life (Borchardt & Sperling, 1997; Kannel *et al*., 2007; Nyanti *et al*., 2018). Therefore, the monitoring of TSS value could be a good predictor of water quality in terms of aquatic life health and support system (Bash *et al*., 2001; Bilotta & Brazier, 2008; Patrick, 1962).

Additionally, the same trend was also shown in the nitrite, where point 5 was found out to have the highest value with 0.063 mg/L. This value was slightly higher than the class II standard with a maximum permissible value of 0.06 mg/L. The high nitrite value at this point was due to the inputs from agricultural and domestic waste. It was highly influenced the landuse condition in point 5. It also illustrated the ongoing nitrification process. Additionally, since the pH value was considered as high, it also demonstrated that the process has not ended completely and would still be continued afterwards. The bio-chemical process in water was strongly influenced by the pH (Dancer *et al*., 1973; Poghossian *et al*., 2003). For the nitrification process, it will be stopped processing once the pH of water became low (Jeschke *et al*., 2013; Villaverde *et al*., 1997).

On the other hand, the point 5, which usually became the one that did not meet the standard, seemed to be in the safe zone for fecal coliform. There were three points which surpassed this parameter in the class II standard, namely point 2, 3, and 4. These three points were above the maximum value of 1,000 fecal coliform per 100 mL. The high value of fecal coliform was most likely caused by the direct influence of bathing, washing, and toilet activities along the river. Rambut River was located in a densely populated area and the highest population density were found at point 2, 3, and 4. Therefore, it was not a surprise that the fecal coliform value was very high in those places. Additionally, the condition became worse because of the lack of domestic wastewater treatment in the settlement along the river bank. Domestic wastewater is the highest contributor of biological pollutants which usually originated from the kitchens, bathrooms, laundry, and othe household waste in the form of yellow, grey, brown, and black water (Crini & Lichtfouse, 2019; Khalifa *et al*., 2020; Sun *et al*., 1998; Welling *et al*., 2020).

All parameters which were not mentioned in the previous paragraphs were below the maximum value in class II standard for all points and considered fine. It indicated that the Rambut River might not be a perfectly clean water bodies, but all the observable parameters indicated that it was generally still in a good condition. However, further assessment was needed from the results of WPI and WQI calculation. By doing so, a more objective judgment could be made based on both indicators.

Table-4. Water quality analysis of Rambut river.

Parameters	Unit	Class II	Point 1	Point 2	Point 3	Point 4	Point 5
TDS	mg/L	<1,000	342	64.4	99.3	247	27,600
TSS	mg/L	<50	2.5	2.5	2.5	2.5	252
BOD	mg/L	<3	2	2	2	2	2
COD	mg/L	<25	7.3	8.1	7.6	8.8	9.2
DO	mg/L	>4	6.9	6.7	6.9	6.1	5.4
Detergent	mg/L	<200	25	25	34.3	25	25
Cadmium	mg/L	<0.01	0.0005	0.0005	0.0005	0.0005	0.0005
Chromium	mg/L	<0.05	0.003	0.007	0.014	0.006	0.002
Nitrate	mg/L	<10	0.5	0.6	0.9	0.8	0.6
Nitrite	mg/L	<0.06	0.021	0.007	0.005	0.004	0.063
pH	mg/L	6-9	7.35	7.36	8.49	7.9	8.11
Phosphate	mg/L	<0.2	0.04	0.04	0.06	0.02	0.02
Zinc	mg/L	<0.05	0.01	0.01	0.01	0.01	0.01
Cyanide	mg/L	<0.02	0.001	0.002	0.001	0.001	0.012
Lead	mg/L	<0.03	0.005	0.005	0.005	0.005	0.007
Copper	mg/L	<0.02	0.011	0.014	0.01	0.011	0.006
Fecal Coliform	amount/100 mL	<1,000	100	4,800	11,500	23,200	400

According to the calculation results of WPI on Rambut River, it was known that the water quality status was decreased from the upstream (point 1) to downstream (point 5) (Table-5). Even though the water quality was only declining moderately, but it still showed that the pollutionlevel might be varied on each point and became worse in the downstream area. The highest Pij value was shown in point 5 with 5.9, while the lowest was found in point 1 with 0.5. The increasing pollution index from each point might be caused by the existence of TDS, TSS, nitrite, and fecal coliform(Effendi & Wardiatno, 2015; Munir *et al*., 2014; Nguyen, 2018). All of these parameters could increased the maximum Ci/Lij value which affected the high outputs of Pij value as well. All sampling points were categorized with ‘Light Pollution’, except in the point 1 which was remarked as ‘Meets standard’. Therefore, by assessing with the WPI indicator, the Rambut River was lightly polluted in general, but still showed a good condition in some parts of the river.

Table-5. Pollution and contamination index results of WPI.

Point	Pij	Remarks
1	0.5	Meets standard
2	3.1	Light pollution
3	4.5	Light pollution
4	5.6	Light pollution
5	5.9	Light pollution

Similar with the results of WPI, there were also some slight differences on the water quality over the different points in Rambut River (Table 6). The Pij values were increasing from the downstream (point 1) to upstream (point 5). The highest Pij value was shown by point 5 with 3.2, while the lowest value was found in point 1 with 0.3. There were tow points which were remarked as a ‘Clean’ category, such as point 1 and 2. However, the other points were regarded as ‘Light pollution’. These differences might be caused by the fecal waste disposal into the rivers at the downstream, making the fecal coliform parameter to had a high concentration(Divya & Solomon, 2016; Irda Sari *et al*., 2018; Mandal *et al*., 2010; Reder *et al*., 2015). Additionally, the agricultural and domestic waste runoff also made the condition worse through the increase of TDS, TSS, and nitrite values(Awomeso *et al*., 2010; Yen & Rohasliney, 2013; Zeb *et al*., 2011). Therefore, it could be stated that Rambut River was lightly polluted in general with some clean conditions in several parts of the water bodies. It made the river to be unsuitable for drinking and agricultural purpose without any proper treatment(Mailisa *et al*., 2020; Ujianti *et al*., 2018). However, it could still be used for animal husbandry, recreation, and sports (Effendi, 2016).

Table-6. Water quality results of WQI.

Point	WQI	Remarks
1	0.3	Clean
2	0.6	Clean
3	1	Light pollution
4	1.6	Light pollution
5	2.3	Light pollution

The comparison of water quality in the Rambut River based on the WPI and WQI indicators was shown in the Table-7 below. Generally, the two indicators showed a similar result, where the Rambut River was lightly polluted, but there was some good condition found on some points. These indicators also shared a same trend that the upstream part of the river was cleaner than the downstream. The difference between upstream and downstream water quality could also befound in Whitehead & Young (1979) and Jain (1996). However, the only difference was found in the condition of point 2, since WPI illustrated that it had a light pollution, while the WQI stated that it was clean or in a good condition. The difference was probably caused by the different calculation data and equation inputs that were used in both indicators. In other words, the difference was still presence, but it still demonstrated the same message about the condition of Rambut River.

Table-7. Water quality classification of WQI.

Point	WPI	WQI
1	Good Condition	Clean
2	Light Pollution	Clean
3	Light Pollution	Light Pollution
4	Light Pollution	Light Pollution
5	Light Pollution	Light Pollution

CONCLUSIONS

The WPI and WQI assessment on this research implied that Rambut River was lightly polluted on the downstream, while the upstream was generally still in a good condition. There were several water quality parameters which exceeded the permissible values based on PP No. 82/2001 on class II standards, such as TDS, TSS, nitrite, and fecal coliform. The pollution was most likely to be caused by the existence of anthropogenic activities around the river bank. There were agricultural area which was dominated by paddy fields and also residential area which regularly discharge domestic wastewater (yellow, grey, brown, and black water). The waste which was discharged into the water bodies was not treated properly, so it was not surprising to see the pollution which occurred in Rambut River. The comparative analysis between WPI and WQI showed that both indicators showed the similar results when determining the water quality of Rambut River. Both of them were agreed that point 1 was still in good condition, while point 3, 4, and 5 were lightly polluted. However, a slight difference was found when determining the water quality of point 2. The WPI results showed that it was in a light pollution, but WQI stated that it met the standards. Moreover, both indicators were also aggreed that the water quality was consecutively worse from upstream to downstream.

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