The Analysis Study on The Self-Purification Capacity of Klampok River, Assessed from Organic Parameter of Dissolved Oxygen (DO) And Biochemical Oxygen Demand (BOD) (Case Study: Segment Sidomukti Village, Bandungan Sub District – Poncoruso Village, Bawen Sub District)

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Abstract. Klampok River is a river that is geographically located in Semarang District. It flows from Sidomukti Village, Bandungan Sub-District to Pringsari Village, Pringapus Sub-District. The fact that population growth and a large number of human activities such as household chores, agricultural (husbandry) and industrial works have eminently impacted on the quality of Klampok River’s water, it has motivated this research to be conducted. Generally, river has its inherent capacity to purify itself on certain defilement condition. The main aim of this study is to determine (discern) the ability of Klampok River’s to self-purify based on DO and BOD parameter by using Streeter-Phelps method to obtain oxygen sag curve and Qual2KW program to simulate the water quality. In this study, the value of deoxygenation constant \( K = 0.226 \) and the reaeration constant \( R = 0.162 \) on segment 2 and \( K = 0.226 \) and \( R = 0.217 \) on segment 3 would be gained. Based on that result, we found the purification constant \( f_s = 0.717 \) on segment 2 and \( f_s = 0.956 \) on segment 3, in which segment 2 functions as active decomposition zone and segment 3 as recovery zone.

1. Introduction

Water is one of the basic needs of all living creatures and river is one of its sources. In human life, water from river has a crucial role for survival, as it is mostly used for drinking, irrigation, fishery, household, and many other activities. Due to these activities, the river are susceptible of being polluted. In addition, the rapid growth of industries can cause the decreased quality of the water.

Essentially, a river has a capacity to clean any pollutants which naturally blend into the water. This inherent capacity of a river to disentangle any pollutants will only be occurred forasmuch as
the contamination ratio is lower than the determined limit because self-purification will only take place in a certain condition [8].

The objective of this research is to detect the quality of Klampok River which is assessed from its DO and BOD rank. In addition, it analyzes the potential of the water to do self-purification along the headwater by using Streeter-Phelps method.

2. Literature Review

Dissolved Oxygen is the numbers of dissolved oxygen inside the water which is originated from photosynthesis process and the atmosphere absorption.

Tchobanoglous (2003) stated that dissolved oxygen is needed as a respiration system for aerobic microorganism. There are only few amount of oxygen dissolved in the water. The actual number of oxygen within the water is mostly formed by the dissolved gas, the partial gas pressure in the atmosphere, temperature, and the water solid concentrate.

The most commonly used parameter to assess the organic pollutant in the waste and surface water is BOD5. To determine the content of organic pollutant, it has to involve the assessment of dissolved oxygen which is used by microorganism during the biochemical oxidizing of organic substances (Tchobanoglous, 2003). The continual reduction of oxygen in the water during the process of natural purification is the difference value of saturation DO and actual DO at the actual time.

\[
Oxygen\ deficit, \ D = Saturation\ DO - Actual\ DO
\]

When the waste water gets into the river flow area which contains a certain number of BOD, the DO will automatically decrease and it causes the decrease of oxygen. To determine the level of deoxygenation and re-aeration (re-oxygenation) we can use the Streeter Phelps method as follow:

\[
D_t = \frac{K_t L_0}{R_t - K_t} \left[ e^{-K_t t} - e^{-R_t t} \right] + D_0 \cdot e^{-R_t t}
\]

\[
L_t = L_0 \cdot (1 - e^{-K_t t})
\]

Where,

\( K = \) deoxygenation constant

\( R = \) re-aeration constant (re-oxygenation)

\( D_t = \) oxygen deficit value in the pollutant source point at time \( t \)

\( L_t = \) BOD concentration (mg/l) at time \( t \)

\( t = \) travel time between two segments (in days)

\( L_0 = \) BOD concentration at \( t=0 \)

\( D_0 = \) oxygen deficit value at \( t=0 \)

The equation below is used to calculate the critical deficit DO,

\[
D_c = \frac{K}{R} L_0 \cdot e^{-K t c}
\]

While the \( tc \) value can be obtained from the equation as follow,

\[
tc = \frac{1}{R_t - K_t} \ln \left[ 1 - D_0 \frac{R_t - K_t}{K_t L_0} \right]
\]

Deoxygenation constant \( K \) in temperature variation can be calculated using the formula below,

\[
K_T = K_{20} \theta^{(T-20)}
\]

Where, \( \theta = \) 1.047 on the temperature 20°C – 30°C

\( \theta = 1.135 \) on the temperature 4°C – 20°C

And, re-aeration/re-oxygenation constant is obtained from:

\[
R_T = R_{20} \theta^{(T-20)}
\]
3. Research Method

This research was conducted in the Klampok river flow Semarang District by taking three samples of river water in three different villages. The villages in which river water was sampled were Sidomukti village, Jimbaran village, and Poncoruso village. The sampling location was determined under several considerations such as, the land use, water used, topography of the area, morphology of the river, potential source of water, potential source of contamination, and administrative territory.

This research had been conducted in four months, from November 1, 2018 to February 28, 2019. Water sampling in Klampok river was carried out based on SNI6989.57:2008 regarding Surface Water Sampling Method. DO parameter testing in the laboratory referred to SNI 6989.72:2009, whereas the BOD parameter testing referred to SNI 6989.14:2004. From the data obtained, DO parameter constant and BOD in the sampling point 1-3, the upstream segment of Klampok River, were analysed. Next, a comparison between the results and the water quality criteria on Government Regulation No. 82 of 2001 on the Management of Water Quality and Water Pollution Control was implemented was compared. To determine self-purification constant, a calculation was performed to find out the level of deoxygenation and reaeration constants. Lastly, the result of DO deficit at any segments were later plotted into oxygen sag curve.

4. Result and discussion

The total length from sampling point 1 to 3 is 4.23 kilometers with various physical characteristics of the river. To that end, the physical characteristics of Klampok River can be seen in the table 1:

| Segmen | Initial height (m) | Final height (m) | Stream length (m) | Upstream width (m) | Downstream width (m) | Depth (m) | Area (m²) | V (m/s) | Stream flow (m³/s) |
|--------|--------------------|------------------|-------------------|-------------------|---------------------|-----------|-----------|---------|------------------|
| 1      | 1010               | 932              | 605.49            | 1.1               | 1.0                 | 0.1       | 0.10      | 0.17    | 0.01785          |
| 2      | 932                | 774              | 1332.97           | 2.55              | 2.45                | 0.1       | 0.25      | 0.37    | 0.0925           |
| 3      | 774                | 609              | 2897.01           | 5.5               | 5.1                 | 0.15      | 0.79      | 0.2     | 0.159            |

Once the value of temperature, pH, DO, and BOD were obtained, it was then compared with the Grade II Quality Standard referring to Government Regulation No. 42 of 2001 on the Management of Water Quality and Water Pollution Control. The results of these comparison can be seen in the table 2. Based on the table, it is evident that at segment 1 of the right section of the river, the BOD level exceeds the Grade II Quality Standard by 0.2 mg/l. As for the other sections, the quality standard for BOD is met, as well as for DO, temperature, and pH. According to [5], the greater the level of BOD in the water, the greater the indication of contamination in the water. The maximum level of BOD allowed for drinking water and supporting the life of aquatic organism is 3.0 – 6.0 mg/l. For the analysis of self-purification capacity of Klampok River, Streeter-Phelps mathematical model was used and was later compared to the Qual2KW program. The Streeter-Phelps mathematical model focuses on two phenomena which are the process of dissolved oxygen reduction (deoxygenation) due to the activity of bacteria in degrading organic substances in the water, and the process of dissolved oxygen increase (reaeration) caused by turbulence in the river flow (Pratama, 2016).
Table 2. Comparison of Pollutant Concentrations with the Grade II Quality Standard

| Parameter | Unit | Grade II Quality Standard | A Segment 1 | Segment 2 | Segment 3 | A Segment 1 | Segment 2 | Segment 3 |
|-----------|------|---------------------------|-------------|-----------|-----------|-------------|-----------|-----------|
| pH        |      |                           | 6-9         | 7,8       | 7,8       | 8,7         | 7,8       | 7,8       | 8,7       |
| Temperature | °C   | Deviation 3               | 25          | 25        | 25        | 25          | 25        | 25        |
| DO        | mg/l |                           | 4           | 7,01      | 6,04      | 6,77        | 6,84      | 5,72      | 7,09      |
| BOD       | mg/l |                           | 3           | 3,2       | 1,13      | 0,97        | 1,53      | 1,29      | 0,88      |

Description: A: The right section of the river, B: The left section of the river

Streeter-Phelps model was applied with a number of assumptions, including:
1. There is only one source of pollution and no other input
2. BOD decomposition rate is comparable to BOD level
3. Oxygen reduction is at the rate of BOD decomposition
4. Oxygen addition is comparable to the decomposition
5. The conditions along the waterbody are almost equal
6. Constant flow rate.

The first thing to do in the calculations using Streeter-Phelps mathematical model was to determine DO saturation value based on temperature at the point of observation. The next step was calculating the value of DO deficit by subtracting the value of DO saturation from the DO concentration measurement result in the laboratory in segments. Next, the value of K (coefficient of deoxygenation) and R (coefficient of reaeration) were calculated in accordance with a known temperature at the point of observations through predefined equation. From the calculation, the oxygen sag curve in segment 2 and 3 of Klampok River were then obtained.

The value of deoxygenation and reaeration constants for segment 2 were obtained as follow:
K (25 °C) = 0,18 (1,047)25-20 = 0,226 /day
R (25 °C) = 0,15 (1,016)25-20 = 0,162 /day

As for segment 3, the value of deoxygenation and reaeration constants were obtained as:
K (25 °C) = 0,18 (1,047)25-20 = 0,226 /hari
R (25 °C) = 0,2 (1,016)25-20 = 0,217 /hari

Next, the calculation of the constants above was resulted in the natural purification constant value of 0,717 in segment 2, and 0,956 in segment 3. The value of deoxygenation and reaeration constants were used to calculate the value of the oxygen reduction value and BOD theoretical value with the following equation:

\[ D_I = \frac{Kt \cdot Lo}{Rt - Kt} \left[ e^{-Kt} - e^{-Rt} \right] + Do \cdot e^{-Rt} \]  \hspace{1cm} (8)

\[ L_I = Lo \cdot e^{-Kt} \]  \hspace{1cm} (9)

In addition, critical time, critical deficit, and critical distance were calculated using the equation below:

\[ t_c = \frac{1}{Rt - Kt} \ln \left[ \frac{Rt}{Kt} \right] \left[ 1 - \frac{Do \cdot (Kt - Kt)}{Kt \cdot Lo} \right] \]  \hspace{1cm} (10)

\[ D_c = \frac{Kt}{Rt} \cdot Lo \cdot e^{-Kt \cdot t_c} \]  \hspace{1cm} (11)

\[ L_I = v \cdot t_c \]  \hspace{1cm} (12)

The reduction of DO and BOD in segment 2 and 3 is presented in the figure 1 and figure 2.
Based on the chart of oxygen reduction in segment 2, there is a decrease of oxygen level in conjunction with the decrease value of BOD. At the same time, the BOD concentration in segment 3 decreases, yet the DO concentration increases. It happens because the deoxygenation rate in segment 2 is greater than the reaeration rate, while the opposite happens in segment 3. In addition, the increase in oxygen throughout segment 3 is thought to be caused by flow turbulence and the input of tributary between segment 2 and 3.

From the calculation, the value of critical point, critical time, and critical deficit in segment 2 and 3 were also obtained. In segment 2, the critical distance is 62.95 km from sampling point 1 with a critical time of 4.29 days and a DO deficit of 2.849 mg/l. On the other hand, the critical point and time valued less than zero/negative values. [2] mentioned that if the value of Xc (critical point) obtained from the calculation was less than or equal to zero, the maximum oxygen deficit would occur at the site of waste disposal. It indicates that the flow along segment 2 represents an active decomposition zone and segment 3 is a recovery zone. When compared with the actual condition, the graph produced becomes:
Figure 3. Comparison chart of concentration values between actual and theoretical DO in segment 2

Figure 4. Comparison Chart of Concentration Values between Actual and Theoretical BOD in Segment 2

Figure 5. Comparison chart of concentration values between actual and theoretical DO in segment 3
From the comparisons above, there are considerable differences between the actual and theoretical concentrations. It is possible because the DO used in the model calculation does not come from the actual DO and BOD values at each point. The concentration in sampling point 1 is used as a reference for initial concentration in segment 2, and concentration in sampling point 2 is used as a reference for initial concentration in segment 3.

The actual DO concentration decreased at sampling point 2 and significantly increased at sampling point 3. Oxygen reduction at the segment 2 is expected due to the crowded activities of hospitality and accommodations along the flow. Meanwhile, the increased level of oxygen at segment 3 could occur due to turbulence along the flow of sampling point 3 and the input from tributary stream from sampling point 2 and sampling point 3. [1] stated that the process of oxygen addition (re-aeration) in the water was caused by flow turbulence resulting in oxygen displacement from air to water. Unlike the Streeter-Phelps method which focuses on the constant state of the flow with no other input, Qual2KW program can be used for unsteady flow in which a pollutant load can pass unexpectedly into the flow. After data running, a graphic is produced as follow:
Figure 8. BOD Profil of Klampok River using Qual2KW

Based on Figure 7 and 8, both DO or BOD models and laboratory results have the same chart pattern, i.e. DO increased in segment 3 and BOD gradually decreased in each segment. With high level of dissolved oxygen concentration in upstream section of Klampok River and considerably low BOD level, there is a little possibility of anaerobic decomposition process. [4] made a statement that microorganisms need the presence of dissolved oxygen in the water for decomposition of organic substances process. If the concentration of dissolved oxygen is very low or even zero, the anaerobic respiration process occurs in the decomposition processs.

5. Conclusion
The water quality parameter DO (Dissolved Oxygen) at all three sampling points on Klampok River met Grade II Quality Standard referring to Government Regulation No. 42 of 2001 on the Management of Water Quality and Water Pollution Control. The result of water sampling for BOD parameter at sampling point 1 on Klampok River exceeded Grade II Quality Standard referring to Government Regulation No. 42 of 2001 on the Management of Water Quality and Water Pollution Control, while sampling point 2 and 3 meet quality standards.

Self-purification process occurred on Klampok River from Sidomukti to Poncisuro Village with segment 2 as the active decomposition zone and segment 3 as the recovery zone. In segment 2, deoxygenation constant value (K) of 0,226 and reaeration constant (R) of 0,162 were obtained, thus the value self-purification coefficient was 0,717. There was no recovery zone in segment 2 of Klampok River. There was only active decomposition zone along the stream as the critical point is outside the flow which is as far as 62,95 km from sampling point 1, with critival time of 4,92 days and critical deficit DO of 2,849 mg/l. In segment 3, deoxygenation constant value (K) of 0,226 and re-aeration constant (R) of 0,217 were obtained, thus the value self-purification coefficient was 0,956. There was only recovery zone because the critical time and critical point values less than zero/negative. Critical time obtained was -0,30 day and critical point distance of -9,54 km with the crutucal DO deficit of 2,433 mg/l.

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