The Study Of Deoxygenation Rate Of Rangkui River Water During Dry Season

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THE STUDY OF DEOXYGENATION RATE OF RANGKUI RIVER WATER DURING DRY SEASON

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ABSTRACT: Rangkui River is a river that passes through the area of Pangkalpinang City, Indonesia. The condition of the River Rangkui is now polluted, especially in the urban areas. Utilization of water quality model is one popular method to recover the river condition. Deoxygenation rate is an important coefficient in the BOD-DO formula used in the water quality model. This study was aimed to find out the actual coefficient of water deoxygenation rate of Rangkui River, especially in the dry season. Sampling was conducted at two location points that are considered to represent the condition of rivers in urban areas. The method of laboratory analysis used in the calculation of deoxygenation rate was using Winkler Method and Slope Method, while empirical formula used in deoxygenation rate calculation was using Hydroscience Equation formula for normal flow. The results showed that the value of deoxygenation rate range (K_1) in the Rangkui River was between 0.14 to 0.41 per day and the BOD Ultimate (La) range was between 8.53 to 70.64 mg / L. As for the value of deoxygenation rate range (K_1) on the River Rangkui using empirical formula was ranging from 0.49 to 0.55 per day. Higher values of deoxygenation rate generated from the empirical formula show the characteristic of typical polluted urban rivers.

Keywords: Deoxygenation Rate, Rangkui River, Slope Method, Winkler Method, Urban River

1. INTRODUCTION

Rangkui River is a river that passes through the area of Pangkalpinang City, Indonesia. It flows from upstream hills of Mangkol, then goes through the Bridge Kace, Bridge 12 and downstream at the end of Pangkalpinang Fish Marketing Center, Bangka Belitung Islands Province. Rangkui River used to be a clear river with many freshwater biotas and served as a source of drinking water and baths. However, the condition of the River Rangkui is now polluted, especially in the urban areas. At the bank of the river, it is inhabited by people's houses with its outlet leading directly to the river. Extraction from domestic and industrial activities suspended in rivers may affect water quality degradation in the Rangkui River. Wastewaters discharged into rivers containing oxygen-consuming elements and organisms usually deplete the oxygen concentration of the river water posing threat to the aquatic lives [1]. This condition is similar to other urban rivers in Indonesia [2]-[5].

Various efforts can be implemented in order to improve the environmental conditions of the Rangkui River, including the use of modeling and prediction calculations. One popular effort to manage and improve the river water quality is the usage of river water quality modeling [2]. Water quality model for river contaminated domestic waste generally use BOD and DO equation. Modeling results can be useful for the formulation of environmental management and the enforcement of quality standards that will result in more appropriate policies for the Rangkui River.

The basic model to estimate the river pollution is the DO model, which is involving several coefficients to calculate the processes of oxygen usage, aeration, and sedimentation in the formula. The rate of deoxygenation indicates the rate of reduced oxygen per day for the decomposition of carbon soluble organic matter in water [6].

The deoxygenation rate coefficients that describe the process of uptake or usage of oxygen by microorganisms in the degradation of organic material are often taken based on the uncertain literature for the stream to be modeled. Typical surface water quality kinetic rates are available in the developed countries, whereas not much is known about the water quality kinetic rates of the remaining part of the world, where the climate, environment, and nature of pollution is different [7]. The typical value usually used is 0.23 per day for polluted water [8]. However, the determination of the deoxygenation coefficient in the laboratory is strongly recommended to obtain more suitable conditions. The calculations supported by the value of laboratory experiments will result in more appropriate policies for each urban river. The quality of the river experiences the worst conditions during the dry season. In this season, some diseases may arise around the banks of the river. Therefore, this research is conducted to provide inputs in the effort of environmental management and water quality improvement efforts of Rangkui River by obtaining the actual deoxygenation rate of Rangkui River water during the dry season.

2. METHODOLOGY

2.1 The Research Location and Sampling Points

The sampling point of the river water was determined to be 2 points in the Rangkui River, i.e. upstream and downstream of the Rangkui River passing through the urban area. The location of this research had the area starting from the first point that was the upstream point in the Pintu Air Street area to the second point of the downstream point in the area of Pasar Burung Trem Street. The reason for taking both points of the samples was because both points have been able to represent the state of both parts of Rangkui River either at the point of upstream or downstream of the river. The segment between those sampling stations is the urban area of Pangkalpinang City. Figure 1 shows the sampling points of the research.

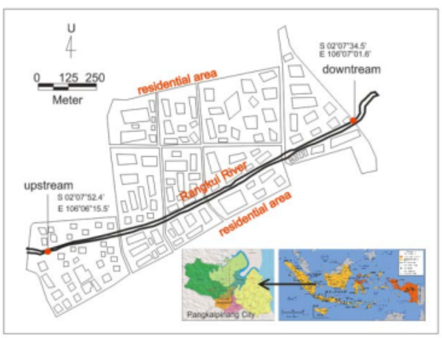

Fig.1Sampling locations.

The upstream station is located in the S 02°07"52.4', E 106°06"15.5' while the downstream station is located in the S02°07"34.5', E106°07"01.6'. Land use of this specific segment is a residential area in dominant; therefore the wastewater discharged into the river has the characteristic of the domestic type. Three samples indicate as the 1st, 2nd, and 3rd, were taken in each sampling points. Those samples also indicated as upstream 1, upstream 2, upstream 3, downstream 1, downstream 2, and downstream 3. Samplings were conducted in dry season during low discharge of Rangkui River. Usually, the dry season gives the higher concentration of pollutants, either organics or non-organics due to the lower dilution process by the rainwater. After sampling, the samples were then being preserved and stored in a cool box.

2.2 The Determination of Deoxygenation Rate Using Laboratory Experiment

The basic examination to determine the rate of deoxygenation was the analysis of DO (dissolved oxygen) concentration. The DO concentration was analyzed using the Winkler Method. The samples were placed in 20°C incubator for 10 days. DO concentrations were measured daily based on the Winkler modification method [9]. The measurement results of DO loss (oxygen usage) for 10 days in each sample point were drawn up to get the DO loss curve against the time. The accumulated value of DO loss generated on each sample was used in the calculation of deoxygenation rate.

Several methods of deoxygenation rate include Thomas'method, least square method, Fujimoto method, rapid ratio method and daily difference method [10].

The calculation of deoxygenation rate using slope method developed by Thomas in 1937 is as follows [11]:

- The calculations include the first determinations of y, y ', y'y and y^2. The value of y is the accumulated value of DO loss, after being able to sum the values of y, y ', y'y then it is inserted into the normal equations to determine the value of K_1 and La. The symbol y is BOD exerted in time with the unit of mg/L, n be the number of measurement minus one, whereas K_1 is the deoxygenation rate in per day, and La is the ultimate BOD in mg/L.
- Two normal equations for determining K_1 and La:

$$na + b\sum y - y' = 0 \qquad (1)$$

$$a\sum y + b\sum y^2 - \sum yy' = 0 \qquad (2)$$

- From the equation above yields a and b values, where the values of K_1 and La can be determined directly from the following relations:

$$K_1 = -b \qquad (3)$$

$$L_a = -a / b \qquad (4)$$

Where:
K_1 is the rate of deoxygenation
L_a is BOD Ultimate.

2.3 The Determination of Deoxygenation Rate Using Empirical Formula

Determining the rate of deoxygenation using the empirical formula should consider physical factor which is the depth of the river. The river depth is very influential on the life of microorganisms in it, where the deeper depth of a river will be less oxygen content and also the number of microorganisms that can live in these waters.

Hydroscience (1971) has developed a relationship for predicting deoxygenation rate in streams and rivers that take into account both stream depth and degree of waste treatment [12], [13]. The formula of Hydroscience (1971) was used for the calculation of the oxygenation rate for normal flow (Chapra, 1997).

$$K_1 = 0.3 \times \left(\frac{H}{8}\right)^{-0.434} \quad , 0 \leq H \leq 8 \text{ ft} \qquad (5)$$

$$K_1 = 0.3 \quad , H > 8 \text{ ft} \qquad (6)$$

Where:

K_1 = deoxygenation coefficient (day^{-1})

H = The depth of the river (ft)

After measuring the depth of the Rangkui River on upstream segments and downstream segments, it obtained the result that did not exceed 2.4 meters, so the formula (3) was used.

2.4 Data Analysis

Data analysis is a thorough examination process and to study the results of a data processing obtained. The data obtained from the measurement of deoxygenation rate range using both laboratory analysis and the empirical formula was based on sampling point and season condition. Then, to know the size of the value of deoxygenation rate generated in this study, it was conducted a comparison toward the literature study and the value of deoxygenation rate obtained from previous research.

3. RESULT AND DISCUSSION

3.1 The Deoxygenation Rate Determined by Laboratory Analysis

Based on the results obtained from the examination of dissolved oxygen concentration by using laboratory analysis, the value of DO in the upstream was lower than that of the DO value in the downstream. This could occur because the water quality in the upstream segment was deteriorated due to the large amount of domestic waste. Meanwhile, on the downstream segment, the organic matter concentration was low. The condition of low concentration of DO can also be caused by the poor reaeration process in the water body. The reaeration process is occurred either by biota-derived oxygen production or fluids turbulence.

In the laboratory, the DO measurement results data for ten days in each sample point was drawn up to get the DO loss curve against the time. DO loss is an indicator of organic pollution which is measured based on the decrease in the amount of oxygen needed by microorganisms during the decomposition of organic matter. After obtained the value of DO loss, then we accumulate the DO loss and to get the calculation of deoxygenation rate of each sample.

Figure 2 and 3 is the graph of DO loss accumulation against time for the first, second and third measurements at the downstream and upstream sampling point respectively.

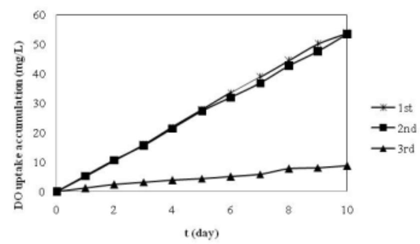

Fig. 2. Accumulation DO uptake at the upstream.

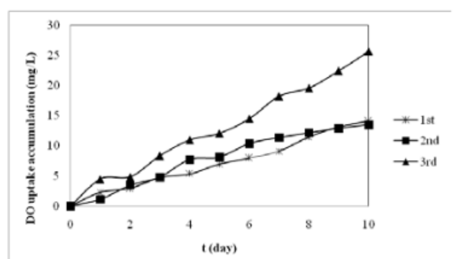

Fig. 3. Accumulation DO uptake at the downstream.

The figures show that the DO loss accumulation phenomenon in the first and second sampling has no significant difference. However, in the third sampling has a different phenomenon. This is likely due to the changing river condition during the third sampling. DO loss at the upstream point shows a relatively higher value compared to the downstream point. The result of DO loss accumulation is used to calculate the value of deoxygenation rate and ultimate BOD. The DO loss value of downstream was accumulated up to approximately 50 mg/L, whereas in the downstream only up to 25 mg/L the highest. The higher accumulation of DO loss shows several indications, i.e. the high concentration of BOD, the more abundant decomposing microorganisms, the healthier condition of water in term of aerobic digestion.

Table 1 shows the results of the deoxygenation rate calculation and the ultimate BOD resulted from the Slope Method.

Table 1. Deoxygenation Rate Values and Ultimate BOD By Using Laboratory Analysis

Sampling Point	Deoxygenation Rate K_1 (per hari)	BOD ultimate La (mg/L)
Upstream1	0.20	60.85
Upstream 2	0.14	70.64
Upstream 3	0.30	8.53
downstream 1	0.18	16.39
downstream 2	0.41	12.97
downstream 3	0.21	27.14

Table 1 shows that overall when it was combined and retrieved the value of the deoxygenation rate range (K_1) for the upstream point in the dry season on the Rangkui River ranged from 0.14 to 0.30 per day. For the rate of deoxygenation (K_1) at the downstream point ranged from 0.18 to 0.41 per day. The values of deoxygenation rates in the upstream and downstream were different to show the activity of microorganisms in the use of oxygen in degrading different organic substances. The value of K_1 determines the speed of the BOD reaction without influencing the magnitude of the ultimate BOD [15]. The rate of carbon deoxygenation also shows the quality performance of the river from self-recovery or self-purification of rivers [6]. Deoxygenation phenomena show the oxygen usage in processes of oxidation of carbonaceous and nitrogenous waste material, the oxygen demand of sediments water body, and use of oxygen for respiration by aquatic plants [16]. Typical values of K_1 for surface water are in the range of 0.1-0.23 per day whereas for weak municipal wastewater and strong municipal wastewater are 0.35 and 0.4 per day, respectively [15] According to these typical values, the deoxygenation rates determined in this research were found suitable for surface water. However, the effect of the season might not be specifically shown. The deoxygenation rate is not strongly different between rainy season and dry season [2].

Meanwhile, for the ultimate BOD value in the dry season on the River Rangkui as a whole ranged between 8.53 mg/L to 70.64 mg/L. The La value had a greater value in the upstream than the downstream. The concentration of ultimate BOD was higher in the upstream water compared to that of the downstream water. It might be caused by severe pollution occurred in the upstream area where the housing is more condensed. In the downstream water, the organic matter had probably been decomposed by the microorganisms.

3.2 The Deoxygenation Rate Calculated by means of Empirical Formula

In determining the deoxygenation rate using this empirical formula, it considered environmental factors such as river depth. The depth of the river affected the life of the microorganisms in it, where the deeper depth of a river would be less oxygen content and fewer microorganisms that could live in these waters. And if the number of microorganisms in the water was less, then the rate of deoxygenation in the river would be low. So, the calculation of deoxygenation rate was also done by using empirical formula related to the depth of the river according to Hydroscience [14],.

Table2 The Value of Deoxygenation Rate and BOD Ultimate Using Empirical Formula

Sampling Point	Depth (H) (m)	(ft)	Deoxygenation Rate K_1 (per hari)
Upstream 1	0.60	1.97	0.55
Upstream 2	0.63	2.07	0.54
Upstream 3	0.70	2.3	0.52
Downstream 1	0.75	2.46	0.50
Downstream 2	0.77	2.53	0.49
Downstream 3	0.80	2.62	0.49

Table 2 showed that overall when the value of the deoxygenation rate range (K_1) combined and taken during the dry season on the River Rangkui ranged from 0.49 to 0.55 per day.

The rate of deoxygenation (K_1) at the sampling site for the upstream point was greater than the rate of deoxygenation (K_1) at the sampling site for the downstream point. It was resulted due to the depth factor at the sampling site for the upstream point which was shallower than the depth at the sampling area for downstream segment because the depth of the river affected the life of microorganisms in it, where the deeper depth of the river would be less oxygen content and fewer the number of microorganisms that could live in these waters. And if the number of microorganisms in the water was less, then the rate of deoxygenation in a river would be low.

Overall, the results of deoxygenation rate based on laboratory analysis and using empirical formula, where the value of the deoxygenation rate range with the formula was greater than the deoxygenation rate using laboratory analysis ranged from 0.49 to 0.55 per day using the formula, while the results of laboratory analysis was between 0.14 to 0.41 per day. The result shows that deoxygenation rate is higher in empirical formula solution. The similar condition had been observed in another urban river such as Citepus and Cikapundung, Bandung, Indonesia [17].

The deoxygenation rate range of Rangkui River in this study ranged from 0.14 to 0.41 per day (laboratory analysis) and from 0.49 to 0.55 per day (empirical formula). The rate of deoxygenation identified the amount of domestic wastewater and the solid waste in the Rangkui River that could increase the concentration of organic matter in river water.

Deoxygenation rate was also influenced by the BOD concentration. Defining the changes in BOD was affected by many factors, including the concentration of the organic contamination and various disturbing factors such as salinity, poisons, etc. [18].

Heavy metal might also exist in the river water due to the wastewater discharged from the home-industry activities. A majority of studies have demonstrated that the toxic effect of heavy metals like chromium, cadmium, and nickel is attributable to a disruption of enzyme function and structure by binding of the metal ions with thiol and other groups on protein molecules or by replacing naturally occurring metals in enzyme prosthetic groups [19].

4. CONCLUSION

The calculation results of K_1 using laboratory analysis for the dry season on the Rangkui River ranged from 0.14 to 0.41 per day and the BOD Ultimate value ranged from 8.53 to 70.64 mg/L. Meanwhile, deoxygenation rate range acquired by using empirical formulas for the dry season on the River Rangkui ranged from 0.49 to 0.55 per day. These results show that the deoxygenation rate obtained by using laboratory analysis was smaller than the value of empirical formula calculated deoxygenation rate. The BOD Ultimate value conditions showed that the amount of organic matter contained in the water of the Rangkui River was due to the flow of the Rangkui River passing through residential areas. Most of the domestic wastes contained organic substances that would increase the use of oxygen by microorganisms to degrade the organic substances. This condition is similar to another urban river in Indonesia, e.g. Citepus River. By the increase of oxygen usage, then the BOD content in the water also increased and the availability of dissolved oxygen in the water decreased. The greater BOD value, there would be smaller availability of dissolved oxygen in water.

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Pp. 266
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