Determinaion of Deoxigenation Rate of Urban River Using Modification Methods

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DETERMINATION OF DEOXYGENATION RATE OF URBAN RIVER USING MODIFICATION METHODS FOR CITEPUS RIVER WATER, BANDUNG, INDONESIA

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ABSTRACT

River water quality modeling needs appropriate and suitable coefficients especially in application for specific river like urban river. **Aim:** This study aims to determine the value of the coefficient with a short term duration and a variable test time span. Several ways and methods of determining the rate of deoxygenation are developed according to the characteristics of the river and the environment. Modification method was applied in this research in which the test time span was unequal. The river chosen in this study is the Citepus River, Bandung, Indonesia representing an urban river in a tropical country. **Methodology and Results:** Sampling was carried out in the dry season. The laboratory analysis method used in determining the rate of deoxygenation uses the Slope Method of data from the short term incubation, which is ten days. The results showed that the Thomas Slope method's deoxygenation rate (K1) was 0.095 per day in the upstream segment, 0.917 per day in the middle segment, and 0.180 per day in the downstream segment. While the Ultimate BOD (La) value is 46.95 mg/l in the upstream segment, 38.70 mg/l in the middle segment, and 37.60 mg/l in the downstream segment. **Conclusion, significance, and impact of study:** The results of this study show that the value of the deoxygenation rate is similar to the theoretical surface water conditions. However, in the upstream segment, there is still a low deoxygenation rate value due to non-optimal activity of microorganisms. This findings will be very useful both in water quality modeling and river management.

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1. INTRODUCTION

River water quality modeling is one of the stakeholders' efforts to formulate management to rehabilitate polluted urban rivers (Ejigu, 2021; Mulyatna *et al.,* 2020). Essential parameters in water quality modeling indicators are DO (dissolved oxygen) and BOD (biochemical oxygen demand) (Thenu and Karnaningroem, 2019). DO has an important role for rivers as an indicator of determining water quality in the river (Handoko and Sutrisno, 2021). Changes in DO can be used to describe the ability of a polluted river to self-purify. Changes in DO concentration in waters are caused by the process of reducing dissolved oxygen due to the activity of microorganisms that use oxygen in decomposing organic matter in water and the process of entering oxygen into the water from the air column (Hendriarianti *et al.,* 2018) (Nugraha *et al.,* 2020). Physical reaeration is caused by turbulence of river flow (Haider *et al.,* 2013). Naturally, the level of pollution that occurs in river water, especially from domestic waste, can be recovered by the presence of decomposing microorganisms and oxygen.

Citepus River is one of the rivers that cross the city of Bandung. The Citepus River is a sub-watershed of the Citarum River watershed. This 10.98 kilometer long river flows through Bandung City and empties into the Citarum River in the southern part of Bandung City. The area drained by the Citepus River is included in the plan to develop a high-density residential area (Firdayati *et al.,* 2015). The most dominant land use is for business and public facilities with the most locations being in the middle of the Citepus watershed. In order to improve the condition of river waters in urban areas that are increasingly polluted, in this case the Citepus River, several pollution control efforts can be carried out, including the use of pollution prediction modeling and calculations for the formulation of environmental management and the implementation of quality standards that will produce more appropriate policies for the Citepus River. One of the essential coefficients to know in modeling is the deoxygenation rate coefficient (Menezes *et al.,* 2015). The use of the suitable deoxygenation rate will produce modeling simulation data that can represent the actual conditions in the field.

Several previous studies have determined the value of the deoxygenation rate using the short-term method for urban river water. However, the minimum results obtained as low as 0.06 per day (Yustiani *et al.,* 2013) that lower than those theoretically which is minimum 0.1 per day (Singh, 2004). This can happen when the test time lags between each analysis are wide,

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resulting in insufficient oxygen in the system. Therefore, it is necessary to improve the method of determining the deoxygenation rate, especially at the testing stage. Specifically, this study aimed to obtain the value of the coefficient of deoxygenation rate (K1) in the Citepus River using short term duration and dry season. The rate will be very useful for two functions, i.e. indicating the condition of water quality concerning self-purification capability of the river and supporting the river water quality modeling. The dry season was chosen as sampling time based on the potential for a relatively higher pollution level than the rainy season (Widodo *et al.,* 2015; Islam *et al.,* 2015).

2. RESEARCH METHODOLOGY

2.1 Sampling Location

Sampling in the study was carried out at 3 locations that represent the flow in the city of Bandung, i.e. first point representing the upstream segment at coordinates 6°53' 44.5128" S and 107°35'15.8964" E; second point represents the middle segment with coordinates 6°54'32.5614" S and 107°35' 29.3316"E; while the third point represents the end segment with coordinates 6°55'23.667" S and 107°35'53.2608" E. Map of sampling locations can be seen in Figure 1.

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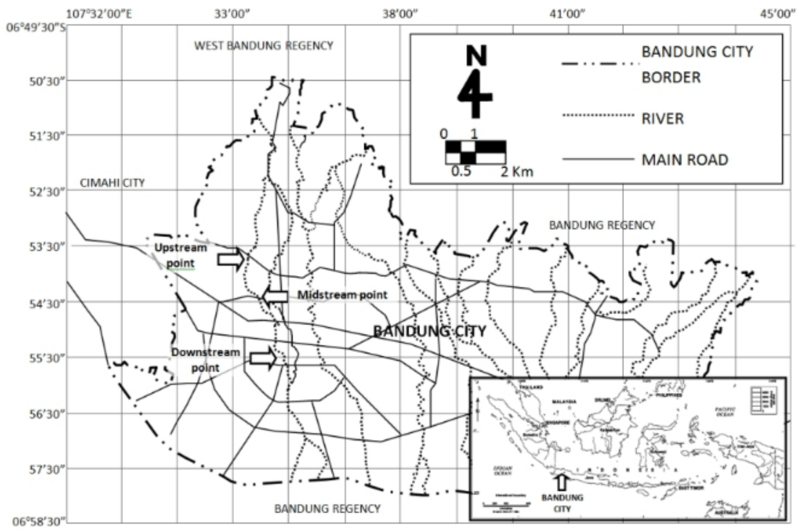

Figure 1 Sampling points location

Samples taken at predetermined points have been considered by looking at the high pollution potential and pollution load. During the trip to the laboratory, water samples were preserved by placing them in a cool box with a temperature of 4ºC, so that bacterial activity was inhibited before laboratory analysis, following the Indonesian Standard of SNI 6989.57:2008.

There are 4 parameters that are directly measured onsite, i.e. dissolved oxygen concentration, pH, temperature, and river discharge. The measurement devised used in this activity was a portable tool.

2.2 Laboratory Works

In the laboratory, samples were stored in an incubator at 20°C for 10 days. During that time, the remaining dissolved oxygen concentration was tested 11 times on the day of 0, 0.25, 1.04, 1.4, 2.2, 2.5, 3.4, 4.4, 6.4, 8.4, and 10.4. The test interval is different between each analysis and not equal throughout the 10 days. At the beginning of the test, the gap was taken relatively tight, while starting on day 4, the testing gap was looser. This testing pause setting is based on the results of previous research (Yustiani *et al.,* 2013). The more frequent time span of the DO concentration analysis at the beginning of this series of analyses was carried out because the use of DO was quite rapid at that time (Yustiani *et al.,* 2021).

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DO concentration was measured based on Winkler's modified method (APHA, 2017). The analysis of the DO concentration was carried out in 3 repetitions at each sampling point to ensure confidence in the test results.

2.3 Oxygen Utilized

At each test interval, a decrease in DO concentration was obtained. This shows that DO is used by microorganisms contained in water to decompose organic compounds. Aeration process is always given after each analysis to ensure that microorganisms continue to work to decompose these organic compounds.

Data on the accumulation of oxygen usage for each test for 10 days shows the deoxygenation phenomenon that occurs. In addition, it can also show the self-purification process in water samples. If the curve formed begins to flatten at the end of the testing period, it is estimated that the self-purification process is almost over (Wahyuningsih *et al.,* 2020). On the other hand, if the curve continues to increase, the self-purification process is still ongoing. Equation 1 is used to calculate the accumulated oxygen usage for each analysis, where DO_{acc} is accumulation of dissolved oxygen usage during incubation, DO_i is oxygen usage in each time span analysis (Yustiani *et al.,* 2013).

$$DO_{acc} = \sum_{i=1}^{n} DO_i - DO_{i=1} \quad (1)$$

2.4 Deoxygenation Rate Calculation

The test results data in the laboratory are processed using the Thomas' slope method, which is based on the first-order reaction equation (Equation 2), where y is BOD, t is time, K_1 is deoxygenation rate, La is ultimate BOD (Lin, 2007).

$$\frac{dy}{dt} = K_1(L_a - y) = K_1 L_a - K_1 y \quad (2)$$

The Thomas' slope method is used in this study because it is the most popular method in

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calculating the deoxygenation rate. The *dy* value is obtained by measure oxygen usage in each time span. Using a test interval that is not uniform, resulting in *dt* is not the same for each data. Detailed calculations for the unequal time increment are required.

3. RESULTS AND DISCUSSION

3.1 Onsite Measurement Results

There are 4 parameters that are measured directly in the field, i.e., DO, pH, temperature, and the discharge of the Citepus River. Measurements were made in the morning when river water samples were taken. Table 1 shows the results of DO, pH, temperature, and discharge measurements of the Citepus River.

Table 1 Onsite measurement parameters

Sampling point	DO (mg/L)	pH	Temperature (°C)	Discharge (m^3/s)
Upstream	6.2	7.3	22.8	0.18
Middle Stream	5.6	7.2	23.1	0.88
Downstream	6.1	8.1	22.7	0.69

Table 1 shows that the DO value is in a relatively good concentration range. DO values above 5 mg/L still provide support for ongoing aerobic processes while the pH is in the neutral range, which is a comfortable condition for microorganisms to live. Aquatic biota will be disturbed at a pH that is not neutral, especially in acidic conditions (Syra, 2017). Similarly, the measured temperature. Water temperature has a significant influence on the physical, chemical, and biological processes of water. The temperature in the middle stream looks warmer than other sampling points, resulting in lower DO values in this place. An increase in water temperature causes a high rate of metabolism and various chemical reactions and reduces the solubility of oxygen in water (Wahyuningsih *et al.,* 2019).

The results of the discharge measurement show very low values. The condition happens because the storm water input from rainfall is decreasing in the dry season. Discharge and low

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water velocity can result in a weak re-aeration process as well.

3.2 Accumulation of Oxygen Usage

Measurement of oxygen in each time span indicates oxygen usage during that period. Figure 2 shows a graph of the accumulation of DO usage for 10 days with a predetermined test time lag for the upstream point water sample. Oxygen is used continuously to decompose the organic matter contained in the sample water. This shows that the self-purification process is running well. However, in Figure 2, it can be seen that the accumulation of DO usage on the 10th day is still increasing. This condition indicates that the self-purification process is still running. Qualitatively, such a curve also indicates a low deoxygenation rate. While in Figures 3 and 4, it can be seen that the use of DO in river water is getting less and less (Penn *et al.,* 2003). Figure 3 displays the accumulation of DO usage at the middle stream point, while Figure 4 is for the downstream point. The curve formed began to flatten out at the time of the 8th day of testing. The use of DO still continued after the 10th day due to the nitrogenous oxygen demand process (N-BOD) (Haider and Ali, 2010).

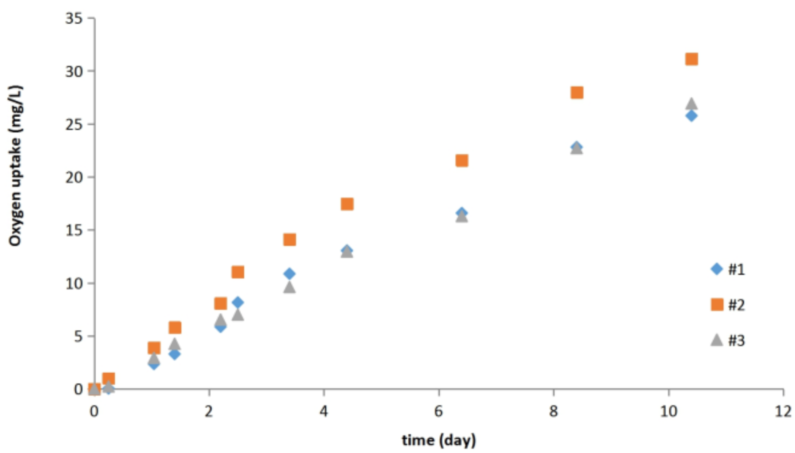

Figure 2 Accumulation of DO utilized at the upstream point

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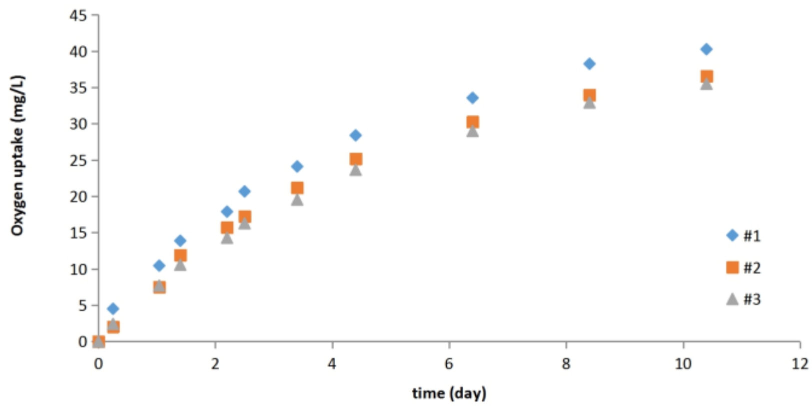

Figure 3 Accumulation of DO utilized at middle stream point

DO use occurs rapidly around 3 days of incubation and slows down thereafter. Both the first, second and third iterations show the same phenomenon.

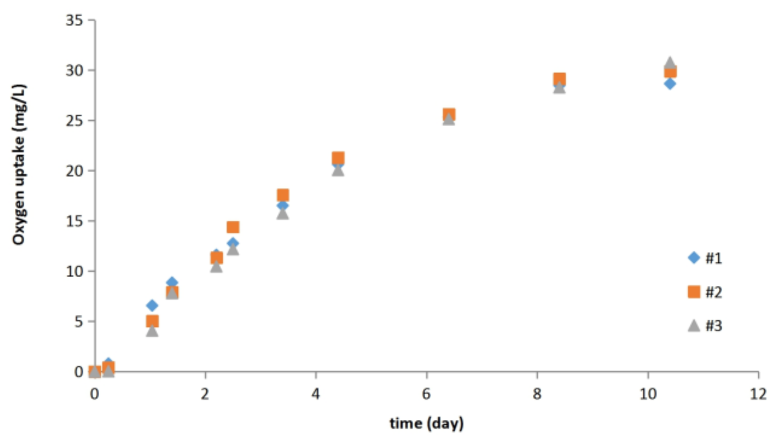

Figure 4 Accumulation of DO utilized at middle stream point

Figure 5 shows the comparison of accumulated DO usage between upstream, middle stream and downstream.

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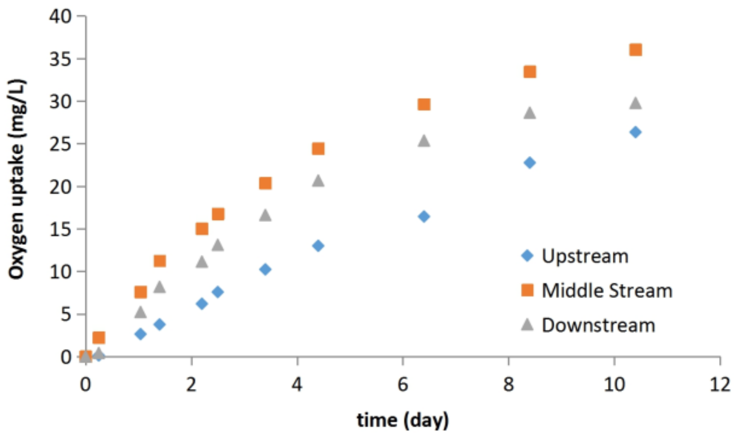

Figure 5 Average oxygen accumulation of each point

From Figure 5, it can be seen qualitatively that the highest deoxygenation rate occurs in the middle stream, while the slowest occurs in the downstream. Although the curve of accumulation of oxygen usage in the upstream looks low, the organic matter content may be high because the self-purification process has not yet shown an almost complete stage (Zubaidah *et al.,* 2019).

3.3 Calculation Results of Thomas' Slope Method

Processing of oxygen usage data for 10 days with the Thomas' slope method provides the value of the deoxygenation rate for each sampling point with 3 repetitions. This method can also be used to calculate the ultimate BOD. Table 3 shows the results of these calculations.

Table 2 Results of the ultimate deoxygenation rate and BOD

Sampling Point	Deoxygenation Rate K_1 (per day)				BOD Ultimate La (mg/L)			
	Repetition #			Average	Repetition #			Average
	1	2	3		1	2	3	
Upstream	0.084	0.15	0.05	0.095	44.86	40.81	55.19	46.95
Middle Stream	1.08	0.85	0.82	0.917	32.46	29.98	53.67	38.70
Downstream	0.18	0.19	0.17	0.180	35.1	39	38.7	37.60

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Based on Table 3, the highest deoxygenation rate value occurs at point 2 (middle stream). This can happen because the activity of decomposing microorganisms takes place quickly even though the level of pollution is not high. Meanwhile at point 1 (upstream) and point 3 (downstream) the deoxygenation rate is not as high as at point 2 (middle stream). This shows that the activity of microorganisms in degrading organic matter is relatively low. The average value of the deoxygenation rate at the upstream point is 0.095 per day. Less than optimal microorganisms can cause this low value to decompose organic matter contained in river water. Disturbances to river water ecosystems can occur due to the content of toxic waste, disinfectants, and other inhibitory compounds. Based on the literature, the typical value for the deoxygenation rate of river water is in the range of 0.1-0.23 per day (Singh, 2004).

The ultimate BOD (L_a) range value on the Citepus River for point 1 (upstream) ranges from 40.81 to 55.19 mg/l with an average value of 46.95 mg/l. L_a value for point 2 (middle stream) ranged from 29.98 to 53.67 mg/L with an average value of 38.70 mg/l, whereas La value for point 3 (downstream) ranged from 35.1 to 39 mg/l with an average value of 37.60. The overall value of La range is 37.60 to 46.95 mg/l. The L_a shows the total oxygen demand in decomposing the organic matters (Penn *et al.,* 2003).

It is discovered from the results of previous studies on the Citepus River, that the deoxygenation rate range is 0.06-0.48 per day (Yustiani *et al.,* 2013). Meanwhile the deoxygenation rate in this study is 0.095-0.9 per day. The value of the deoxygenation rate in this study was higher than previous studies indicating the high number of microorganisms found in the Citepus River so that organic matter was rapidly degraded. The higher the deoxygenation value, the faster the use of oxygen by microorganisms in degrading organic matter. In normal condition, where microorganisms perform organic matters decomposing, the ultimate BOD value will influence the deoxygenation rate. High BOD concentration may cause high rate of deoxygenation (Hendriarianti and Karnaningroem, 2015).

The deoxygenation rate value obtained in this research is higher than those of the previous studies. Cikapundung River study that used laboratory observations for 10 days obtains the value of the deoxygenation rate ranges from 0.01 to 0.37 per day (Yustiani *et al.,* 2018). A study at the Cicadas River water shows a deoxygenation rate ranging from 0.01 to 0.17 per day (Yustiani *et al.,* 2019). Meanwhile, from Citarum River study, which was using the 30-day

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long-term duration method, obtained a deoxygenation rate value ranging from 0.37 to 0.45 per day (Yustiani *et al.,* 2021).

4. CONCLUSION

The value of the deoxygenation rate range (K_1) using a modified test method and the Slope Method as a whole is in the range from 0.095 to 0.91 per day. Determination of the value of the deoxygenation rate using this modified method shows results that are close to the theoretical range as a characteristic of surface water. Thus, this modified method can improve the previous technique on a short period of time. The overall BOD Ultimate (La) ranges from 37.60 to 56.96 mg/l. This shows that the Citepus River is experiencing moderate pollution levels, and efforts to improve its quality are needed.

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