The Deoxygenation Rate Determination Based on Phsycal Condition

by Yonik Meilawati

The Deoxygenation Rate Determination Based on Physical Condition of River Body, Case Study of Citepus River

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Abstract. The rate of deoxygenation is one important parameter in the calculation of river water quality. Deoxygenation process itself can be a general characteristic of the river in the perspective of its biological activity, i.e. the uptake of oxygen by microorganisms in performing the decomposition process. Determination of the rate of deoxygenation is usually performed in the laboratory by carry out incubation and analysis on the sample of water for 10-20 days. However, to obtain the rate of deoxygenation with a shorter time, the physical condition of the river can be used in several equations proposed by Hydroscience. These equations utilize the physical condition of the river body, i.e. water depth, for the calculation of deoxygenation rate. In this study, the results of these empirical equations for the value of the rate of deoxygenation were compared to the results of laboratory analysis for Citepus River. Based on the laboratory analysis, the deoxygenation rate was highly varied around 0.06 to 0.48 per day, whereas the result of the empirical equation calculation shows numbers that are not too varied, i.e. 0.42 to 0.64 per day. In this case, the highest value of deoxygenation rate resulted from laboratory analysis similar to the lowest value of calculation using Hydroscience equation.

Keywords: deoxygenation rate, Hydroscience equation, river water depth.
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INTRODUCTION

Recently, the function of rivers located in Bandung City turns into the discharge place of domestic and industrial wastewater. The water quality in Bandung Basin becomes deteriorated, especially in Citarum River. The dominant pollution source is domestic activities. The West Java Environmental Protection Agency estimates that the domestic wastewater was discharged from 3.5 million people directly and indirectly into the urban rivers around Bandung City. The domestic wastewater reaches up to 60% of total wastewater pours into the rivers.

Population sizes are growing rapidly causing the increment of domestic wastewater derived from the municipal activities. It causes the deterioration of water quality directly and indirectly in long term [1]. Concerning this condition, especially for the surface water quality which is often used as drinking water source, thus its pollution potency need to be modeled.

Utilization of environmental quality modeling can be very useful, inexpensive, simple, and efficient in time. The uses of river quality models are very useful to give prediction of conditions in the future, so that the environmental management measures can be formulated by the river immediately prior to the contamination or other disaster. Mathematical formula used in the modeling of river water environmental quality is Streeter Phelps, the formula with coefficients involvement impairment is often referred to the deoxygenation rate or the rate of BOD decomposition in the formula. Empirical analysis to determine the coefficient of the rate of deoxygenation needs to be done in order to obtain the appropriate water quality modeling for urban rivers. The deoxygenation rate coefficient will also describe the characteristics of urban river water contamination has been contained.

During this time, in the use of water quality models for Bandung City rivers, the coefficients were frequently taken based on literature from other countries with a low level of accuracy. Therefore, a study of the deoxygenation rate specially for urban river in Indonesia is very important.

Determination of the rate of deoxygenation in the laboratory have suggested by the USEPA (United States Environmental Protection Agency), even though

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their values can be obtained by total BOD removal rate that takes into account the rate of deposition of BOD [2]. Several ways can be done to analyze the results of laboratory experiments, such as Thomas method, least squares, Fujimoto, Rapid Ratio, Moment, and the Daily Difference [3].

Determination of the rate of deoxygenation is usually performed in the laboratory by carry out incubation and analysis on the sample of water for 10-20 days. However, to obtain the rate of deoxygenation with a shorter time, the physical condition of the river can be used in several equations proposed by Hydroscience [4]. These equations utilize the physical condition of the river body, i.e. water depth, for the calculation of deoxygenation rate. In this research, the investigation of physical condition of the river using the empirical equation was carried out. Utilization of the equation would be very helpful and uncomplicated if it can represent the field condition.

RESEARCH METHODOLOGY

The deoxygenation rate was obtained from Hydroscience empirical Eq (1)[4] which is using the physical condition of the river, its water depth.

$$K_d = 0.3 \times \left(\frac{H}{8}\right)^{-0.434} \quad (1)$$

where: K_d = deoxygenation rate (day^{-1}), H = water depth (ft).

In order to analyze the equation results, the deoxygenation rate was also measured from the water samples. Water sampling locations were in the crossing area of Citepus River with Pajajaran Street (upstream) and Imhoff Tank Street (downstream). Fig. 1 shows the sampling site.

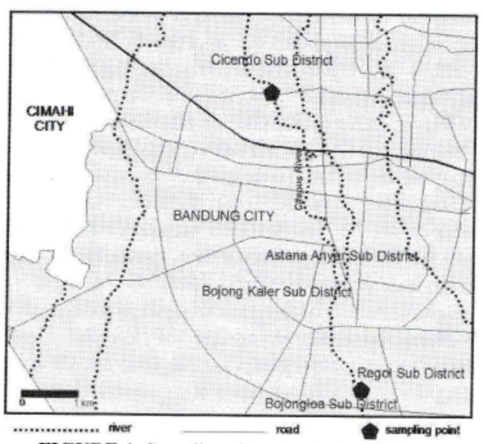

FIGURE 1. Sampling site in the Citepus River.

Water samples were taken from the water column so as not impaired by sediment. In order to obtain these conditions, the sampling points chosen at the point with sufficient water depth, which is at least 50cm. Preservation of samples is by using the method of cooling in the coolbox for a trip to the laboratory. Samplings were conducted 6 times repetition during August 2011-January 2012.

Analyzes were carried out to determine the rate of deoxygenation using the dissolved oxygen concentration measured in the water samples. Incubation process using a BOD bottle, carried out for 10 hours in 20°C incubator. DO concentrations were measured every day based on the modified Winkler method [5]. Based on the methods of the USGS (United State Geological Survey), when the DO reaches a value below 2 mg/L, aeration should be conducted to see a decrease in oxygen concentration on the next day [6].

DO concentration results for 10 days for each sample point were then used to determine the deoxygenation rate by utilize slope method introduced by Thomas (1937). Non-linear regression method, least squares, and Thomas are the first choice method for estimating the parameters BOD [7].

Thomas method for BOD determination and deoxygenation rate is based on the similarity of two functions, a graphical analysis using the following function [3].

$$\left[ty^{-1}\right]^{1/3} = (2.3kL)^{-1/3} + k^{2/3}\left(3.43L^{1/3}\right)^{-1} t \quad (2)$$

where:
k = BOD deoxygenation rate (day^{-1})
L = ultimate BOD (mg/L)
y = BOD uptake in time interval (mg/L)
$[ty^{-1}]^{1/3}$ = can be plot as a function of time (t) t, with slope $k^{2/3}(3.43L^{1/3})^{-1}$
$2.3kL^{-1/3}$ = intercept point.

Slope method introduced by Thomas (1937) gives a constant BOD through least-squares treatment (least squares) to form the basis of the first order reaction equation [8].

$$\frac{dy}{dt} = K_1(L_a - y) = K_1 L_a - K_1 y \quad (3)$$

where: dy = increase in BOD per unit time at time t
K_1=deoxygenation constant, per day
L_a = first stage ultimate BOD, mg/L
y = BOD exerted in time t, mg/L

This differential equation (Eq. (3)) is linear between dy/dt and y. Let $y'=dy/dt$ to be the rate of change of BOD and n be the number of BOD measurements minus one. Two normal equations for finding K_1 and L_a are shown in Eq. (4) and Eq. (5).

$$na + b\Sigma y - \Sigma y = 0 \quad (4)$$

$$a\sum y + b\sum y^2 - \sum yy' = 0 \quad (5)$$

Solving Eqs. (4) and (5) yields values of a and b, from which and L_a can be determined directly by following relations:

$$K_1 = b \quad (6)$$

$$L_a = -a/b \quad (7)$$

RESULT AND DISCUSSION

Table 1 shows the water depth of Citepus River during 6 times water samplings. The results indicate that Citepus River is quite shallow with the maximum water depth of 1.1m. Shallow water depth should give high rate of deoxygenation and aeration. Comparation of water depth between upstream and downstream sampling points shows that downstream area has deeper water than upstream area, which can be assumed that deoxygenation rate would be lower in the downstream area.

TABLE 1. Water depth of Citepus River during measurements (m).

Location/Time	Upstream	Downstream
1	0.45	0.64
2	0.64	0.72
3	0.42	0.62
4	0.7	0.72
5	0.72	1.1
6	0.64	0.93

Laboratory analysis shows that BOD ultimate concentration of Citepus River ranges between 14.80~38.95mg/L (Table 2). The upstream water quality was averagely better than the downstream.

TABLE 2. BOD ultimate concentration (mg/L).

Time/Location	Upstream	Downstream
1	14.8	22.25
2	18.08	23.58
3	18.17	24.51
4	16.91	27.61
5	30.77	38.95
6	23.06	19.18

In the location of downstream sampling point of Citepus River, there is an outlet of domestic wastewater treatment. The effluent of this treatment may affect the water quality in the area. Some researches on water quality in the area of Bandung have been done earlier. BOD concentration of Citarum Hulu River (upstream segment of Citarum River) can reach 226 mg/L due to inefficiency of Cisirung WWTP (Waste Water Treatment Plant) [9].In the previous study of the River Citepus (segment of Dr. Setiabudhi Street–Caringin Street) obtained that the maximum BOD concentration is 7.56 mg/L [10]. This segment is located upper than sampling location of this research.

Deoxygenation rates in the upstream area of Citepus River water is presented in the Table 3. This result shows that the deoxygenation rate ranges between 0.09~0.42 day^{-1} based on the laboratory analysis. Calculation of the deoxygenation rate using the empirical equation gave the value between 0.509~0.643 day^{-1}. This calculation show higher results compared to those laboratory results.

TABLE 3. Deoxygenation rates in the upstream area of Citepus River (day^{-1}).

Time	Laboratory determination	Equation determination
1	0.132	0.624
2	0.22	0.536
3	0.223	0.643
4	0.42	0.515
5	0.09	0.509
6	0.21	0.536

Table 4 show the result of laboratory experiments and calculation of deoxygenation rate for the water samples taken from the downstream of Citepus River.

TABLE 4. Deoxygenation rates in the downstream area of Citepus River (day^{-1}).

Time	Laboratory determination	Equation determination
1	0.064	0.536
2	0.12	0.509
3	0.2	0.543
4	0.15	0.509
5	0.48	0.423
6	0.44	0.455

Similar to the previous results, Table 4 also indicate that the deoxygenation rate calculated using empirical equation gives higher value than those using laboratory determination. The rate is ranging between

0.064~0.48 day^{-1} by the laboratory experiments, and 0.423~0.543 day^{-1} by the empirical equation determination.

Previous research conducting for the Citarum Hulu River showed that the deoxygenation rate are 0.03~0.95 day^{-1} based on modeling calibration process [10].

The range of values for the rate of deoxygenation of Citepus River water in this study showed that the activity of microorganisms in the river relatively low. For comparison, the rate of deoxygenation obtained for several rivers in other countries are as follows [11-13]:

- Ravi River (Pakistan) 0.14 – 0.27 day^{-1}
- Swan River (Western Australia) 0.23 day^{-1}
- Gomti River (India) 0.45 day^{-1}

High values of deoxygenation rate show that the activity of the decomposition of BOD by microorganisms is relatively high. In the case of Citepus River, low rate of deoxygenation was obtained although the water depth is quite shallow. This can be assumed that the activity of microorganism to decomposed organic matter is slow in the river water. This can be caused due to an inhibition of growth and performance of microorganisms such as industrial waste containing heavy metals, high acidity, and others. In addition, medical waste from hospitals or clinics can also be inhibiting the activity of the decomposition of organic matter by microorganisms in the river, especially if the waste contains toxic chemicals that can kill microorganism.

The conditions of Citepus River demonstrate that laboratory experiment is the best appropriate method to determine the deoxygenation rate. Having the deoxygenation rate range between 0.06~0.48 day^{-1} as the value determined by laboratory analysis and 0.42~0.64 day^{-1} as the value determine by empirical equation, it can be assumed that physical condition of the river can be used only to determine the high value in the range of deoxygenation rate.

CONCLUSION

Laboratory analysis shows that BOD ultimate concentration of Citepus River ranges between 14.80~38.95mg/L The upstream water quality was averagely better than the downstream. The deoxygenation rates in the upstream area of Citepus River water shows that the deoxygenation rate ranges between 0.09~0.42 day^{-1} based on the laboratory analysis. Calculation of the deoxygenation rate using the empirical equation resulting the value between 0.509~0.643 day^{-1}. This calculation show higher results compared to those laboratory results. Deoxygenation rate in the downstream of Citepus River calculated using empirical equation gives higher value than those using laboratory determination. The rate is ranging between 0.064~0.48 day^{-1} by the laboratory experiments, and 0.423~0.543 day^{-1} by the empirical equation determination. In the case of Citepus River, low rate of deoxygenation was obtained although the water depth is quite shallow. This can be assumed that the activity of microorganism to decomposed organic matter is slow in the river water. Having the deoxygenation rate range between 0.06~0.48 day^{-1} as the value determined by laboratory analysis and 0.42~0.64 day^{-1} as the value determine by empirical equation, it can be assumed that physical condition of the river can be used only to determine the high value in the range of deoxygenation rate.

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