Determination Of Deoxygenation Rate of Citarum River

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Submission date: 23-Aug-2023 04:02PM (UTC+0700)
Submission ID: 2149872301
File name: 11._Determination_Of_Deoxygenation_Rate_of_Citarum_River.pdf (679.94K)
Word count: 3682
Character count: 18540

Journal of Environmental Treatment Techniques 2021, Volume 9, Issue 2, Pages: 505-509

Journal of ENVIRONMENTAL Treatment Techniques

J. Environ. Treat. Tech.
ISSN: 2309-1185

Journal web link: http://www.jett.dormaj.com
https://doi.org/10.47277/JETT/9(2)509

Determination of Deoxygenation Rate of Citarum River Water using Long Term Technique

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Received: 26/01/2021 Accepted: 18/02/2021 Published: 20/06/2021

Abstract

Citarum River is a large river located in West Java Province. The current condition of the Citarum River is highly polluted, especially in urban areas. Utilization of river water quality models is one of the popular methods to support river recovery. The deoxygenation rate is an important coefficient in the BOD-DO formula used in the water quality model. Usually, the deoxygenation rate is determined in laboratory in short term. A long term technique of laboratory test will likely gives better results. This study aims to determine the actual coefficient of the deoxygenation rate of the Citarum River water by using the long term technique. Sampling was carried out at 2 points which were considered to be able to represent the condition of the Citarum River. The laboratory analysis method used in the calculation of the deoxygenation rate uses the Thomas' Slope Method and the empirical formula of Hydroscience. The results showed the value of the deoxygenation rate range using the Slope method as a whole that ranged from 0.33 to 0.56 per day. While the value of the deoxygenation rate ranges using the Empirical formula ranges from 0.37 to 0.46 per day. The overall BOD (La) range ranges from 44.03 to 55.03 mg/L. The value of the deoxygenation rate obtained from the long term technique give similar range to that of empirical formula result. It suggests that the long-term technique can improve the results of the short-term deoxygenation rate method.

Keywords: Citarum River, Deoxygenation rate, Long term technique, River water quality model

1 Introduction

River is one of the natural freshwater that has many functions for urban activities (1). Citarum River is a large river located in West Java Province that passes through Bandung Regency. The current condition of the Citarum River is highly polluted, especially near urban areas. The Government Regulation of the Republic of Indonesia Number 82 of 2001 concerning Management of Water Quality and Water Pollution Control states that water is one of the natural resources that have a very important function for the life of various living things, including humans. Therefore, river management is important so that the function and sustainability of using rivers as water resources can be maintained.

The development of industry in the Citarum River watershed is one of the causes of the deteriorating of the river water quality. This is mainly (2) caused by industrial waste disposal which is not treated in accordance with the provisions of the capacity of receiving water bodies. Waste from households is also a source of pollution for Citarum River water. This condition often occurs, especially in rivers in urban cities (3). Various efforts can be carried out in order to improve the environmental conditions of the Citarum River (4). One of the activities that can be performed is the prediction of water quality through modeling and information system (5, 6).

Dissolved oxygen concentration (DO) has been used as a main indicator of river water quality (7). This is one of the important parameters to show water condition. Oxygen in water is used by aquatic biota for life; therefore this parameter is the first concern in preserving river quality. BOD (Biochemical Oxygen Demand) has a strong relationship with DO because it shows the oxygen needed to decompose organic matter contained in water bodies. As such, BOD is an indicator used to evaluate the level of water and waste contamination with organic substances (8). Biodegradation capacity of river water is also strongly affected by BOD concentration (9).

Quality models for rivers polluted by domestic waste generally use the BOD and DO equations. One method for assessing river water quality is from verified modeling results from field measurements. Modeling is an easy, inexpensive, and time-saving method. The mathematical formula used in modeling the quality of the aquatic environment is Streeter Phelps, a formula with the involvement of the deoxygenation rate coefficient in the formula. Deoxygenation rate is the rate of decline in the value of oxygen dissolved in water because it has been used by aerobic bacteria to decompose organic substances that can reduce the quality of river water. Empirical analysis to determine the value of the deoxygenation rate coefficient needs to be done in order to obtain the results of water quality modeling that is suitable for urban rivers. This deoxygenation coefficient will also describe the characteristics of polluted urban river water.

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Determination of the rate of deoxygenation in the Citarum River has been done in previous study (10). But the method used is only 10 days of treatment in the laboratory. The results obtained do not necessarily represent the actual condition of the river. The long term technique in determining the coefficient of deoxygenation rate is likely to be a better way of determining. The goal of this study is to determine the value of the deoxygenation rate coefficient (K_1) in the Citarum River by using long term technique.

2 Methodology

Sampling was carried in the upstream segment of the Citarum River with research segments ranging from Nanjung to Dayeuhkolot. This segmen is situated in Bandung Regency, West Java Province, Indonesia. Map of sampling locations can be seen in Figure 1.

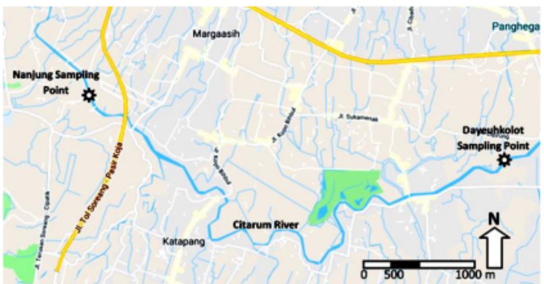

Figure.1: Sampling Sites

Figure 1 shows 2 sampling points, i.e. Nanjung and Dayeuhkolot. Both points are located in the southern area of Bandung City. Several tributaries flow their water into this segment of Citarum River. Those sampling locations represent the river water quality that is affected by urban activities waste.

Samples are taken at points that have been determined with consideration to see the high potential for pollution. Water samples are taken using Winkler bottles which are directly taken to the laboratory. During the trip to the laboratory the water sample is preserved by placing it in a cool box so that bacterial activity is inhibited during the trip.

Water samples were taken as many as 2 repetitions for each point during the study, i.e. #1 and #2. This repetition is intended to obtain data representing time conditions, certain conditions in order to obtain a better average data value. Direct measurements were carried out to determine water quality parameters that can only be measured on site. Measurements made at the location were measurements of discharge, temperature and DO (Dissolved Oxygen).

Discharge measurements consist of several measurements, including measurements of depth, river width and river flow velocity. Measurement of pH and DO is done by using a digital instrument that is a pH meter and DO meter.

Water quality analyses were carried out in the laboratory. In order to determine the deoxygenation rate water samples were placed in Winkler Bottle and incubated. The incubation process was carried out for 30 days in an incubator of 20°C. The DO concentrations were measured 12 times in duration incubation period of 0, 0.5, 1, 2, 3, 4, 5, 7, 10, 15, 25, 30 days for #1 experiment. In the #2 experiment, the duration periods are 0, 0.125, 0.25, 0.5, 1, 1.5, 2, 5, 10, 15, 25, and 30 days. DO concentrations were analyzed at any given time span based on the modification of Iodometric method (11) in accordance with Indonesian Standard SNI 06-6989.14-2004.

The value of deoxygenation rate was determined using Thomas Slope and Empirical Methods. Thomas method is the common methods in use which gives the BOD constant via least square treatment of the basic form of the first order reaction (Eq. 1) (12).

$$\frac{dy}{dt} = K_1(L_a - y) = K_1 L_a - K_1 y \qquad (1)$$

where dy is increase in BOD per unit time at time t; K_1 is deoxygenation rate (day^{-1}); L_a is first stage ultimate BOD, mg/L; and y is BOD exerted in time t, mg/L. This different equation 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. 2 and Eq. 3 (12).

$$na + b\sum y - \sum y' = 0 \qquad (2)$$

and

$$a\sum y + b\sum y^2 - \sum yy' = 0 \qquad (3)$$

Solving Eqs. 2 and 3 yields values of a and b, from which K_1 and La can be determined directly by following relations, i.e. Eq. 4 and Eq. 5.

$$K_1 = -b \qquad (4)$$

and

$$L_a = -a/b \qquad (5)$$

Empirical formula, the environmental factor considered is the depth of the river. The depth of a river affects the life of microorganisms in it, where the deeper a river will be the less oxygen content and the fewer amounts of aerobic microorganisms that can live in these waters. The deoxygenation coefficient calculation used for this organic pollution model in water is a formula according to Hydroscience (13, 14) for normal flow as follows:

If $0 \leq H \leq 2.4$ m, then

$$K_1 = 0.3 \times \left(\frac{H}{2,4}\right)^{-0,434} \qquad (6)$$

If $H \geq 2.4$ m, then $K_1 = 0.3$

where K_1 is deoxygenation rate (day^{-1}) and H is river depth (m).

3 Result and Discussion

3.1 Onsite Measurement

Table 1 shows the results of the Citarum river flow measurement. The Citarum watershed, which has an area of 177,100 ha, has a tropical climate with two seasons, namely rain and dry season; during the rainy season from November to April it covers 70% of the average annual rainfall. In the rainy season the Citarum river discharge is around 250m^3/s, while in the dry season it is around 10m^3/s measured at the Nanjung station (15).

Table 1: River Water Discharge

Sampling point	River width (m)	River depth (m)	Discharge (m^3/s)
Dayeuhkolot	34	0.895	10.34
Nanjung	25.5	1.5	12.62

Fluctuations in the flow of the Upper Citarum River are very high. At the height of the rainy season the flow rate can reach 578m^3/s, causing floods in the Majalaya, Banjaran and Dayeuhkolot areas. Conversely, in the peak dry season the flow rate was very low, around 2.7m^3/s, causing drought and failure of rice harvests and reduced water supply to the Saguling Hydroelectric Power Plant (16). From the results of the study, when compared with previous studies the Citarum River discharge at the time of measurement was still classified as the dry season because the discharge ranged from 10.34m^3/s to 12.62m^3/s, where the value was relatively low. The results of direct measurements in the field can be seen in Table 2.

Table 2: River Water Temperature and DO

Sampling point	Temperature (Celsius)	Dissolved Oxygen (mg/L)
Dayeuhkolot	24.9	0.8
Nanjung	27.8	1.8

From Table 2, both points have DO below the quality standard of 6 mg/L, this can be due to the potential pollution of domestic and industrial waste. The location of the sampling point is in a residential area and a textile factory.

3.2 Deoxygenation Rate

The Slope Method or the Thomas Method uses the results of DO (dissolved oxygen) Loss accumulation calculations which are then entered into the graph. DO loss depicts the oxygen usage during incubation. It can be seen the accumulation of the amount of dissolved oxygen used by microorganisms in breaking down organic matter on a daily basis which causes DO concentrations to decrease continuously from day 0 to completion. Figure 2 and Figure 3 show the results of DO Loss calculation at point 1 which is on Nanjung, and point 2 located on Dayeuhkolot. From each sampling point, there were 2 serial tests in the laboratory to determine the deoxygenation rate. The first test indicated by blue line (#1) and the second test indicated by orange line (#2) as depicted in Fig. 2 and Fig 3.

Accumulation of DO loss showed in Fig. 2 and 3 give data to calculate deoxygenation rate and BOD ultimate concentration. It was clearly showed that in #2 experiment, DO loss accumulation is higher than that in #1 experiment. Apparently, shorter period of analysis in early stage of decomposition will give a more complete DO usage measurement. Table 3 shows the value of deoxygenation rate and BOD concentration. Based on Table 3 it can be seen that the range of deoxygenation rate (K_1) in the Citarum River for experiments 1 and 2 for the Nanjung point ranged from 0.21 to 0.9 per day with an average value of 0.56 per day, and deoxygenation rate values (K_1) for the Dayeuhkolot point ranged from 0.16 to 0.49 per day with an average value of 0.33 per day. As a whole the range of deoxygenation rate (K_1) is taken in the Citarum River which ranges from 0.33 to 0.56 per day. This value indicates a relatively high deoxygenation rate. This is probably caused by the rapid use of oxygen by river water for biochemical processes such as decomposition (decomposition) of organic material or BOD that enters the Citarum River water.

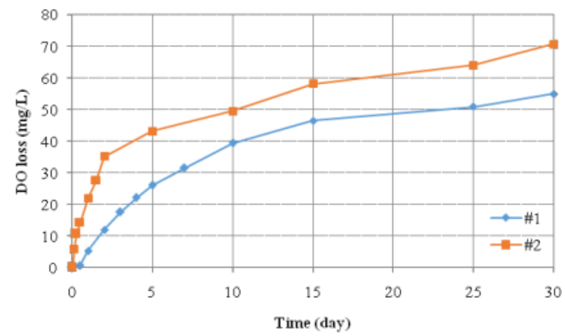

Figure 2: DO loss of river water samples of Nanjung sampling point

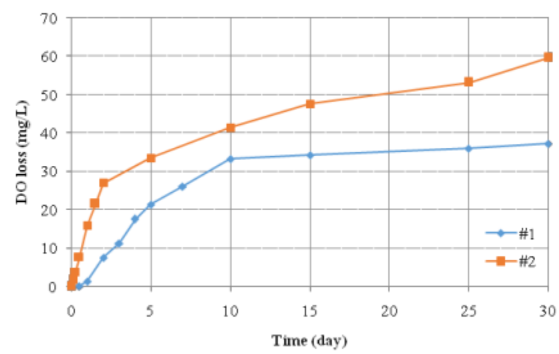

Figure 3: DO loss of river water samples of Dayeuhkolot sampling point

Table 3: Deoxygenation rate and BOD Ultimate Concentration

Sampling point	Deoxygenation Rate (day^{-1})	Ultimate BOD (mg/L)
Dayeuhkolot	0.56	52.03
Nanjung	0.33	44.03

The range of deoxygenation rates for surface water is 0.10-0.23 mg/L (17). In comparison, the deoxygenation rate for the Citarum River during the rainy season is in the range of 0.1 to 0.17 per day (3, 10). Deoxygenation values at each different point indicate the activity of microorganisms in using dissolved oxygen in river water to degrade organic substances differently (18-19).

As for the value of the ultimate BOD range (La) in the Citarum River for experiments 1 and 2 at the Nanjung point ranged from 49 to 55.05 mg/L with an average value of 52.03 mg/L, and the Ultimate BOD (La) value for the Dayeuhkolot point ranging from 42.06 to 46 mg/L with an average value of 44.03 mg/L. The La value shows that the water content in the upstream segment of the Citarum River contains organic matter. This is likely due to the upstream segment of the Citarum River that passes through residential areas and industries, where most of the waste contains organic material.

In previous studies, deoxygenation rate (K_1) was obtained, ie 0.1 to 0.17 per day for the middle segment Citarum River in the dry season (10), 0.019 to 0.046 per day for the Brantas River Malang (20). When compared with previous studies the results of K_1 obtained in this study ranged from 0.33 to 0.56 per day. This is probably caused by the rapid use of oxygen by river water for biochemical processes such as decomposition (decomposition) of organic material or BOD that enters the Citarum River water.

3.3 Calculation of Deoxygenation Rate Using Empirical Formulas

In determining the rate of deoxygenation by using this empirical formula considers physical condition factors such as river depth. The depth of a river affects the life of microorganisms that are in it, where the deeper the depth of a river the less oxygen content and the small number of microorganisms that can live in these waters. Based on previous studies, usually, the deoxygenation rate derived from the empirical formula give higher value than those of laboratory experiments (21).

After measuring the depth of the upstream segment of the Citarum River, the results obtained at point 1 were 0.895 m and at point 2 was 1.5 m. After calculating, the deoxygenation rate (K_1) is obtained by using the empirical formula for each sample as in Table 4.

Table 4: Deoxygenation Rate Values with Empirical Formulas

Sampling point	River Depth (m)		Deoxygenation
	(m)	(ft)	rate (day^{-1})
Dayeuhkolot	0.895	2.93	0.46
Nanjung	1.5	4.92	0.37

The deoxygenation rate range (K1) in the Citarum River using an empirical formula ranging from 0.37 to 0.46 per day.

4 Conclusions

The value of the deoxygenation (K1) rate range using the Slope method as a whole is in the range of 0.33 to 0.56 per day. While the values of the deoxygenation rate (K1) range using the Empirical formula ranges from 0.37 to 0.46 per day. The overall BOD (La) range values range from 44.03 to 52.03 mg/L. From these results prove that the deoxygenation rate in the Citarum River is quite high. The value of the deoxygenation rate range (K_1) using laboratory analysis is quite similar to that resulted from using the empirical formula. It suggests that the long-term technique can improve the results of the short-term deoxygenation rate method. Small difference is due to empirical calculations that only use river depths in calculations without looking at other parameters such as physical, chemical, and biological parameters.

Aknowledgment

This study was financially supported by the Faculty of Engineering, Universitas Pasundan and the Ministry of Research and Technology of the Republic of Indonesia.

Ethical issue

Authors are aware of, and comply with, best practice in publication ethics specifically with regard to authorship (avoidance of guest authorship), dual submission, and manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work is original and has not been published elsewhere in any language.

Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution for data collection, data analyses and manuscript writing.

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