Determination of deoxygenation Rate Coeficient as component in water

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Determination of Deoxygenation Rate Coefficient as Component in Water Quality Modeling of Middle Segment of Citarum River, Indonesia

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Abstract: *Citarum River is a river that passes in the Purwakarta City at its middle segment. The riverbank is overflowing with people's houses with its wastewater outlet leading directly to the river. Various efforts can be implemented in order to improve the environmental conditions of the Citarum River. One of the activities that can be conducted is the prediction of water quality through the modeling of river quality. This domestic waste polluted river model generally uses BOD and DO equations which require the coefficient of deoxygenation rate in its calculations. This study aims to determine the value of the coefficient of deoxygenation rate using the method of laboratory experiment and using the empirical formula. The coefficient will gives more accurate result of urban river quality modeling. Samplings were carried out at two locations that are considered to represent river condition. The laboratory analysis method used in the calculation of deoxygenation rate is using Winkler Method and Slope Method, while Empirical Formula is used in calculating deoxygenation rate using Hydroscience Equation. The results of the analysis and calculations show that the value of the deoxygenation rate range (K1) in the middle segment of Citarum River ranges from 0.10 to 0.17 per day and the BOD Ultimate (La) concentration ranges from 18.46 to 24.43 mg/L. As for the value of deoxygenation rate range (K1) on Citarum River using empirical formula ranged from 0.270 to 0.278 per day. The difference in value can be attributed to the actual deoxygenation rate in the Citarum River is hampered by the factors that disrupt the process of decomposition of organic matter and its capability on self purification process.*

Index Terms: *Deoxygenation rate, Middle segmen of Citarum River, Slope Method, Winkler Method.*

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I. INTRODUCTION

Today the water quality of the Citarum River starts to decline very significantly[1][2]. Visually, it is observed from the change of river color and the smell that occurs in Citarum River caused by several activities. One of tht\e factors causing the decline of Citarum River condition is wastewater, both domestic wastewater and industrial wastewater. To prevent the occurrence of expansion of pollution, some activities such as improvement of processing from the industrial plant in order to reduce the chemicals issued. Environmental quality modeling simulation is also being considered in determining pollution load standard for the river. Middle segment of the Citarum River passes in Purwakarta City. On the outskirts of the river is overflowing with people's houses with its outlet leading directly to the river. Wastewater from domestic and industrial activities suspended in rivers can affect water quality in the middle segment of Citarum River. Various efforts can be implemented in order to improve the environmental conditions of the Citarum River. One of the activities that can be done is the prediction of water quality through modeling. Water quality model for domestic waste contaminated river generally use BOD and DO equation. The appropriate useful formula utilized in the model is Streeter-Phelps equation that considers aeration and deoxygenation processes[3]. The rate of deoxygenation is the rate of decrease in the value of dissolved oxygen in water because it has been used by aerobic bacteria to decompose organic substances that can re-purify the quality of river water[4]. Dissolved oxygen concentration in the river water can give description on how healthy the water body is. Declining of the DO concentration can be caused by several factors such as water temperature, high amount of organic matter, low rearation process, etc. When DO concentration decrease, sensitive biota will not be able to survive[5]. The deoxygenation rate can be applied in the river water quality model when it has suitable value to the river condition. Laboratory analysis that is followed by statistic data analysis is needed to determine the value of the deoxygenation rate. Water quality of the middle segment of Citarum River is influenced by domestic and industrial waste.

This specific condition gives a strong recommendation on particular laboratory analysis of the deoxygenation rate value. This value can be used for water quality modeling both in the process of estimating river quality at present and predictions in the future. The result of model calculation using coefficient value of deoxygenation rate will also give description about the environmental characteristics of the river[4].

II. METHODOLOGY

A. *Sample Point Determination*

River water sampling point is determined 2 points on the Citarum River, i.e. in the upstream and downstream locations. The location of this study has an area starting from the upstream point that is on the Outlet Jatiluhur Dam to the point to Curug. These points were determined to represent the surrounding activities influence on the river water quality. The passes through several companies that dispose of waste products of factories, as well as plantations, agriculture and domestic waste from floating public toilets around the river. Fig. 1 shows the research location and sampling points.

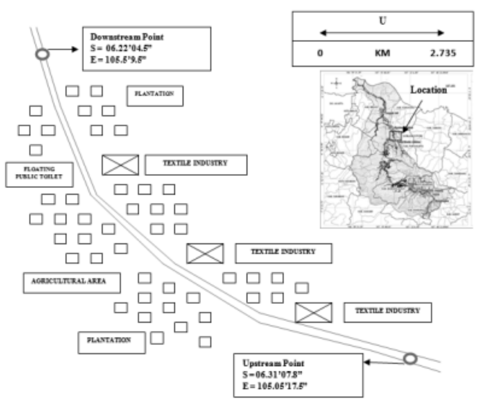

Fig. 1. Research location and sampling points.

Three samples were taken from each sampling point, indicated by code 1st, 2nd, and 3rd, respectively. The parameters measured directly are the water and air temperature, performed by using a thermometer. Determination of water discharge was conducted through several measurement phases, including measurement of river depth, river width and river flow velocity. Onsite pH and DO measurements are carried out using pH meter and DO meter. Water samples were taken to the laboratory with cooling method preservation.

B. *Determination of Deoxygenation Rate Range in Laboratory*

After water samples are taken with appropriate procedures, water quality checks are conducted at the laboratory. Water samples were then being stored in 20°C incubator. Analysis of DO concentration was taken place by using Winkler Method. DO concentrations were measured daily based for 10 days. The results of DO Loss measurements for 10 days for each sample point are plotted in Cartesian coordinate graphic to get the DO Loss versus time curve. The accumulated value of DO Loss generated on each sample is used in the calculation of its deoxygenation rate. Calculation of deoxygenation rate using slope method developed by Thomas which gives the BOD constant via least square treatment of the basic form of the first order reaction (Eq. 1) [6].

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

where dy is increase in BOD per unit time at time t, K_1 is deoxygenation rate coefficient, per day, 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 [6].

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

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 K1 and La can be determined directly by following relations, i.e. Eq. 4 and Eq. 5.

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

and

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

C. *Determination of Deoxygenation Rate by Using Empirical Formula*

The deoxygenation rate coefficient determination by using empirical formula was conducted to compare the laboratory result. Calculation in this determination was conducted based empirical formula established by Hydroscience [7] for normal flow can be assumed that when $0 \leq H \leq 2.4$ m, then $K_1 = 0.3 \text{ x } \left(\frac{H}{8}\right)^{-0.434}$; and when $H \geq 2.4$m, then K_1=0.3, where H is water depth.

III. RESULT AND DISCUSSION

A. *Onsite Measurement Results*

Parameter of DO, pH and temperature that have been measured onsite can be seen in Table 1. The DO concentration was varied between 3.8mg/L to 6.8 mg/L. The value of pH gives rather base condition of water, while temperature shows a stable range. Water discharge was measured 4.6-5.49m3/s.

Table 1. Onsite Measurement Data

Sampling point	Parameter		
	DO (mg/L)	pH	Temperature (deg C)
Upstream 1st	6.8	9.3	27.9
Upstream 2nd	4.8	8.5	28
Upstream 3rd	5.2	8.3	28.1

Downstream 1st	5.1	8.6	28.8
Downstream 2nd	3.8	7.3	28.6
Downstream 3rd	4.7	7.2	28.4

B. Determination of Deoxygenation Rate in the Laboratory

Based on the results obtained from the examination of the dissolved oxygen concentration (DO) by using laboratory analysis, the downstream DO concentration is lower than the upstream DO value. This may be due to the poor quality of water in the downstream area, because in terms of land use, there are several textile industry factories and domestic activities that dispose of waste into rivers. Ten days of DO measurement results data for each sample point are graphs to get the DO Loss curve over time. DO Loss is an indicator of organic pollutants as measured by the decrease in the amount of oxygen needed by microorganisms during the decomposition of organic matter[4]. After obtained the value of DO Loss then accumulated DO Loss is to get the calculation of deoxygenation rate of each sample. Fig. 2 shows the accumulation of DO Loss of upstream point, while the Fig. 3 shows the DO Loss downstream point. Both in upstream and downstream water analysis give similar set of DO Loss value (1st, 2nd and 3rd samples).

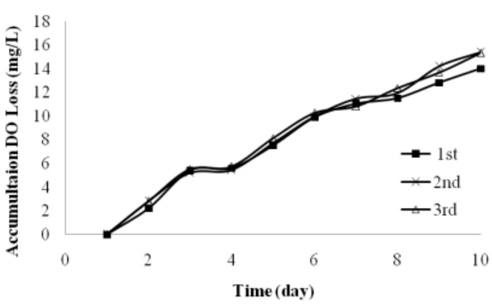

Fig. 2. Accumulation of DO Loss of Upstream Point of the Middle Segment of Citarum River.

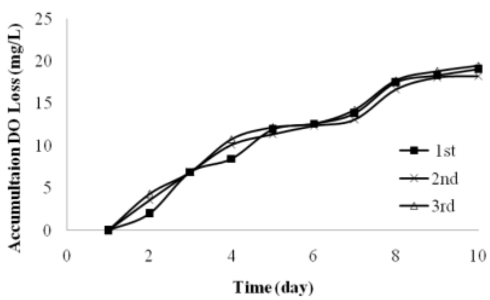

Fig. 3. Accumulation of DO Loss of Downstream Point of the Middle Segment of Citarum River

After the calculation is obtained the value of deoxygenation rate (K1) and BOD Ultimate value by using laboratory analysis for each sample can be determined. Table 2 shows the deoxygenation rate and ultimate BOD concentration of each sampling stations. The value of deoxygenation rate (K1) for the upstream point on the Citarum River ranges from 0.10 to 0.15 per day, while for the downstream point ranges from 0.16 to 0.17 per day. Deoxygenation values upstream and downstream show different activity of microorganisms present in the use of oxygen in degrading different organic substances.

Table 2. Deoxygenation Rate Values and Ultimate BOD By Using Laboratory Analysis

Sampling point	Deoxygenation Rater (per day)	BOD Ultimate (mg/L)
Upstream 1st	0.150	18.46
Upstream 2nd	0.100	24.00
Upstream 3rd	0.130	20.46
Upstream average	0.130	20.97
Downstream 1st	0.160	24.43
Downstream 2nd	0.170	22.76
Downstream 3rd	0.170	24.00
Downstream average	0.166	23.73

Table 2 also shows that ultimate BOD value on the Citarum River ranges between 18.46 mg/L to 24.43 mg/L. The ultimate BOD has a greater value downstream than in the upstream. Domestic pollutions might contaminate the river water near the downstream sampling point.

C. Calculation of Deoxygenation Rate Using Empirical Formulas

In determining the rate of deoxygenation using this empirical formula considers environmental factors such as river depth. The depth of a river affects the life of the microorganisms present in it, where the deeper the depth of a river the less oxygen content and fewer microorganisms can live in the waters, and if the number of microorganisms in the water is less then the rate of deoxygenation in a river will be low, then the calculation of deoxygenation rate is also done by using empirical formula related to the depth of a river that is by the formula according to Hydroscience[8]. After measuring the depth of the Citarum River middle segment at the upstream and downstream points obtained results that exceeded 2.4 meters, so the formula used is K1 = 0.3 per day. Therefore, it can be observed that the deoxygenation rate range (K1) by using empirical formula on the Citarum River has a larger value ranging from 0.30 per day rather than those obtained by the laboratory experiments. This empirical formula is a formula applied to a river that has a relatively high microorganism activity so that the value of deoxygenation rate will be high in shallow water.

D. Analysis of Deoxygenation Rate Values in Several Rivers

To have more information on the deoxygenation rates in other rivers, here are some studies in several rivers in different regions, in determining the value of deoxygenation rate, among others:

- Rangkui River in the dry season resulted in deoxygenation rates with laboratory analyzes ranging from 0.14 to 0.41 per day, while Ultimate BOD concentration range is 8.53 to 70.64 mg/L[4].
- Research for Citepus River Bandung in dry season and rainy season resulted in deoxygenation rate value with laboratory analysis ranging from 0,0309 to 0,0328 per day, and BOD Ultimate value is 35,02 to 44,23 mg/L[8].
- Using empirical formula, the Citepus River has deoxygenation rate ranges 0.42-0.64 per day[8].
- Cikapundung River has deoxygenation rate ranges 0.010 to 0.370 per day [9].
- Cimanuk River has 0.06-0.12 per day for laboratory experiment result on the deoxygenation rate, and 0.422-0.462 per day for empirical formula utilization [10].

The range of deoxygenation rates in the Citarum River middle segment in this study ranged from 0.10 to 0.17 per day with laboratory analysis and 0.3 per day for empirical formula. The rate of deoxygenation is the rate of decrease in the value of dissolved oxygen in water because it has been used by aerobic bacteria to decompose organic substances that can degrade the quality of river water. Low value of deoxygenation rate represents the unhealthy condition of the water in performing self purification process[10][4]. Viewed from the comparison with some previous research, on the middle segment of Citarum River value of K1 is similiar to the conditions in other urban rivers in Indonesia. In addition to the organic matter contained in numerous river waters and small amounts of microorganisms, thus the activity in decomposing organic matter is relatively low, the low rate of deoxygenation rate range (K1) is also likely due to growth inhibitors and microorganisms' performance such as industrial waste containing metals weight that can inhibit activity will even kill microorganisms. It was possibly occurred because in the middle segment of Citarum River there are 3 companies of textile industry that dispose of their wastewater into the river. Characteristics of the textile industry that contain content high amount of ammonia (NH3), sulfide, phenol and heavy metals that are corrosive that can kill plants and water biota because the toxic characteristic. Heavy metals, such as Cu, Zn, Pb, Cd, Co, Ni, Cr were discovered in sludge from textile industrial wastewater[11]. Ammonia is suspected as one of the major stressor for water biota[12]. Cadmium was one of the heavy metals that was found in Citarum River[1]. It may lead to unfavorable environment for the decomposer organisms. Other heavy metals that can affect the aquatic biota are nickel, copper, lead, cadmium, chromium, iron, zinc, manganese, magnesium and arsenic[13]. Also from land use along streams there are agriculture and plantations that allow for the presence of pesticides entering water bodies, which can cause changes in water quality such as changes in water color which can reduce the penetration of sunlight into the water, photosynthesis of plants in the water will be disrupted, also the amount of dissolved oxygen in the water becomes reduced and the life of organisms in the water is also disturbed then when degradation will decompose into a volatile and foul-smelling compounds e.g. NH_3. Pesticide was identified as one of the cause of declining of biodiversity in Citarum River[14]. From domestic waste also contribute a lot of waste into the river, from the activities of bathing-laundry-defecate, such as detergent, soap and the content of fecal coli derived from the floating toilets on the river side. The soap solution will raise the pH of the water so that it can disrupt the life of the organism in the water, and detergents using nonphosphoric materials will raise the pH of the water to about 10.5-11.0. Detergent was found as one pollutant that harm the aquatic microorganism in Citarum River[14].The antiseptic material added to the soap or detergent also interferes with the life of microorganisms in the water and can even be deadly[15].

IV. CONCLUSION

From this research, the results obtained K1 by using laboratory analysis in the middle segment Citarum River is 0.1 to 0.17 per day while calculations with the empirical formula resulted in K1 value of 0.30 per day. BOD Ultimate concentration ranged from 18.46 to 24.43 mg/L. The deoxygenation rate of laboratory result appears lower than that of empirical formula result. Low value of deoxygenation rate in high BOD concentration indicates that self-purification process is not well-performed. The low rate of deoxygenation rate range is also likely due to growth inhibitors and microorganism activities such as industrial waste containing heavy metals that can inhibit activity and even kill microorganisms. Having the specific rate of deoxygenation for the middle segment of Citarum River will improve the validation of river water quality modeling result. The rate is found quite low, similar to other urban rivers waters that were influenced by untreated wastewater from industrial and agricultural activities.

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