

DETERMINATION OF MAXIMUM BOD LOAD USING WATER QUALITY MODELING OF UPSTREAM CITARUM RIVER

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ABSTRACT: Citarum River as the largest river in West Java gives an important role for the life of the community either directly or indirectly. However, the pollution that occurs on the Citarum River is very high that its tributary water cannot be used properly. One of the efforts to rehabilitate the quality of the Citarum River is by utilizing the water quality modeling. The purpose of this study was to obtain the maximum BOD values that can be accepted by the Citarum River for the rehabilitation purpose. The modeling prepared in this research was using the Streeter-Phelps equation. The data analyzed in this study is derived from the West Java Province Government monitoring sampling in 2013, 2014 and 2015. Sampling area covers Dayeuhkolot area to Nanjung. The calculation result using Streeter Phelps equation provides the concentration value of deficit oxygen and BOD load. The deficit oxygen calculated by the model shows its concentration was ranging between 3.20 mg/L and 3.68 mg/L, while the maximum BOD load concentration is ranging between 8.06 mg/L and 23.83 mg/L. Using this value, the government can create a strategy for managing the Citarum River so that its water quality can be returned in accordance with its designation.

Keywords: Deficit oxygen, BOD, Upstream Citarum River, Water quality modeling

1. INTRODUCTION

Citarum River is the main river and one of the largest rivers in West Java with a length of ± 297 km, and the watershed area of 6,614 km². Citarum River at Wayang Mountain located in District Kertasari Bandung Regency at an altitude of 2182 m above sea level and empties into the Java Sea. Citarum River crosses 7 districts and 2 cities of Bandung, Sumedang, Cianjur, Bogor, Purwakarta, Karawang, Bekasi, Bandung and Cimahi. The Citarum river amount to ± 36 tributaries. The Citarum River and its tributaries are utilized for various needs such as agricultural irrigation, industrial activities, raw water sources [1a], water sources for fisheries and as hydroelectric power plants.

Environmental damage in the upper part of the Citarum river can be seen from the community's behavior such as dumping garbage directly into the river, resulting in the accumulation of garbage, the decrease of land conservation areas, the density of population settlements, river pollution by domestic and industrial waste, and others causing floods, drought, and landslides often occur in the upper reaches of the Citarum River. This indicates that the quality decline has already begun in the upstream area of Citarum [2].

Monitoring is an important aspect that needs to be conducted properly in stakeholder's responsibilities, authorities and resources [3]. One effort to monitor and control river water pollution is to analyze the water quality data of the river

using the modeling. Modeling is a more time-saving effort, effort and cost compared to direct measurement. The purpose of this research is to analyze the water quality of Upper Citarum River by modeling dissolved oxygen (DO) and biochemical oxygen demand (BOD) with Streeter Phelps method as the effort to determine the maximum organic pollutant load that can be discharged to the water body. The maximum load will contribute to regulating wastewater discharge of industries and other activities along with an upstream region of Citarum River.

2. METHODOLOGY

2.1 Research Location

This location the research takes place on the upper region of Citarum River with segments from Dayeuhkolot to Nanjung. Some of the problems of the Upper Citarum Watershed especially for the Dayeuhkolot area to Nanjung are the development of settlements around river banks. The housing was developed without good planning. There are many daily activities of people who throw garbage directly into the river, the remnants of fertilizers or pesticides from agricultural areas, hospital waste, and cattle manure waste. There is also the development of the textile industry and dispose of its waste into the river so that the river becomes the final disposal without first processing. Figure 1 shows the Citarum watershed as well as the research sites on the upstream. The figure also

gives information on the watershed performance of Citarum River, where the light brown shaded indicates a rather poor performance area and the yellow shaded indicates poor performance area, considering the environmental quality.

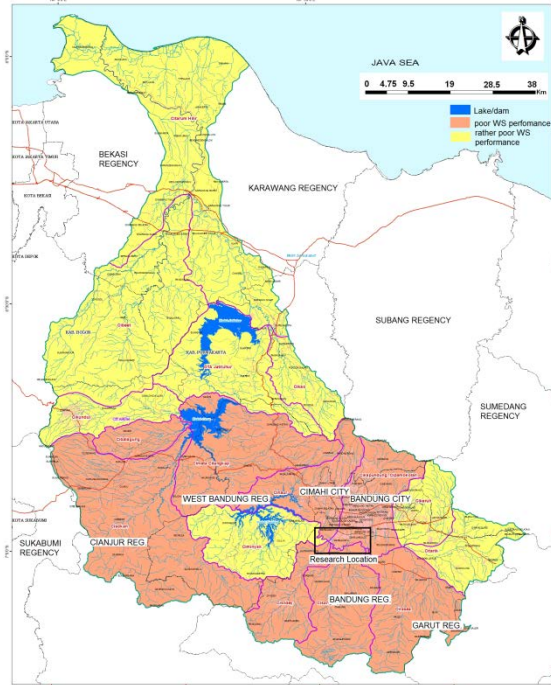


Fig.1 Citarum Watershed [4] and research location.

Figure 2 shows the location of the sampling station on the upstream Citarum River.



Fig. 2 Sampling station points.

There are 5 points along the upper Citarum River sampled. The sampling points have the following coordinates: 6°59'29.8"S 107°37'47.5"E, 6°59'21.3"S 107°37'28.7"E, 6°59'07.3"S 107°33'46.7"E, 6°58'41.5"S 107°33'06.3"E, 6°56'50.8"S 107°32'05.1"E respectively for Stations 1, 2, 3, 4 and 5. While along the segment is divided into sub-segment as the area of pollution load calculation. Determination of sampling point is with the consideration that the point can represent the water quality condition of Upper Citarum River, can represent the level of pollution

caused by the activity of industry, agriculture and domestic and can represent the condition of incoming creek discharge. Figure 3 shows the schematic diagram of the research segment for the purposes of calculating water quality and pollutant load. Samplings were conducted during the dry season.

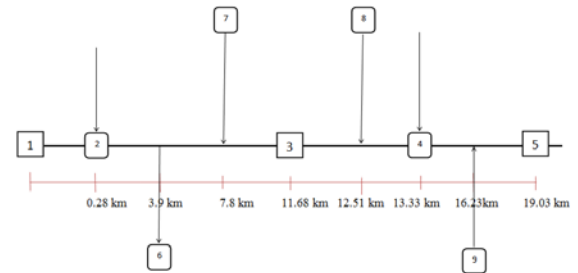


Fig. 3 Diagram of domain segmentation.

2.2 Laboratory Analysis

Laboratory analysis was conducted using Standard Methods [5]. The BOD measurements consist of sample dilution, incubation for 5 days at 20°C and dissolved oxygen measurements before and after incubation. Dissolved oxygen concentration was measured using the electrochemical method. The method of determining dissolved oxygen by the electrochemical method is a direct way to determine dissolved oxygen by means of DO meter.

2.3 Equations

Some of the equations used in the calculation of water quality and pollutant load in this study are equations for calculating ultimate BOD (Eq. 1)[6], [7], Streeter Phelps' oxygen deficit (Eq. 2)[7] and maximum pollutant load (Eq. 3). The maximum pollutant load equation was a modification of classic Streeter Phelps equation which focusing in the remaining capacity of river water in receiving pollutant.

$$L_a = L_0 e^{-\frac{k_d}{u}x} \quad (1)$$

Where:

L_a = concentration of BOD ultimate (mg/L)

L_0 = concentration of BOD₅ at the initial position (mg/L)

K_d = deoxygenation rate coefficient (1/day)

x = distance from initial position (m)

u = flowrate (m/s)

$$D = D_0 e^{-\frac{k_a}{u}x} + \frac{K_d \cdot L_a}{K_a - K_d} \left(e^{-\frac{k_d}{u}x} - e^{-\frac{k_a}{u}x} \right) \quad (2)$$

Where:

D = deficit oxygen concentration (mg/L)

k_a = reaeration rate coefficient (1/day)

L_a = concentration of BOD ultimate (mg/L)

D_0 = concentration dissolved oxygen in $x=0$ (mg/L)

$$\log L_a = \log D_{all}$$

$$+ \left(1 + \frac{k_d}{k_a - k_d} \left(1 - \frac{D_0}{D_{all}} \right)^{0.418} \right) \log \frac{k_a}{k_d} \quad (3)$$

Where:

D_{all} : allowed oxygen deficit (mg/L)

3. RESULT AND DISCUSSION

According to the water quality monitoring, the DO concentrations measured were under the government standard. Figure 4 shows the concentration of DO in the upstream Citarum River of the year 2013, 2014 and 2015. Figure 5 displays the concentration of BOD of Citarum River in the year of 2013, 2014 and 2015.

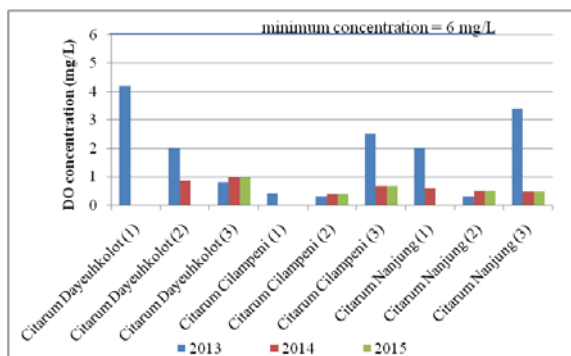


Fig.4 DO concentration in the upstream Citarum River.

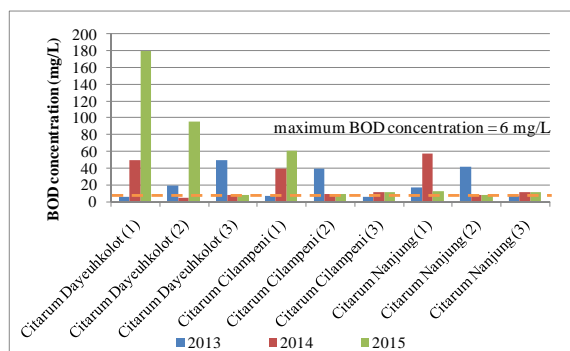


Fig.5 BOD concentration in the upstream Citarum River.

The monitoring of BOD concentrations was also indicated that pollution has occurred in the recent year. Almost all BOD concentrations were recorded above the maximum allowed standard. High concentration of BOD can be indicated as the pollution activities from the domestic and

agricultural area.

Based on the monitoring results, primary samplings were conducted in the more detail segmentation between Dayeuhkolot and Nanjung area.

Table 1 shows the result of sample river water analysis for the parameter of temperature, pH, DO and BOD.

Table 1 Laboratory analysis result

Parameter	Unit	Standard*	Sampling Location (Station No.)				
			1	2	3	4	5
Temperature	°C	normal	23.8	24.9	26.5	25.3	24.1
pH	-	5-9	6.61	6.15	6.51	6.41	6.41
DO	mg/L	≥6	3.2	4.6	3.3	6.1	3.4
BOD	mg/L	6	0.5	10.5	5.5	16	2.5

*) Standard of West Java Province, Governor Decree no.39, the year 2000

DO concentrations of almost all sampling points do not meet the B class standard. 39 of 2000 except only point 4 that meets the predetermined quality standard of 6.1 mg/L. B class of the standard that regulates the water quality for the purpose of raw water for drinking water. BOD concentrations that meet the quality standard of Group B of Governor's Decree no. 39 of 2000 are at point 1, 3 and 5. At that point, there is already a pollutant input from domestic and nondomestic waste, but still within the standard limit. Calculations using the Streeter Phelps model use DO and BOD data as the basis for determining pollution profiles. The Phelps Streeter model links the rate of change in oxygen deficit with distance to deoxygenation rate (oxygen depletion) and deoxygenation or reaeration (addition of oxygen in water).

In order to calculate the oxygen deficit and actual DO, the value of saturated DO is necessary. The saturated DO concentrations were obtained based on the actual temperature of river water. Table 2 displays the saturated dissolved oxygen in the sampling stations.

Table 2 Saturated DO

Sampling Station	Temp (°C)	Saturated DO (mg/L)
1	23.8	8.47
2	24.9	8.30
3	26.5	8.06
4	25.3	8.24
5	24.1	8.43

In every tributary point, the concentration of DO, BOD and temperature after mixing were calculated using the mass balance equation

considering each water discharge, then Eq. 1 was used to calculate the ultimate BOD. The deoxygenation constant used is the range k_d for the Cikapundung River flow between 0.10 - 0.37 [8], where Cikapundung River is one of the tributaries Citarum. This value is similar and in the range of urban rivers in Indonesia deoxygenation rate coefficient, i.e Citepus River, Rangkui River, Cimanuk River [9-11]. The ultimate BOD value can be seen in Figure 6. The ultimate BOD can be defined as the oxygen demand that has been supplied to degrade almost all of the organic matter.

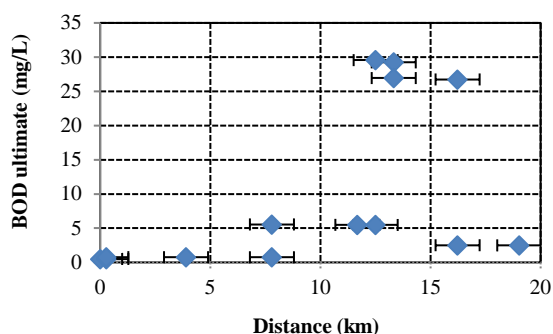


Fig.6 BOD ultimate

At km 0 to km 12.51 before mixing the BOD value still meet the quality standard that is less than 6 mg/L. At km 12.51 after mixing up to km 16.23 before mixing the BOD value increases and exceeds the quality standard that is more than 6 mg/L due to the intensive influent of domestic waste into the river. High concentrations of BOD concentration occurred in the middle river area was caused by the influent of waste from plastic factories and other industries entering the river and densely populated areas. The highest concentration occurred nearly 30 mg/L. At km 16.23 after mixing up to km 19.03 BOD decreases which is likely due to the occurrence of dilution by rainwater discharged from the residential area.

The value of dissolved oxygen concentration along the river can be seen in Figure 7.

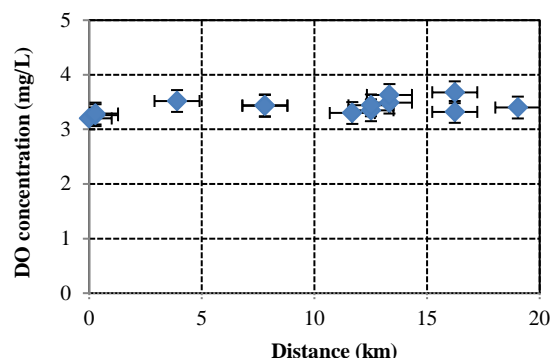


Fig. 7 The concentration of Dissolved Oxygen (mg/L)

DO concentrations ranging from km 0 to km 19.03 up and down and did not meet the quality standard of Group B Governor's Decree no. 39 of 2000 which is less than 6 mg/L. It was probably occurred due to a large number of domestic waste from the high density of the population. Other potential sources were several industries that discharge their wastewater into the river without prior proper treatment.

The calculation of the maximum load of BOD is conducted by using the Eq. 3. The maximum load is affected by the actual BOD load and the deoxygenation rate. Maximum load values can be viewed in Figure 8.

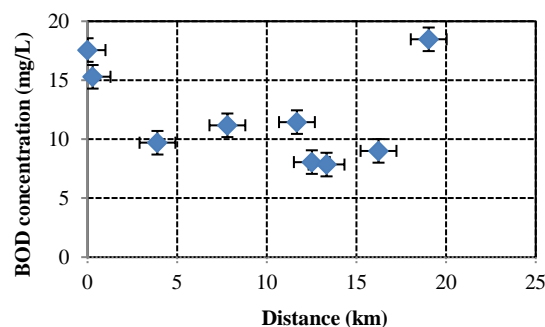


Fig.8 Maximum BOD load.

The modeling results show that the maximum pollutant loads in the middle part of the research segment are low. The lowest BOD load is 8.06 mg/L located at km 12.51, whereas the highest BOD load is 18.47 mg/L at km 19.03. In the middle section, the pollution has already been high and the river capacity to perform self-purification restricts any additional pollutant to enter the water body.

4. CONCLUSIONS

Several important findings can be summarized from this research, i.e.:

- The pollutant source for Upstream Citarum River comes from domestic waste, agricultural waste, and industrial waste.
- The sample measurement data shows for DO parameters that almost all points did not meet the quality standard of Group B of Governor's Decree No. 39 the Year 2000.
- BOD concentration of the sample water also shows pollution in several points.
- The calculation result with Streeter Phelps method shows that the DO concentration range is as low as 3.20 mg/L to 3.68 mg/L. BOD maximum load value of 8.06 mg/L to 23.83 mg/L.
- Based on the research results, the water quality of the Upper Citarum River shows that they do not meet the quality standard.

- Using the water quality model, it was found that the maximum pollutant loads in the middle part of the research segment are low. The lowest BOD load is 8.06 mg/L located at km 12.51, whereas the highest BOD load is 18.47 mg/L at km 19.03.

According to all the findings, it is recommended a major rehabilitation on the river water quality of Citarum River, both in the pollution sources and in the river.

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6. REFERENCES

- [1] Afiatun E., Notodarmodjo, S., Effendi, A.J., Sidarto, K.A. Cost minimization of raw water sources by integrated water supply systems (A case study for Bandung, Indonesia). *International Journal of Geomate*, June 2018, Vol. 14, Issue 46, pp. 32-39. DOI: 10.21660/2018.46.9 813
- [2] Fulazzaky M.A. Water quality evaluation system to assess the status and the suitability of the Citarum river water to different uses. *Environ. Monit. Assess*, 168, 2010, pp. 669-684.
- [3] Ginkel, C.H. Water Quality in Upper Citarum River Basin: towards a better understanding of a heavily polluted catchment. *Student Undergraduate Research e-Journal*, Vol 2, 2016, <https://doi.org/10.25609/sure.v2.1469>
- [4] Ministry of Environment and Forestry. Citarum Watershed (Map). <http://sipdas.menlhk.go.id/documents/170>, access June 8, 2018.
- [5] American Public Health Association-APHA; American Water Works Association-AWWA; Water Environment Federation-WEF. *Standard Methods for the Examination of Water and Wastewater*. 22nd edition. Washington. 2012.
- [6] Ajayi, A.A., Peter-Albert, C.F., Ajojesu, T.P., Bishop, S.A., Olasehinde, G.I., Siyanbola, T.O. Biochemical Oxygen Demand and Carbonaceous Oxygen Demand of the Covenant University Sewage Oxidation Pond. *Covenant Journal of Physical and Life Sciences (CJPL)*, Vol 4 no. 1, 2016, pp. 11-19.
- [7] Chapra, S.C. *Surface Water – Quality Modeling*. McGraw-Hill International Editions, 1997, p.391
- [8] Yustiani, Y.M., Nurkanti, M., Suliasih, N., Novantri, A. Influencing Parameter of Self Purification Processes in the Urban Area of Cikapundung River, Indonesia. *International Journal of Geomate*, Vol. 14, Issue 43, 2018, pp. 50-54. DOI:10.21660/2018.43.3546
- [9] Yustiani, Y.M., Mulyatna, L., Pranata, F. The Deoxygenation Rate Determination Based on Physical Condition of River Body, Case Study of Citepus River. *Padjadjaran International Physics Symposium 2013, AIP Conf. Proc.* 1554, pp. 281-284. DOI: 10.1063/1.4820340
- [10] Yustiani, Y.M., Pradiko, H., Amrullah, R.H. The study of deoxygenation rate of Rangkui River water during dry season. *International Journal of Geomate*, Vol. 15, Issue 47, 2018, pp. 164-169. DOI: 10.21660/2018.47. 28822
- [11] Yustiani, Y.M., Wahyuni, S., Alfian, M.R. Investigation on the deoxygenation rate of water of Cimanuk River, Indamayu, Indonesia. *Rasayan J.Chem*, vol. 11, no. 2, 2018, pp. 475-481. DOI: 10.7324/RJC.2018.1121892

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