Determination Of Deoxygenation Rate Of Rivers

by Yonik Meilawati

Submission date: 23-Aug-2023 12:36PM (UTC+0700)
Submission ID: 2149813986
File name: 1._Determination_Of_Deoxygenation_Rate_Of_Rivers.pdf (446.29K)
Word count: 3638
Character count: 19811

Poll Res. 35 (3) : 475-481 (2016)

ISSN 0257–8050

DETERMINATION OF DEOXYGENATION RATE OF RIVERS LOCATED IN THE URBAN AREAS TO CHARACTERIZE THE POLLUTANTS

YONIK MEILAWATI YUSTIANI[1]

[1] *Department of Environmental Engineering, Pasundan University, Jl. Dr. Setiabudhi 193, Bandung 40153, Indonesia,*

(Received 22 April, 2016; accepted 30 May, 2016)

ABSTRACT

The deoxygenation coefficient is the use of oxygen in the process of organic matter decomposition and nitrification. The deoxygenation process for highly polluted rivers mainly crossing the urban areas has rarely been determined, therefore, this research aims to specify the range of the rate which can later be used for modeling purposes. Water samples were taken from 2 rivers in Indonesia, Cikapundung and Citepus. Dissolved oxygen (DO) usage was then being analyzed daily for 10 days. Slope method, proposed by Thomas was used to calculate the deoxygenation rate. The laboratory analyses and calculation results show that Cikapundung River and Citepus River have deoxygenation rate ranges between 0.010-0.370 day^{-1} and 0.031-0.480 day^{-1} respectively, while the BOD (Biochemical Oxygen Demand) ultimate concentration range are 1.17-75.08 mg/L and 14.80-80.80 mg/L respectively. The rates acquired are relatively low compared to that of empirical equation results. It indicates that the degradation process is not optimal, probably due to the high concentration of pollutants that inhibit the degradation process. It will give a strong recommendation on controlling the heavy metals, toxic, and chemical pollutants discharged into the river, especially at the point that has low flow rate. Improvement of river water quality needs to be held concerning those kinds of pollutants.

KEY WORDS : Deoxygenation rate, River, Streeter-phelps equation, Urban area

INTRODUCTION

Many rivers are passed through urban areas. Those rivers as multipurpose functions, such as source of drinking water, transportation way, recreation location, etc. Rivers are key natural and ecological sites from a water management perspective (Lincheva, 2014). Several parameters were set in quality standard in order to maintain the healthiness of the river.

Dissolved oxygen (DO) concentrations have been used as primary indicator of stream water quality (Sarkar and Pandey, 2015). It is one of an important parameters to indicate the water healthiness. Oxygen in the water is used by the water biota to live, therefore this parameter becomes the first concern on the river quality preservation. BOD (Biochemical Oxygen Demand) has a strong relationship with DO because it indicates the oxygen needed to decompose the organic matter contained in the water body. Thus, the BOD is an indicator used to evaluate the degree of the contamination of water and sewages with the organic substances (Siwiec *et al.,* 2011).

One popular effort to manage and improve the river water quality is usage of river water quality modeling. By using the model, the recommendation of management can be formulated. The model of DO has made great progress in theoretical research and practical applications (Berkum, 2005). The equation popular in DO simulation is Streeter-Phelps' formula. The equation was used in natural purification since 1925 (Streeter and Phelps, 1925). The Streeter-Phelps model describes "as oxygen demand decreases in a river or stream along a certain distance by degradation of biochemical

Corresponding author's email: yonik@unpas.ac.id

oxygen demand (BOD). Changes in the oxygen content of polluted waters over time can be studied by using the dissolved oxygen sag curve" (Von-Sperling, 2014 from Menezes *et al.*, 2015). Estimation of deoxygenation rate is important for selecting a solution curve that best represents a real system.

The resultant DO concentration at any location in a river is the result of many processes occurring the upstream location, which include, de-oxygenation, re-aeration, photosynthesis, respiration, sediment oxygen demand, water temperature and the discharge (Sarkar and Pandey, 2015). When the organic matter is less in the water body, the DO demand will also be small. The aeration process will then increase the concentration of DO and purify back the water. But when the organic matter concentration is too high and continuously pollute the water, the aeration process will not be sufficient to perform the natural self purification (Harsono and Nomosatryo, 2010).

Rivers in urban area of Indonesian cities mostly have heavy polluted condition. Bandung City, the capital city of West Java Province, has 46 main rivers. According to the Storet Index valuation, most of those rivers' water severe with heavy polluted status (Bandung City Environmental Protection Agency, 2014). Prediction of wastewater generated from the community living near Cikapundung River in the year of 2020 is approximately 1,172 m^3 per day. Around 88% of the houses have bathroom and water closet facilities but do not provide them with the septic tanks (Djoeffan and Mukhsin, 2003).

River water quality improvement efforts have been done with various activities, both physically and non-physically. However, the progress is somehow slow because those actions were not integrated and not well-managed. Water-quality simulation models are normally embedded within a waste-load allocation model framework in order to describe relationships between river water-quality levels and wastewater control strategies (Qin *et al.*, 2009).

Usage of river water quality model is still not popular due to lack of data and information concerning the characteristic of the urban river water, especially in determination of coefficient values that are used in the model. Several researchers have conducted research on the deoxygenation carbon at the rivers outside Indonesia, but still limited to the river in Indonesia (Hendriarianti and Karnaningroem, 2015).

Coefficient of deoxygenation rate indicates oxygen usage in the processes of (Thomann & Mueller, 1987):

1. Oxidation of carbonaceous waste material
2. Oxidation of nitrogenous waste material
3. Oxygen demand of sediments of water body
4. Use of oxygen for respiration by aquatic plants

Water quality models are used to address the relationships between the pollutant loadings and environmental responses in a stream (or a river), and analyze the potential impacts of alternative pollution control plans (Qin *et al.*, 2009).

To conduct the modeling process in urban river water quality improvement, the specific of deoxygenation rate need to be provided. Field data are crucial in determining the CBOD deoxygenation rate in the receiving water (Lung, 1993 from Lung, 2001). Thus the aim of this research is to determine the deoxygenation rate of river located in the urban area with heavy pollution condition.

METHODOLOGY

Cikapundung and Citepus rivers were selected to represent the urban river. Those rivers pass through the most crowded area of Bandung City. Many illegal houses are built on the riverbanks of those rivers; mostly do not have the wastewater treatment facility and discharge the waste directly into the rivers. Thus, this condition makes the river water quality very unpleasant. The Cikapundung River holds a very strategic role as one of the water supply source for Bandung, but the water quality is decreasing over the years (Darul, et.al, 2016). The watershed of Cikapundung is one of the sub Watershed of Citarum that functioned as the main drainage canal of the Bandung City (Jatnika and Rahardyan, 2015).

The deoxygenation rate was determined by means of laboratory analysis of oxygen uptake of the river water. Figure 1 shows the location of Cikapundung and Citepus Rivers and the sampling points. From each river, the samples were collected in 2 points, i.e. upstream and downstream. Between upstream and downstream stations, the riverbanks have very crowded illegal houses. The water samples were collected in dry season and rainy season during 2011-2015.

Measurement of DO concentrations were conducted according to APHA's Standard Method (APHA, 2005), i.e. Winkler method. The daily usage of DO, or can be indicated as BOD, was measured for 10 consecutive days in order to estimate the rate

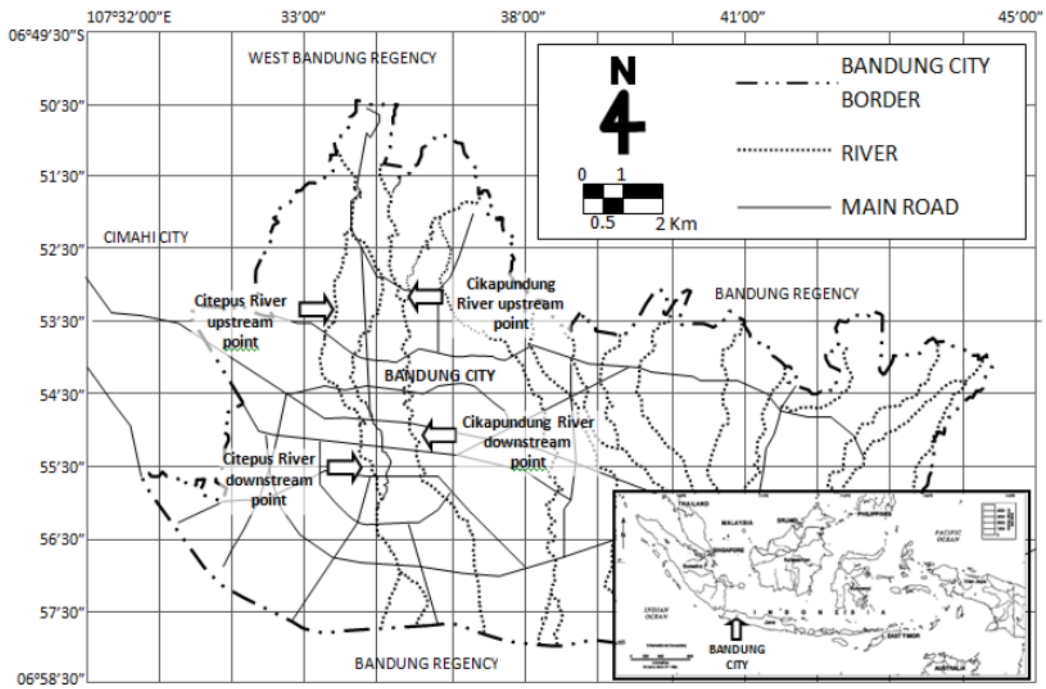

Fig. 1. Research location and sampling points.

of deoxygenation. A minimum of 6 observations are usually required to give consistent results (Lin, 2007).

Determination of the deoxygenation rate can be achieved using several methods such as Thomas' method, least square method, Fujimoto method, rapid ratio method and daily difference method. Thomas' and least square methods are the common methods in use (Adewumi, 2005). This research uses the slope method of Thomas which gives the BOD constant via least square treatment of the basic form of the first order reaction (Eq. 1) (Lin, 2007).

$$\frac{dy}{dt} = K_1(L_a - y) = K_1L_a - K_1y \qquad \text{Eq. 1}$$

where dy/dt = 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 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 (Lin, 2007).

$$na + b\sum y - \sum y' = 0 \qquad \text{Eq. 2}$$

and

$$a\sum y + b\sum y^2 - \sum yy' = 0 \qquad \text{Eq. 3}$$

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.

$$K_1 = -b \qquad \text{Eq. 4}$$

and

$$L_a = -a/b \qquad \text{Eq. 5}$$

Reed *et al.*, (1931) published a paper on the statistical treatment of velocity data, that is recognized as the most comprehensive and accurate approach to the estimation of the velocity constants of the first order model for the BOD kinetics. However, as this method requires laborious calculations and therefore one is discouraged from estimating k and L_0 (Merske *et al.*, 1972 from Singh, 2004).

RESULTS AND DISCUSSION

Thomas' slope method gives the deoxygenation rate as shown in the Figures 2, 3, 4, and 5.

Generally, there is no significant pattern of deoxygenation rate differences between upstream and downstream as well as between dry season and rainy season. The highest values of the rate were observed at the downstream points in rainy season, both Cikapundung and Citepus Rivers, i.e. 0.370 and 0.48 per day respectively, whereas the lowest value was observed also in the rainy season at the downstream point of Cikapundung River. The deoxygenation rate is as low as 0.010 per day. The Citepus River's lowest deoxygenation rate was observed in the dry season at the upstream point.

Figures 6, 7, 8, and 9 show the concentrations of ultimate BOD.

In general, the concentrations of ultimate BOD were higher at the downstream points due to the pollution activities occurred between the two sampling points. However, the upstream point

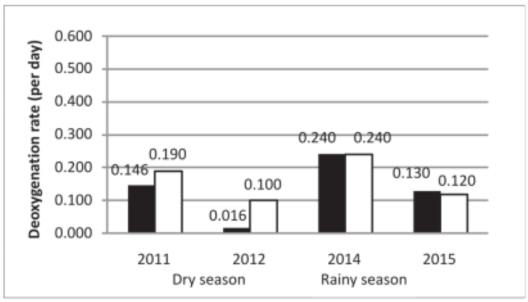

Fig. 2. The deoxygenation rate of Cikapundung River water in the upstream point.

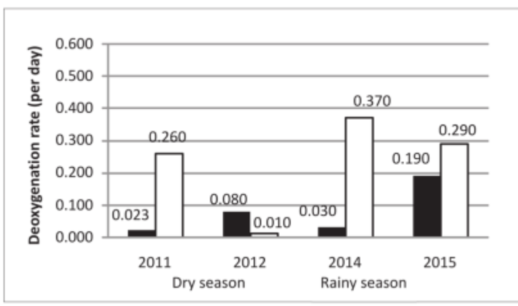

Fig. 3. The deoxygenation rate of Cikapundung River water in the downstream point.

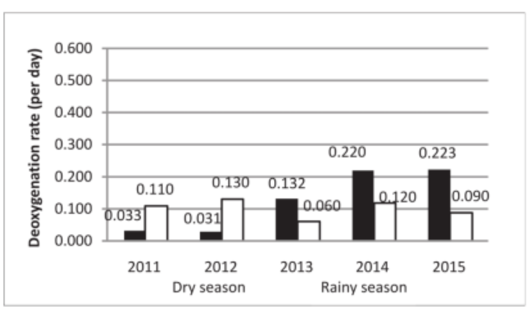

Fig. 4. The deoxygenation rate of Citepus River water in the upstream point.

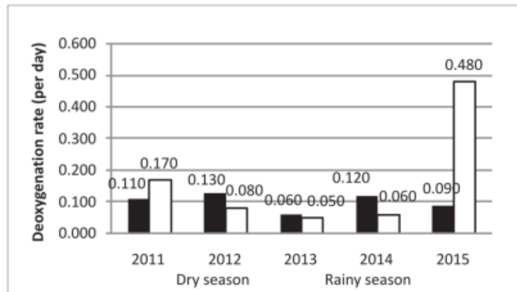

Fig. 5. The deoxygenation rate of Citepus River water in the downstream point.

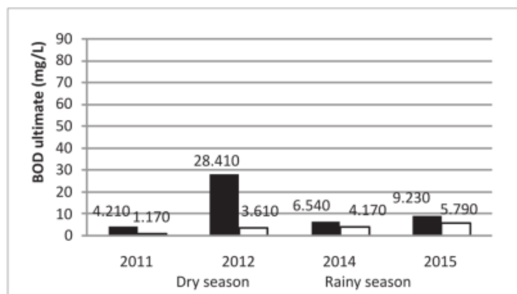

Fig. 6. The ultimate BOD concentration of Cikapundung River water in the upstream point.

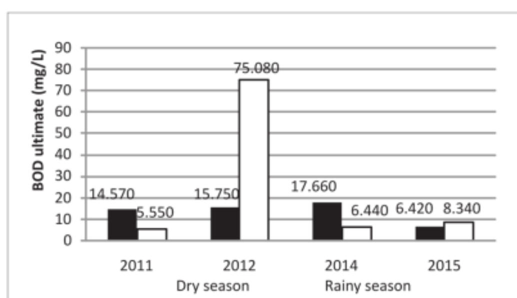

Fig. 7. The ultimate BOD concentration of Cikapundung River water in the downstream point.

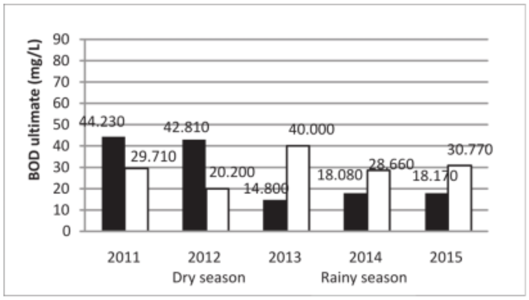

Fig. 8. The ultimate BOD concentration of Citepus River water in the upstream point.

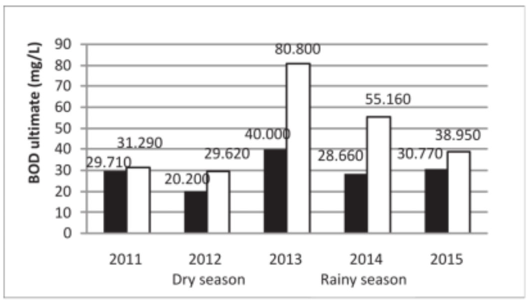

Fig. 9. The ultimate BOD concentration of Citepus River water in the downstream point.

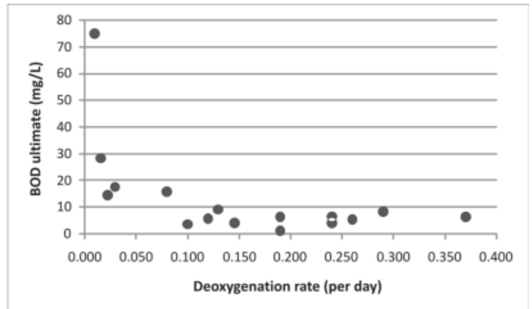

Fig. 10. Distribution of deoxygenation rate in correlation with ultimate BOD in Cikapundung River.

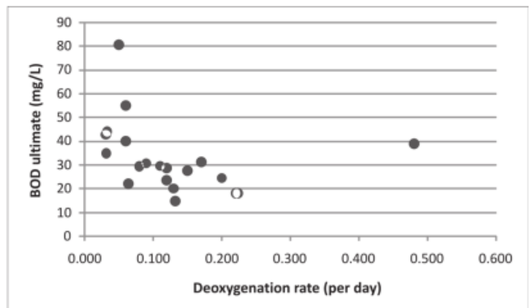

Fig. 11. Distribution of deoxygenation rate in correlation with ultimate BOD in Citepus River.

sometimes is observed having higher concentration of ultimate BOD, probably due to the pollution occurred in the upper stream.

The highest concentrations of ultimate BOD were measured in the rainy season at the downstream points, both in the Cikapundung and Citepus Rivers, i.e. 75.080 and 80.800 mg/L respectively.

Based on Peavy (1985), the typical values of the deoxygenation rate for surface water is 0.1-0.23 per day, with the BOD ranges between 1-30 mg/L. Higher BOD concentration will lead the higher deoxygenation rate (Peavy, 1985). The data acquired from this research do not follow that phenomenon. Figures 10 and 11 are displaying the distribution of deoxygenation rate in correlation with ultimate BOD concentration.

Distribution data of deoxygenation rate in correlation with ultimate BOD in Cikapundung and Citepus Rivers give the information that the low BOD concentration is uncorrelated with low deoxygenation rate. The highest BOD concentrations of Cikapundung and Citepus Rivers even have deoxygenation rate as low as <0.10 per day.

Compare to the range of the deoxygenation rate for surface water published by Peavy (1985), several data of Cikapundung and Citepus can be categorized as very low value. Approximately 39% of the rates were obtained under 0.1 per day although the ultimate BOD concentrations were observed more than 1 mg/L. For another comparison, the rates of deoxygenation of rivers outside Indonesia are also in the normal range such as Ravi River in Pakistan has 0.14-0.27 per day (Haider *et al.*, 2010), Swan River in Western Australia has 0.23 per day (Kurup *et al.*, 2002), and Gomti River in India has 0.45 per day (Jha *et al.*, 2008). Beside the low content of BOD of the river, the low of deoxygenation rate can also be caused by the turbulent condition of river flow (Hendriarianti and Karnaningroem, 2015).

An increasing temperature has the most impact on the deoxygenation rate, and results in an increased critical deficit. Furthermore, a decreased of saturated DO concentration occurs with increasing temperature, which leads to a decrease in the DO concentration (Schnoor, 1996).

Considering the processes indicated by the deoxygenation rate, i.e. oxidation of organic material and aquatic plants respiration, the low value of the rate can probably denote a non-optimal condition of the processes. Decomposition of organic matter by the microorganism can be inhibited by several conditions, such as toxic material and heavy metals. The river quality data of Cikapundung and Citepus show that several heavy metals were detected above the concentrations standard, i.e. Cr^{+6}, Zn, Mn, Cu, and Pb. Hg concentration was also detected higher than standard in Citepus River (Wardhani, 2009). Studies on the effect of metals on organic pollutant bio-degradation are not extensive but demonstrate that metals have the potential to inhibit pollutant biodegradation under both aerobic and anaerobic conditions (Sandrin and Maier, 2003).

Heavy metals are toxic to the mixed culture of microorganisms responsible for the decomposition of organic compounds in surface waters. As aerobic biological processes are an essential part of the self-purification process occurring in surface water, heavy metals diminish the ability of such waters to purify themselves (Mala and Maly, 2009).

Other pollutant that can reduce the rate of deoxygenation in the river is antibiotic drug discharged from the medical activities. An antibiotic is chemotherapeutic agents that inhibits or abolishes the growth of natural (produced by microorganism) semi-synthetics (derivatives or natural antibiotics with structural modification) and fully synthetics (Castillo *et al.*, 2014).

The urban rivers also severe with the wastewater discharged from the laundry activity. The surfactant contains in the wastewater can affect the deoxygenation rate. It was reported that detergent concentration ranged between 0.407-1.29 mg/L in the downstream of Citepus River (Komarawidjaja, 2004). An experimental substantiation was given to the potential environmental significance of the effect caused by the influence of synthetic surfactants on hydrobionts and the relationship between these effects and the hazard of anthropogenic impact on the processes of water self-purification (Ostroumov, 2004).

CONCLUSION

The deoxygenation rate of Cikapundung and Citepus Rivers represent the condition of urban rivers in Indonesia. The range of the deoxygenation rates are 0.010-0.370 per day for Cikapundung River and 0.031-0.480 per day for Citepus River. As much as 39% of the rates are observed under 0.100 per day, indicated the slow processes of oxidation of waste material and self purification. The ultimate BOD concentrations were observed relatively low. The averages of the concentrations are 7.891 and 18.726 mg/L for upstream and downstream Cikapundung River, respectively. Citepus River has higher average of ultimate BOD concentration than Cikapundung River. The average values are 28.743 and 36.879 mg/L for upstream and downstream, respectively.

The low value of deoxygenation rates indicate that the rivers are polluted not only by the domestic wastewater but also by industries and other activities causing the pollution of heavy metals, synthetic surfactant, antimicrobial substances, etc. Toxic pollutants from various activities often pollute the urban river, therefore the deoxygenation rate suitable for the water quality modeling for those kinds of rivers are relatively low.

Furthermore, having that toxic pollutants contained in the rivers, one important effort that need to be applied is installation of wastewater treatment plants, especially for non domestic activities.

ACKNOWLEDGMENT

This research was funded by the Ministry of Research, Technology, and Higher Education of the Republic of Indonesia.

REFERENCES

Adewumi, I., Oke, I. A. and Bamgboye, P. A. 2005. Determination of the deoxygenation rates of a residential institution's wastewater. *Journal of Applied Sciences.* 5 (1) : 108-112.

American Public Health Association-APHA; American Water Works Association-AWWA; Water Environment Federation-WEF. 2005. *Standard Methods for the Examination of Water and Wastewater.* 21th edition. Washington.

Berkun, M. 2005. Effects of Ni, Cr, Hg, Cu, Zn, Al on the dissolved oxygen balance of streams. *Chemosphere.* 59 : 107-25

Castillo, F. Y. R., Harel, J., Flores, A. C. M., Muro, A. L., Barrera, A. L. G. and González, F. J. A. 2014. Antimicrobial Resistance: the role of aquatic environments. *International Journal of Current Research and Academic Review.* 2 (7) : 231-246.

Darul, A., Irawan, D. E., Trilaksono, N. J., Pratama, A. and Fitria, U. R. 2016. Conceptual model of groundwater and river water interactions in Cikapundung riverbank, Bandung, West Java. IOP *Conf. Series: Earth and Environmental Science.* 29.

doi:10.1088/1755-1315/29/1/012026.

Djoeffan, S. H. and Mukhsin, D. 2003. Inventarisasi Sarana dan Prasarana Permukiman di Lembah Cikapundung. (Identificaton of Facilities of Settlements in the Cikapundung Valley), In Indonesian. *Ethos*. 1 (2) : 87-98.

Environmental Protection Agency of Bandung City. 2014. *River water quality report*.

Haider, H. and Ali, W. 2010. Development of dissolved oxygen Model for highly variable flow river: A case study of Ravi River in Pakistan. *Environmental Model Assessment*. 15 : 583-599.

Harsono, E. and Nomosatryo, S. 2010. Pencirian Karbon Organik Air Sungai Citarum Hulu dari Masukan Air Limbah Penduduk dan Industri (Characterization of Organic Carbon of Citarum Hulu River Water Derived from the Domestic and Industrial Wastewater Effluents). In Indonesian. *Jurnal Biologi Indonesia* 6 (2) : 277-288.

Hendriarianti, E. and Karnaningroem, N. 2015. Deoxygenation Rate of Carbon in Upstream Brantas River in the City of Malang. *Journal Applied Environmental and Biological Science*. 5 (12) : 34-41.

Jatnika, L. and Rahardyan, B. 2015. Aplikasi Metode Valuasi Kontingen dalam Upaya Peningkatan Kebersihan Sungai Cikapundung Kota Bandung. (Application of Contingent Valuation Method in the Effort to Cikapundung River Quality Improvement) in Indonesian. *Majalah Ilmiah Globe*. 17 (1) :059-066.

Jha, R. and Singh, V., P. 2008. Analytical Water Quality Model for Biochemical Oxygen Demand Simulation in River Gomti of Ganga Basin, India. *KSCE Journal of Civil Engineering*. 12(2) : March 2008.

Komarawidjaja, W. 2004. Kontribusi Limbah Deterjen terhadap Status Kehidupan Perairan di DAS Citarum Hulu. (Contribution of Wastewater containing Detergent to the Water Live Status) In Indonesian. *Jurnal Tek. Ling. P3TL-BPPT*. 5 (3) : 193-197.

Kurup, R.G. and Hamilton, D. P. 2002. Flushing of Dense, Hypoxic Water from a Cavity of the Swan Estuary, *Western Australia, Estuaries*. 25 (5) : 908-915.

Lin, S. D. 2007. *Water and Wastewater Calculations Manual*. Second edition. McGraw-Hill. Pp. 10-41

Lincheva, S., Todorova, Y., Topalova, Y. 2014. Long-term assessment of the self-purification potential of a technologically managed ecosystem: the Middle Iskar cascade. *Biotechnology and Biotechnological Equipment*. 28 (3) : 455-462.

Lung, W. S. 2001. *Water Quality Modeling for Wasteload Allocations and TMDLs*, John Wiley & Sons, Inc. pp. 82

Mala, J. and Maly, J. 2009. Effect of Heavy Metals on Self-Purification Processes in Rivers. *Applied Ecology and Environmental Research*. 7 (4) : 333-340.

Menezes, J. P. C., Bittencourt, R. P., Farias, M. D. S., Bello, I. P., Oliveira, L F. C., Fia, R. 2015. Deoxygenation rate, reaeration and potential for self-purification of small tropical urban stream. *Ambiente & Água-An Interdisciplinary Journal of Applied Science*. 10 (4) : 748-757.

Ostroumov, S. A. 2004. The effect of synthetic surfactants on the Hydrobiological Mechanisms of Water Self-Purification. *Water Resources*. 31 (5) : 502-510.

Peavy H.S., Donal R. Rowe and George Tchobanoglous 1985. *Environmental Engineering*. McGraw Hill, New York p. 43

Qin, X., Huang, G., Chen, B. and Zhang, B. 2011. An Interval-Parameter Waste-Load-Allocation Model for River Water Quality Management Under Uncertainty. *Environmental Management*. 43 : 999-1012.

Sandrin, T.R. and Maier, R.M. 2003. Impact of metals on the biodegradation of organic pollutants. *Environ Health Perspect* 111 : 1093-110.

Sarkar, A. and Pandey, P. 2015. River Water Quality Modelling using Artificial Neural Network Technique. *Aquatic Procedia* 4 : 1070-1077.

Schnoor, J. 1996. *Environmental Modeling, Fate and Transport of Pollutants in Water, Air and Soil*, Wiley-Interscience.

Singh, B. 2004. Determination of BOD Kinetic Parameters and Evaluation of Alternate Methods. A Master of Environmental Engineering Thesis. Department of Biotechnology and Environmental Sciences, Thapar Institute of Engineering and Technology.

Siwiec, T., Kiedryñska, L., Abramowicz, K., Rewicka, A. and Nowak, P. 2011. BOD measuring and modeling methods - review. *Land Reclamation*. 43 (2) : 143-153.

Streeter, H. W. and Phelps, E. B. 1925. A Study of the Pollution and Natural Purification of the Ohio River III. *Public Health Bulletin* No. 146. United States Public Health Service, Washington.

Thomann, R. and Mueller, J. 1987. *Principles of Surface Water Quality Modeling and Control*. Harper & Row, Publishers, New York. Pp. 266

Wardhani, E. 2009. Identifikasi Pencemaran Logam Berat Raksa di Sungai Citarum Hulu Jawa Barat. (Identification of Heavy Metal Mercury in Citarum Hulu River, West Java) In Indonesian. *Jurnal Teknik Kimia Indonesia*. 8(1) : 17-23.

Determination Of Deoxygenation Rate Of Rivers

ORIGINALITY REPORT

22%	18%	14%	10%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

2%

★ cyberleninka.org

Internet Source

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		