Study of carrying capacity of Karang Mumus River using the QUAL2Kw Program

Sri Lestari[1,2*], Diana Arfiati[3], Aniek Masrevaniah[4], Moch. Sholichin[4]

[1]Doctoral Program of Environmental Science, University of Brawijaya, Malang, Indonesia
[2]Chemistry of Education, University of Mulawarman, Samarinda, Indonesia
[3]Faculty of Fisheries and Marine Science, University of Brawijaya, Malang, Indonesia
[4]Water Resources Engineering Department, University of Brawijaya, Malang, Indonesia

Abstract

Karang Mumus River is one of the Mahakam tributaries that passes through Samarinda city. Strategic location for water sources and easy access to workplaces make the Karang Mumus Riverbank a residential destination for migrants in Samarinda. People who live along the riverbank still consume the river water for various purposes. The river water is used for bathing, washing clothes and eating utensils, as well as for other purposes. Home industries such as tofu and tempeh industries also utilize the river water. Traditional markets also use it mainly to wash fish and chicken. These facts in addition to being able to have an impact on public health also contribute to the decline in the quality of the Karang Mumus River. The purpose of this study was to determine the carrying capacity of river water for total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), total phosphorus, and Coliform parameters by using the QUAL2KW program. The determination of carrying capacity is done by making a simulation of the model that has been done. The carrying capacity of the Karang Mumus River can be determined from simulations that condition the source of pollutants originating from tributaries and drainage channels that have met the Class II water quality standards. The determination of the carrying capacity of the Karang Mumus River for TSS, DO, BOD, total phosphorus, and Coliform parameters show that the Karang Mumus River only has a carrying capacity of the P-total parameter, whereas the TSS, DO, BOD, and Coliform bacteria parameters have exceeded the carrying capacity.

Keywords — *Carrying Capacity, QUAL2Kw, Karang Mumus River*

I. INTRODUCTION

Karang Mumus River is one of the tributary Mahakam River divides the city of Samarinda in East Kalimantan Province. Strategic locations across the city and its role as a source of water and water transport lines made along the Karang Mumus River into a residential destination for migrants and community center. In line with population growth that can lead to settlements along the Karang Mumus River more densely and slums, the stern of the houses and latrines overhanging to the river and economic activity along the river such as the market, tofu, and tempeh industry, making the Karang Mumus River like a trash can. Ahmad et al. [1], stating the existence of domestic sewage, industrial activities, and agriculture can increase the BOD and chemical oxygen demand (COD) in water. As a result of the pollution of the environmental balance will be disturbed, for example, outbreaks of infectious diseases. According to Nwida et al. [2], there is a correlation between the number of people affected by infectious diseases with a number of bacterial pathogens in water.

Results of monitoring in 1999 on 22 point Karang Mu-mus River parameter DO, BOD, COD, and total dissolved solids (TDS) in a row are 0.2 to 5.0 mg/L; 2.3 to 12.1 mg/L; 16 to 119 mg/L; and 19.2 to 120 mg/L, respectively. Even for the Coliform parameter value has exceeded the threshold is over 2.400 per 100 mL [3]. According to Rahayu and Wijayanti [4], the Karang Mumus River included categories that require immediate recovery through the PROKASIH program for parameter DO, BOD, COD, and TSS.

Based on East Kalimantan Governor Decree No. 2 of 2011, the River Karang Mumus River has been designated as a Grade II water bodies so that really is not fit for use for domestic purposes. Moreover, the condition of the waters of the Karang Mumus River lately become increasingly serious, which is black and smells especially in the dry season.

Although the water quality of the Karang Mumus River not feasible, the river is still used especially communities who live along the river. The water of the river used for bathing, washing clothes and kitchen equipment, and household activities. The poor water quality can affect public health. With such conditions, we want to know the river carrying capacity. The river carrying capacity is the ability of the river to support the natural purification process without causing pollution to the river. In this research, the determination of carrying capacity is done using QUAL2Kw modeling.

II. METHODS

A. Study Area

This research was conducted in the Karang Mumus River of dams Benanga up the estuary on the

Mahakam River with a length of about 17 km, located between 0°17'50"-0°30'00"S and 117°06'00"-117°22'00"E.

B. Method Of Collecting Data

Sampling was carried out every month at 9 stations/points using purposive sampling method, ie the area below the dam upstream Benanga (station I), Lempake River (station II), Gunung Lingai river (station III), Sempaja River (station IV), Gunung Lingai river (station V), Gelatik drainage (station VI), Ruhui Rahayu drainage (station VII), Gatot Subroto drainage (station VIII), and downstream (IX station).

C. Determination of Carrying Capacity

Determination of the carrying capacity uses data that includes a map, river hydraulic conditions, river water quality, and point source water quality. The data obtained is then entered into the QUAL2Kw program to build the model. After the model is formed, calibration is carried out by varying the water quality coefficient on Reach Rates. The model is said to be calibrated if it has approached the data. This is known from the trends formed by the model resembling the trends formed by the data on the graph.

III. RESULD AND DISCUSION

A. Karang Mumus River Water Quality with QUQL2Kw model

Water quality modeling is recognized as a useful tool for obtaining valuable information for optimal water quality management [5] and can provide basic knowledge for assessing water quality even when monitoring data are inadequate [6]. Water quality modeling aims to obtain a chart of river water pollution profiles. If in the analysis of the quality status only the condition of pollution of each point (monitoring station) is known within a certain time, then by modeling it will be known the condition of water quality along the river body. By using water quality modeling, it can be predicted the condition of river water quality for some time to come.

Water quality modeling in Karang Mumus River uses QUAL2Kw computational modeling method version 5.1. In this modeling, the Karang Mumus River is divided into 4 segments as shown in table 1. Segment distribution is based after meeting with creeks and drainage channels leading to the Karang Mumus River. There are 3 tributaries of the Karang Mumus River, namely, the Lempake River, the Gunung Lingai River, and the Sempaja River, as well as several drainages leading to the Karang Mumus River. The results of data processing of water quality parameters can describe the general state of water quality along the Karang Mumus River.

TABLE I
Reach of Karang Mumus River

No	Nama of reach	distance (Km)	Elevation (m)	
			Upstream	Downstream
1	Benanga-Lempake	6.79	11.647	10.870
2	Lempake-Gunung Lingai	2.60	10.870	6.792
3	Gunung Ligai-Sempaja	0.72	6.792	6.492
4	Sempaja-Mahakam	7.38	6.492	4.06

The results of data processing using modeling can be seen that the TSS content along the Karang Mumus river still does not meet the quality standards set by the Governor of East Kalimantan, which is 50 mg/L. The high TSS content in all segments is due to the high TSS content carried by tributaries and drainage channels as well as the presence of domestic waste from settlements along the Karang Mumus riverbanks. According to Pramaningsih [7], the degradation of domestic waste mainly from public bathing, washing, and toilet facilities activities will produce solid particles. Meanwhile, according to Indeswari et al. [8], the presence of plants and animals that die and rot will produce suspended organic material that can contribute to TSS content in waters. The TSS content from upstream to estuary has slightly decreased (Figure 1) this is due to an increase in the Karang Mumus River water discharge so that the particles in the water body will experience dilution. This additional discharge is derived from tributaries and drainage channels entering the Karang Mumus River.

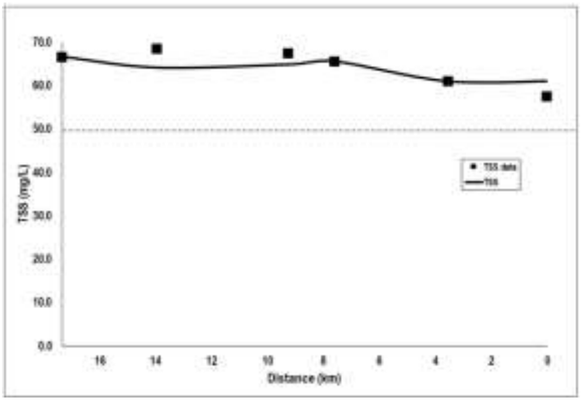


Fig. 1: TSS profile of Karang Mumus River water QUAL2Kw running results

TSS (Total Suspended Solids) or total suspended solids are suspended materials of more than 1 µm in diameter which are retained in the Millipore filter with a pore diameter of 0.5 µm. TSS consists of mud and fine sand and microorganisms. The main source of TSS in waters is soil erosion or soil erosion carried into water bodies. TSS concentrations that are too high will inhibit the penetration of light into the water and cause disruption of photosynthesis [9].

The level of dissolved oxygen in the upstream is still relatively high (as shown in Figure 2), this shows the quality of the water around the upstream is still good to sustain the life of aquatic biota. The high level of dissolved oxygen might be caused by a fall at the exit of the dam. Upstream of the Karang Mumus River is the Benanga dam which serves as a flood controller for the city of Samarinda. The level of dissolved oxygen decreases at kilometer 14 from downstream, this shows that more oxygen is needed by various elements of water to carry out activities or reactions. This also means that the heavier water burden is caused by the influx of pollutants that require oxygen in the degradation process. Even though oxygen can be transferred from the atmosphere through natural aeration processes (due to turbulence, flow, etc.), but the amount that enters is not proportional to the amount oxygen needed for all processes in water so that it will decrease. Potential sources of pollutants in this area come from agriculture and settlements around the banks that dump their waste into the river.

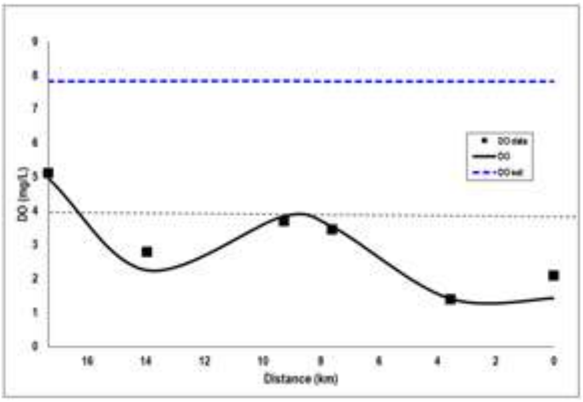


Fig. 2: DO profile of Karang Mumus River water QUAL2Kw running results

Furthermore dissolved oxygen levels increased to kilometers 9.5 from upstream. This increase is likely due to the not too dense settlement of residents around the banks of the Karang Mumus River. This condition will the burden of incoming pollutants is reduced which causes the river to have the opportunity to self-purification. From kilometer 9.5 to downstream the dissolved oxygen content decreases, because in this area there are a tributary of the Karang Mumus tributary, the Gunung Lingai River (in segment 3) that passes through residential areas and traditional markets and the Sempaja river (in segment 4) and several drainage channels (drainage) from urban, hotels, and malls. In addition, this area is part of the Karang Mumus River which passes through the densely populated Samarinda city and there are several traditional markets. Dissolved oxygen plays an important role as an indicator of water quality, most of the dissolved oxygen is used by aerobic bacteria to oxidize carbon and nitrogen in organic matter into carbon dioxide and water and ammonia, such as the following reaction:

$$C_nHaO_bN_c + [n+a/4-b/2-3/4c]\ O_2 \rightarrow nCO_2 + [a/2 - 3/2c]\ H_2O + cNH_3$$

In general, the decreasing value of dissolved oxygen indicates that water bodies are starting to become polluted. Pollutants that enter the body of water are not comparable to the process of water bodies doing self-purification. The ability of water bodies to perform self-purification will de-crease because the rate of oxidation reactions in water bodies decreases due to oxygen limitations. This is likely because the sources of pollutant sources entering the body of water are too many and the distances are very close, not the safe distance where the water has the opportunity to restore its quality. The same thing as said Kurniadi et al., [10] that if the pollution of river water occurs continuously then the ability of the river to accommodate (support) pollutants will have a limit and ultimately will cause environmental damage.

BOD or Biochemical Oxygen Demand is the amount of oxygen (mg/L) needed by aerobic bacteria to decompose (oxidize) almost all dissolved organic substances and some substances that are suspended in water. The COD is commonly used to indirectly measure the amount of nonbiodegradable organic compounds in water [11]. Organic materials can be in the form of fat, protein, and carbohydrates. Organic matter is the result of decaying plants and animals that have died or are discharged from domestic and industrial waste [9].

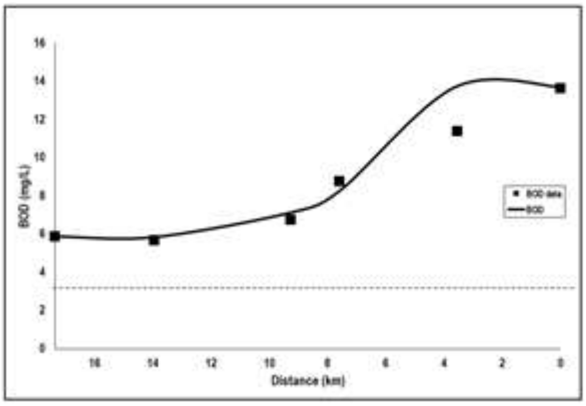


Fig. 3: BOD profile of Karang Mumus River water as a result of running QUAL2Kw

Figure 3. indicates that the upstream BOD value of the Karang Mumus River is relatively high, this indicates that there is biological activity upstream which is a reservoir. The condition of the reservoir is very alarming because it is covered with aquatic plants (eutrophication). The eutrophication process that occurs in reservoirs is due to a large amount of organic material in the form of fish food waste and fish dung from cages that are widely available in reservoirs. After kilometer 14 reached the estuary the BOD value increased, this was due to an increase in pollutants entering the river. Potential sources of pollutants are generated from inputs from the Lempake River, Gunung Lingai River, Sempaja

River, and several drainage channels that enter the Karang Mumus River and settlements on the banks that dispose of their waste directly into the river. Lempake, Gunung Lingai, and Sempaja rivers are Karang Mumus tributaries that pass through residential and agricultural areas, there are several household industries of tofu and tempeh on the banks of the Gunung Lingai and Sempaja rivers that dump their waste directly into the river. The presence of domestic waste, industrial activities, and agri-culture can increase the value of BOD in waters [1].

BOD is one of the parameters used for monitoring water quality parameters, especially the levels of organic matter that can be decomposed by decomposing microorganisms, such as proteins, carbohydrates, and fats [12]. In general, the BOD value of the Karang Mumus River in all segments has exceeded the Class II water quality standard.

Based on the modeling results (Figure 4.), the total phosphorus value in all segments of the Karang Mumus river still meets class II water quality standards. Total phosphorus describes the total amount of phosphorus in the form of solids or dissolved, inorganic or organic [9]. According to Morse, et al. [13], 10% of phosphorus comes from natural processes in the aquatic environment itself, 7% from industry, 11% from detergents, 17% from agricultural fertilizers, 23% from human waste, and 32% from waste animal husbandry.

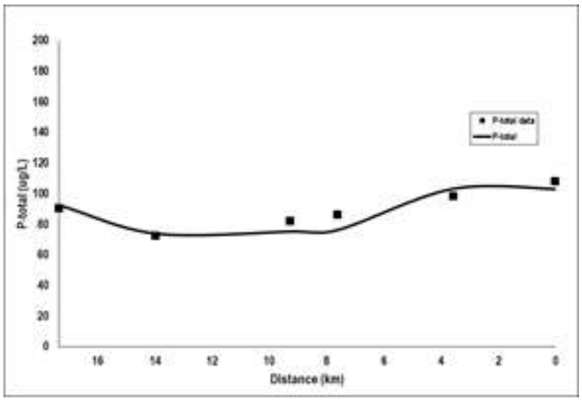


Fig. 4: P-total profile of Karang Mumus River water as a result of running QUAL2Kw

A large amount of organic waste entering the Karang Mumus River will produce phosphorus in water bodies because organic phosphorus is abundant in waters that contain a lot of organic matter waste [9]. In addition, the source of phosphorus pollutants in runoff from agricultural areas carried by tributaries of the Karang Mumus river (Lempake river) that passes through the agricultural area.

After kilometer 8, the total phosphorus value has relatively increased, this is due to the increasing density of settlements on the banks of the Karang period of time it will have an impact on the emergence of diseases such as inflammation of the intestine, diarrhea, infection of the urinary tract, and bile [16].

Mumus river and there are several traditional markets in this area (segment 3 and segment 4). Almost all people living on the banks of the river use the Karang Mumus river for activities of public bathing, washing, and toilet facilities. This activity will produce waste containing phosphorus. Phosphorus is widely used as fertilizer, soap or detergent, ceramic industrial materials, catalysts, and so on [14].

Phosphorus is not toxic to humans, animals, and fish. Excessive phosphorus accompanied by the presence of nitrogen can cause algae to bloom in the water (algae bloom). Excessive algae can form layers on the surface of the water which will further inhibit the penetration of oxygen and sunlight.

The term Coliform is intended for a group of bacteria that have the characteristics of a short rod-shaped, forming a chain, not diaspora, aerobic or facultative anaerobes. This group can live in water or soil. Some of which belong to this group are Escherichia coli, Enterobacter aerogenes, and Serratia marcescens. The presence of this group of bacteria in waters is one indicator of human feces or warm-blooded contamination. So that this group of bacteria can be used as an indicator of the quality of water [15].

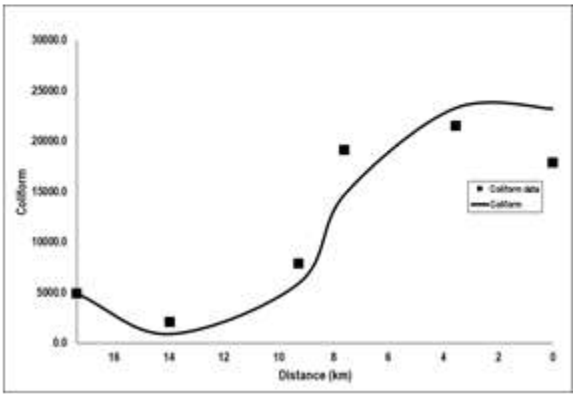


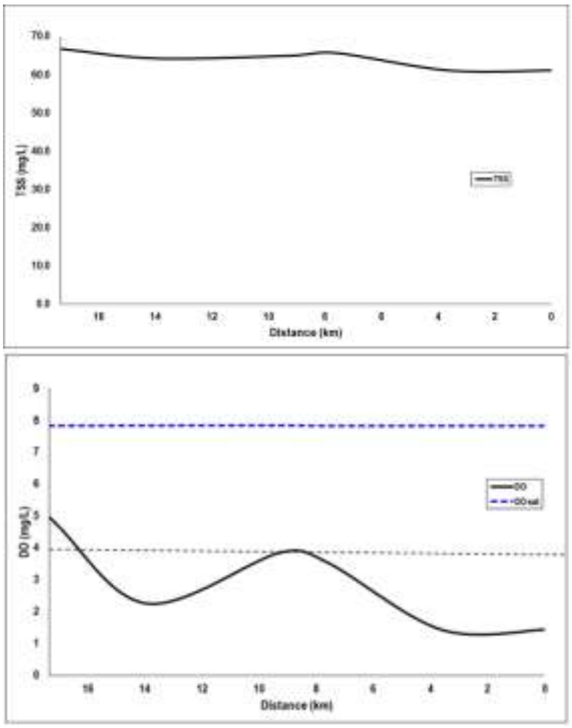
Fig. 5: Coliform profile of Karang Mumus River water as a result of running QUAL2Kw

The content of Coliform bacteria in the upstream to kilometer 14 still meets class II water quality standards, this is due to the small number of settlements found on the banks of the Karang Mumus River, but after kilometer 14 it has increased and after kilometers 10 to downstream it is already above the specified quality standard (as in figure 4.6). This is due to a large number of settlements built on the banks of the Karang Mumus River in this area (especially segment 3 and segment 4) which make the river a latrine or trash can from economic activities along the Karang Mumus River. If in water contaminated with Coliform bacteria consumed continuously over a long

B. Carrying Capacity of Karang Mumus River

The carrying capacity of a river is the ability of a river to support its natural purification process without causing pollution to the river. The determination of carrying capacity is done by making a simulation of the model that has been done. The carrying capacity of the Karang Mumus River can be determined from simulations that condition the source of pollutants originating from tributaries and drainage channels that have met the Class II water quality standards.

The simulation results in Figure 6, the Karang Mumus river only have the carrying capacity of the parameter of total phosphorus, while the parameters TSS, DO, BOD, and Coliform have exceeded the carrying capacity. By condition that the pollutant source meets the quality standard, it turns out that water quality parameters in all Karang Mumus River segments still exceed the established quality standards. This is due to the fact that too many non-point source pollutants have entered, namely in the form of discharges from settlements and traditional markets located on the banks of the Karang Mumus River. Domestic waste can be in the form of household water discharges such as solid waste, bathroom, washing water or feces discharged into the river will increase the levels of BOD and Coliform bacteria in the river [17]. Excessive amounts of pollutants cause the environment to not be able to clean itself (self-purification). Many rivers in Indonesia have reached an alarming level of pollution, especially rivers that flow through urban areas (densely populated areas) and industrial areas [18].



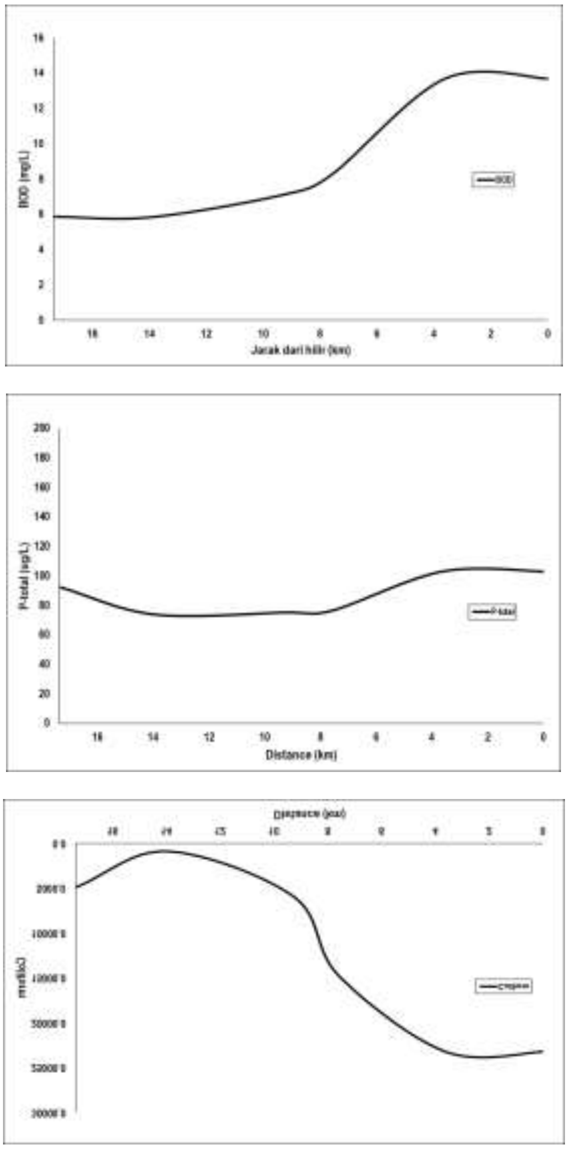


Fig. 6: Carrying capacity of the Karang Mumus River on (a) TSS, (b) DO, (c) BOD, (d) P-total, and (e) Coliform parameters

IV. CONCLUSIONS

Determination of the carrying capacity of the river can be determined using the QUAL2Kw program by comparing the results of simulation models with predetermined standards. The determination of the carrying capacity of the Karang Mumus River only has a carrying capacity of the P-total parameter, whereas the TSS, DO, BOD, and Coliform bacteria parameters have exceeded the carrying capacity.

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REFERENCES

[1] M.J. Ahmed, M.R. Haque, A. Ahsan, S. Siraj, M.H.R. Bhuiyan, S.C. Bhattacharjee, and S. Islam, "Physicochemical Assessment of Surface and Groundwater Resources of Greater Comilla Region of Bangladesh. Pak", J. Anal. Environ. Chem. Vol. 11, pp. 1-11, 2010.

[2] L.L. Nwidu, B. Oveh, T. Okoriye, and N.A. Vaikosen, "Assessment of the Water Quality and Prevalence of Waterborne Diseases in Amassona, Niger Delta, Nigeria", African Journal of Biotechnology, Vo. 7. 2993-2997, 2008.

[3] Anonim, "Neraca Kualitas Lingkungan Hidup Daerah Kaltim", 2000.

[4] D.E. Rahayu and D.W. Wijayanti, "Sistem Pengolahan Air Limbah Domestik dan tinja di IPAL Jl. Jelawat Samarinda", Aplika, vol. 8. 14-18, 2008.

[5] J. Vieira, A. Fonseca, V.J.P. Vilar, R.A.R. Boaventura, and C.M.S. Botelho, "Water Quality Modelling of Lis River, Portugal", Environmental Science and pollution Research, pp. 1-29, 2012.

[6] J. Grabic, A. Bezdan, P. Benka, and A. "Salvai, Spreading and Transformation of Nutrient in the Reacq of The Becej-Bogojeco Canal Serbia Carpatian", J. Earth Environ. Sci. Vol. 6, pp. 277-284, 2011.

[7] V. Pramaningsih, S. Suprayogi, and I.L.S. Purnama, "Kajian Persebaran Spasial Kualitas Air Sungai Karang Mumus Samarinda, Kalimantan Timur", Jurnal Pengelolaan Sumber Daya Alam dan Lingkungan, vol. 7, pp. 71-76, 2017.

[8] L. Indeswari, T. Hariyanto, and C.B. Pribadi, "Pemetaan Sebaran Total Suspended Solid (TSS) Menggunakan Citra Landsat Multitemporal dan Data In Situ (Studi Kasus: Perairan Muara Sungai Porong, Sidoarjo)". Jurnal Teknik ITS. Vol. 7, pp. 71-76, 2018.

[9] J.E. Girard, Principles of Environmental Chemistry, second edition, Massachusetts, Jones and Bartlet, 2010.

[10] B. Kurniadi, S. Hariyadi, and E.M. Adiwilaya, "Kualitas Perairan Sungai Buaya di Pulau Bunyu Kalimantan Utara pada Kondisi Pasang Surut", JIPI, vol. 20, pp. 53-58, 2015.

[11] D., Birva and D. Hemangi, "Evaluation of Water Quality Index for Ground Water of Residential Area of Surat City, Gujarat, India" International Journal of Agriculture & Environmental Science, vol. 5, pp. 53-65, 2018

[12] Metcalf and Eddy, Wastewater Engineering, Treatment Disposal Reuse, New York, Mc.Graw Hill Book Company, 1991.

[13] G.K. Morse, S.W. Brett, J.A. Guy, and J.N. Lester, "Review: Phosphorus Removal and Recovery Technologies", The Science of the Total Environmental, vol. 212, pp. 69-81, 1997.

[14] J.R. Casali, J. Gimenez, J. Dicz, Alvarez, J. Nozos, D.V. de Lersundi, M. Goni, M.A. Campo, Y. Chahor, R. Gastesi, and J. Lopez, "Sediment Production and Water Quality of Watersheds with Contrasting and Land Use in Navarre (Spain)", Agricultural Water Management, vol. 97, pp. 1683-1694, 2010.

[15] R. Wolff, Myticulture en Rade de Toulon la Daie du Lazaret, Risques Epidemiologiques, These Doctoral Institut National de Medecine Agricole. France, 1991.

[16] W.E. Levinson, "Review of Medical Microbiology and Immunology", McGraw Hill, New York, 2008.

[17] P. Hendrawan, "Kualitas Air Sungai dan Situ di DKI Jakarta", Makara Journal of Technology Universitas Indonesia, vol. 9, pp. 13-19, 2005.

[18] S. Yudo, "Kondisi Kualitas Air Sungai Ciliwung di Wilayah DKI Jakarta Ditinjau dari Parameter Organik, Amonia, Fosfat, Deterjen, dan Bakteri Coli", Jurnal Air Indonesia, vol. 6, pp. 12-17, 2010.