Total Maximum Daily Load of the Curug Subdistrict Segment of The Cirarab River, Indonesia

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Abstract. Although The Cirarab River has a highly polluted status, it is used as a source for clean and drinking water for people in Tangerang City. Pollution occurs due to poor river quality management. This study examines the Total Maximum Daily Load/TMDL of The Cirarab River at The Curug Subdistrict Segment using QUAL2Kw with two modeling scenarios. The first scenario was used to obtain the existing load, and the second scenario was used to determine TMDL. The existing loads results obtained were 12,032.26 kgBOD/day and 48,946.69 kgCOD/day. The TMDL results obtained were 2,234.30 kgBOD/day and 18,619.20 kgCOD/day. The existing loads entering each subsegment have exceeded TMDL that they need to be reduced. TMDL calculation is useful as a basis for an effective river management strategy.

1 Introduction

The availability of clean water is one of the Sustainable Development Goals. Pollution greatly affects the availability of clean water [1]. Most water quality problems are caused by wastewater from human activities. The growing number of people will subsequently increase the need of clean water [2], and runoff into rivers due to domestic wastewater released can reduce the river water quality [3,4]. Currently, as many as 1.8 billion people use drinking water contaminated by pollution that poses risks to their health [5]. The scarcity of access to clean and feasible water is a common problem throughout the world, including in Indonesia [6].

In 2015, 67.94% of rivers in Indonesia were heavily polluted; 23.62% were moderately polluted, 6.13% were mildly polluted, and only 2.30% fulfilled the water quality index [7]. In 2017, river water quality further decreased seen from the monitoring result of 84 rivers throughout Indonesia. There were 38 rivers with heavily polluted status (45%), 26 rivers with mildly-heavily polluted status (31%), 11 rivers with mildly polluted status (13%), five rivers with lightly-mildly polluted status (6%), three rivers with lightly-heavily polluted status (4%), and only one river that fulfilled the lightly-heavily polluted status along with its flow (1%) [8]. Based on the STORET calculation, The Cirarab River is heavily polluted [9] despite the fact that it acts as a source of drinking water for people in Tangerang City.

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The pollutants of The Cirarab River are originated from human residential and industrial activities [10].

River pollution occurs due to poor wastewater management, and 80% of wastewater flows back to the ecosystem without prior treatment [11]. At present, most cities have inadequate infrastructure and resources to tackle wastewater treatment in an efficient and sustainable manner [12]. One effort in managing river water quality is, among others, by establishing river capacity. The total maximum daily load (TMDL) is the river's ability to receive pollutant load input without polluting the water. Computerized numerical modeling is one phase to calculate TMDL [13]. Mathematical modeling is a solution to the limitations of the experimental and analytical approaches in determining water quality along with the river flow [14].

Model is substantial to evaluate the effectiveness of actions before implementation in a holistic approach, yet this approach allows additional challenges to the way system is modeled because the scale and scope enlargement significantly increase the complexity [15]. Therefore, the simplified model is more favorable when dealing with an integrated system [16-19]. There are currently a few models for river water quality simulation used by researchers, such as HSPF [20,21], WASP7 [22], QUAL2E [23], QUAL2Kw [24 – 28], RWQM [29, 30], InfoWorks RS [31], and SWAT [32]. The six most wildly used models are TOMCAT (Temporal Overall Model for Catchment), SIMCAT (Simulation Catchment), QUAL2E, QUAL2Kw, WASP7 (Water Quality Analysis Simulation Program), and QUASAR (Quality Simulation along Rivers) [25].

This research applied QUAL2Kw to calculate the TMDL of The Cirarab River. QUAL2Kw is a more advanced model of QUAL2E [13, 15] with few advantages in terms of the ability to simulate river in one dimension with the non-uniform and stable flow on a time scale and to simulate the load input and output of pollutant source [33]. Further, the QUAL2Kw model is the most popular and easiest to use [14]. Calculation of total maximum daily load is a requirement to control pollutants originating from pollutant sources entering the river by considering the intrinsic river condition and the specified water quality index. Calculation of total maximum daily load is useful as a ground for an effective river management strategy.

2 Materials and methods

2.1 Research location

This research was conducted in The Cirarab River that passes through The Tangerang District, the Curug Sub-district segment (Figure 1). The upstream of The Cirarab River is situated in Bogor District, and the downstream is in The Tangerang District. The Cirarab River in The Curug Sub-district segment was chosen as the research location because it is the river segment before entering The Tangerang City, where the water is also used as drinking water for people in The Tangerang City. The research location was then divided into three subsegments, namely: Kadu Jaya, Cukang Galih, and Curug Kulon.
The pollutants of The Cirarab River are originated from human residential and industrial activities [10]. River pollution occurs due to poor wastewater management, and 80% of wastewater flows back to the ecosystem without prior treatment [11]. At present, most cities have inadequate infrastructure and resources to tackle wastewater treatment in an efficient and sustainable manner [12]. One effort in managing river water quality is, among others, by establishing river capacity. The total maximum daily load (TDML) is the river's ability to receive pollutant load input without polluting the water. Computerized numerical modeling is one phase to calculate TDML [13]. Mathematical modeling is a solution to the limitations of the experimental and analytical approaches in determining water quality along with the river flow [14].

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2.2 Study method

2.2.1 Data collection

The data needed in building water quality modeling were: river quality and water discharge data, and wastewater quality and discharged both in its input and output along with the river flow. River water quality is the primary data. Secondary data were collected from The Tangerang District Environment and Hygiene Office consisting of river length, river cross-section, river depth, air temperature, wind velocity, and air humidity data. Data on industrial wastewater quality, wastewater discharge, and operational time were collected from the semester report of companies gathered by The Tangerang District Environment and Hygiene Office. Pollutant source data was divided into two, namely point source and non-point source. Pollutant sources from point source data were acquired from The Tangerang District Environment and Hygiene Office of which is the number of factories...
that dispose of wastewater into The Cirarab River, the Curug Sub-district segment. Data on pollutant sources from the non-point source were obtained from the Statistics Indonesia/BPS data, which is the population data of inhabitants residing on the western and eastern part of The Cirarab River, The Curug Sub-district segment.

Water sampling of The Cirarab River gathered from sampling stations were tested in BOD and COD measurements. Samples were collected in three monitoring points, namely in Curug Kulon Village (S: 06° 15' 38.718" E: 106° 32' 18.78"), Cukang Galih Village (S: 06° 15' 05.6484" E: 106° 32' 26.0124"), Kadu Jaya Village (S: 06° 13' 24.4088" E: 106° 33' 17.9136"). The three points were considered meeting the requirements to determine the water quality condition of The Cirarab River - the Curug District segment for they represented the water quality, in the beginning, middle, and end sections of the Curug Sub-district. Sampling collection was conducted in five collection times between 07:00 AM – 10:00 PM with an interval of four hours for each collection. The procedure for water sampling was executed based on the Indonesian National Standard/SNI 6989.57:2008. BOD measurement was conducted based on the Indonesian National Standard/SNI 6989.72:2009, and COD measurement was carried out based on the Indonesian National Standard/SNI 6869:2:2009.

2.2.2 Data analysis

BOD and COD data obtained from testing results on river samples in The Tangerang District Environment and Hygiene Office lab were later processed and analyzed by the QUAL2Kw model to generate TMDL values. QUAL2Kw is a modeling program on river water quality developed by US EPA [26]. The model is able to simulate or predict the changes in river water quality if the wastewater flow is added or reduced. This simulation is handy to determine the river's total maximum daily load with the specified water quality index.

QUAL2Kw model is run after data input is completed [33]. Steps carried out in model building are as follows:

1. Input the BOD and COD values obtained
2. Determine the coefficient of the model by repeatedly running the model until the result that is appropriate or closely related to the existing condition is obtained, afterward, perform auto-calibration.
3. Model validation. Re-run the adjusted model coefficient to get validation data. Model validation is obligatory after the resulting output is obtained. Validation is a determination process to decide whether the model is an accurate representation of the real system. Model validation compares simulation output with the real system of which by comparing the BOD and COD values obtained from lab tests with the existing BOD and COD values (monitoring at 10:00 PM), using the coefficient of determination (R²) and root mean square error (RMSE). The R² value was close to number 1, thus indicated that the model used was more precise, and the RMSE value was below 20%, thus indicated that the model was valid [34, 35].

\[
R^2 = 1 - \frac{\sum (K_{pi} - Km)^2}{\sum (K_{pi} - Km)I^2} \tag{1}
\]

\[
RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \left( \frac{K_{mi} - K_{pi}}{K_{pi}} \right)^2} \tag{2}
\]
Of which: \( R^2 = \text{coefficient of determination} \)  
\( \text{RMSE} = \text{root mean square error value} \)  
\( K_{pi} = \text{BOD and COD values from lab test-i} \)  
\( K_m = \text{average value} \)

QUAL2Kw model automatically creates output and input files. Output results are presented in two ways, in graphs and tabs. Tabular output can be seen in worksheet WQ Output, while the graphical output can be seen in the Spatial worksheet Chart [33].

3 Results and discussion

Model building to obtain TMDL was conducted using two scenarios, namely:

1. Scenario 1 was carried out to acquire a model that represents the existing water quality. In this scenario, data of existing water quality, wastewater quality both inflow and outflow-entering, and leaving the river from point sources and non-point sources were inputted. Further, trial and error were carried out on the reaction speed value until the BOD and COD parameter values were close to the existing values. Validation of the model began by performing auto-calibration, then the coefficient determination (\( R^2 \)) and Root Mean Square Error (RMSE) were calculated.

2. Scenario 2 was carried out to gain TMDL values. The validated water quality model was then used to obtain TDML values, by conducting trial and error on inflow wastewater discharge and quality to achieve simulation result that was close to the permitted water index quality.

The QUAL2Kw model allows the researcher to calculate inflow pollutant loads that enter the river based on the quality of the model. The model will generate parameter concentration of river water quality in every subsegment. Based on scenario 1, the total pollutant loads entering The Cirarab River the Curug distric segment were 12,032.26 kgBOD/day and 48,946.69 kgCOD/day (Table 1)

| Subsegment   | Discharge (m\(^3\)/s) | Concentration (mg/L) | Pollutant Load (kg/day) |
|--------------|------------------------|-----------------------|-------------------------|
|              |                        | BOD\(_m\)  | COD\(_m\)  | BOD  | COD  |
| Curug Kulon  | 5.04                   | 18.96      | 65.82      | 8,258.36 | 28,661.85 |
| Cukang Galih | 1.4                    | 15.60      | 61.52      | 1,886.70  | 7,441.29  |
| Kadu Jaya    | 2.18                   | 10.02      | 68.19      | 1,887.21  | 12,843.54 |
| Total        |                        | 44.58      | 195.53     | 12,032.26 | 48,946.69 |

The largest amount of pollutant loads in Curug Kulon subsegment was 8,258.36 kgBOD/day and 28,661.85 kg/day. Followed by Kadu Jaya subsegment of 1,887.21 kgBOD/day and 12,843.54 kgCOD/day. The lowest amounts of pollutant loads were in Cukang Galih subsegment of 1,886.70 kgBOD/day and 7,441.30 kgCOD/day. Pollutant loads are originated from residential and industrial activities. Based on previous research [10], the main contributor of pollutant loads in Curug Kulon and Cukang Galih subsegment is residential, domestic wastewater, while industrial wastewater is the main contributor in Kadu Jaya subsegment.

This pollutant load calculation was applied after the modeling result was affirmed to be correct and valid through coefficient determination (\( R^2 \)) and RMSE calculation. Running the BOD and COD parameters in QUAL2Kw provided values of \( R^2 \) and RMSE. The values of \( R^2 \) and RMSE from BOD parameters were 0.84 and 1.72%, respectively. The values of \( R^2 \) and RMSE from COD parameters were 0.85 and 1.72%, respectively.
and RSME from COD parameters were 0.75 and 8.06%, respectively. These values met the requirements of a valid and correct model because $R^2$ values were close to the number 1, and RSME values were below 20%. A valid model means that the concentration values of BOD and COD generated by the model do not differ greatly from the measured BOD and COD concentration values, and they are still in the acceptable range. These values were in accordance with previous research in different study areas of which $R^2$ and RMSE values were close to the number 1 and 10%; the results were still acceptable, and the models were stated to be valid and precise [35, 36]. The results from running scenario one are presented in Figure 1.

![Fig. 2. Results of Scenario 1 Running for (a) BOD parameter, (b) COD parameter](image-url)
Essentially, the closer to the downstream, the lower the BOD value. This happens due to the self-purification process in the river. This finding is in line with previous research [37]. Similarly, the COD value got smaller, but the COD value increased when entering Kadu Jaya subsegment due to the improperly treated industrial and domestic wastewater.

The main sources of pollutant load in The Cirarab River are domestic and industrial wastewater originated from residential and factories that dispose of their wastewater into the river [10, 38]. Pollutants from residential and industrial activities are generated by 154,399 inhabitants and 209 factories in the river basin, with details shown in Tables 2 and 3.

| No | Subsegment     | Western Area | Eastern Area |
|----|----------------|--------------|--------------|
|    |                | Village      | Population   | Village      | Population   |
| 1  | Kadu Jaya      | Kadu Jaya    | 23,028       | Bitung Jaya  | 15,060       |
|    |                |              |              | Bunder       | 16,373       |
| 2  | Cukang Galih   | Cukang Galih | 14,485       | Dukuh        | 17,589       |
| 3  | Curug Kulon    | Curug Kulon  | 21,682       | Ciakar       | 46,182       |
|    |                |              | 59,195       |              | 95,204       |

Table 2 provides information that the largest non-point source is in Curug Kulon subsegment of 67,864 people, followed by Kadu Jaya subsegment of 54,461 people, and Cukang Galih subsegment of 32,074 people. More people means domestic wastewater dumped into the river. This causes Curug Kulon subsegment has the highest BOD value compared to the other two.

Pollutant sources in the point source originated from industrial wastewater are classified according to the International Standard Industrial Classification of All Economic Activities (ISIC) in accordance with production activities [42]. Table 3 lays out information on the numbers of factories located in the three subsegments. Kadu Jaya subsegment has the highest number of factories of 137, followed by Cukang Galih subsegment of 50 factories, and Curug Kulon of 22 factories. The high number of factories causes the COD value in Kadu Jaya subsegment to be higher than the other two.

BOD and COD values that far exceed the permissible water quality index imply an ineffective water pollution control. In the Indonesian regulation context, some law and regulations have yet to be implemented in an optimal matter; they are Law/UU No. 23/2014 on Local Government, Government Regulation/PP No 82/2001 on Water Quality Management and Water Pollution Control, and Ministry of Environmental Regulation No 1/2010 on Water Pollution Control Procedures. As proof of this, there has neither a comprehensive study on identification and inventory of pollutant source nor a stipulation of pollutant load capacity in The Cirarab River. This demonstrates difficult condition because the study is of importance to determine the course of The Cirarab River management policy, such as the stipulation of river class and river quality standard which further influence the granting of Wastewater Disposal Permit/Pemberian Izin Pembuangan Air Limbah (IPLC). In addition, there are still some factories that violate the industrial permit requirements in managing their generated wastewater, of which the implementation of Environmental Management Efforts/Upaya Pengelolaan Lingkungan (UKL) and Environmental Monitoring Efforts/Upaya Pemantauan Lingkungan (UPL) are among key subjects in industrial Environmental Impact Analysis/AMDAL documents.
### Table 3. Pollutant Source in The Cirarab River Point Source [38]

| No | Types of Industries/Factories                                      | Curug Kulon | Cukang Galih | Kadu Jaya | Total |
|----|---------------------------------------------------------------------|-------------|--------------|-----------|-------|
| 1  | Chemical industry and chemical products                            | 6           | 9            | 18        | 33    |
| 2  | Manufacture of wood, paper, printing and reproduction of recorded media | 5           | 12           | 20        | 37    |
| 3  | Manufacture of rubber and plastics products, and other non-metallic mineral products | 5           | 12           | 31        | 48    |
| 4  | Manufacture of food products; beverages and tobacco products       | 2           | 1            | 8         | 11    |
| 5  | Manufacture of basic metals and fabricated metal products         | 1           | 5            | 24        | 30    |
| 6  | Other Manufacturing; repair and installation of machinery and equipment | 1           | 0            | 0         | 1     |
| 7  | Manufacture of Textiles, Wearing Apparel, Leather and Related Products | 1           | 8            | 16        | 25    |
| 8  | Manufacture Of Computer, Electronic And Optical Products           | 0           | 1            | 2         | 3     |
| 9  | Manufacture of Coke, Refined Petroleum Products                    | 1           | 1            | 0         | 2     |
| 10 | Manufacture of other transportation equipment                      | 0           | 0            | 8         | 8     |
| 11 | Manufacture of Machinery and Equipment n.e.c                       | 0           | 1            | 4         | 5     |
| 12 | Manufacture of plastics products and electric cables               | 0           | 0            | 3         | 3     |
| 13 | Manufacture of basic pharmaceutical products and pharmaceutical preparations | 0           | 0            | 3         | 3     |
|    | **Total**                                                          | 22          | 57           | 137       | 209   |

Further, the number of environmental supervisors is one of the crucial matters for effective waste management as regulated in the Minister of State Apparatus Empowerment and Bureaucratic Reform Regulation No 39/2011 on Functional Position of Environmental Supervisor and Credit Number that states that maximum burden of 1 supervisor is to monitor 50 factories. In 2018, there were only 12 environmental supervisors in The Tangerang District to supervise 2800 factories, which means one person for 233-234 factories. This disproportionate number causes ineffective supervision.

TMDL values were obtained by running scenario two simulations, as illustrated in Table 2. Total TMDL values were 2,234.30 kgBOD/day and 18,619.96 kgCOD/day. This indicates that in each subsegment, pollutant load entering the river has exceeded the TMDL values. The highest TMDL values found in Curug Kulon subsegment of 1,306.37 kgBOD/day and 10,886.40 kgCOD/day. Followed by Kadu Jaya subsegment of 565.06 kgBOD/day and 4,708.80 kg/day. Cukang Galih subsegment had the lowest TMDL values of 362.88 kgBOD/day and 3,024.00 kg/day. In comparison, pollutant load values entering
the river were higher than the TMDL values, which indicate that the river can no longer contain the entering pollutant load. The highest values of pollutant loads that must be reduced are in Curug Kulon subsegment, followed by Cukang Galih and Kadu Jaya. Simply put, despite Curug Kulon had the highest TMDL values, the river will still be polluted if pollutant loads entering the river far exceed the river's capacity.

Table 4. TMDL Values of The Cirarab River, the Curug Sub-district

| Subsegment | Existing Pollutant Load (kg/day) | Total Maximum Daily Load (kg/day) | Pollutant Load Reduction (kg/day) | Percentage of Pollutant Load Reduction per/sub-river basin |
|------------|---------------------------------|----------------------------------|----------------------------------|----------------------------------------------------------|
|            | BOD                             | COD                              | BOD                              | COD                                                      |                                                          |
| Curug Kulon| 8258.36                         | 28661.85                        | 1306.37                          | 10886.40                                                 | 6951.99                                                 | 17775.45                                                 | 71%                                                   | 59%                                                      |
| Cukang Galih| 1886.70                         | 7441.29                         | 362.88                           | 3024.00                                                  | 1523.82                                                 | 4417.29                                                   | 16%                                                   | 15%                                                     |
| Kadu Jaya  | 1887.21                         | 12843.54                        | 565.06                           | 4708.80                                                  | 1322.15                                                 | 8134.74                                                   | 13%                                                   | 27%                                                     |
| Total      | 12032.26                        | 48946.69                        | 2234.30                          | 18619.20                                                 | 9797.96                                                 | 30327.49                                                   | 100%                                                  | 100%                                                    |

This research estimates the amount of pollutant load reductions for each subsegment. In the Kadu Jaya subsegment, BOD and COD pollutant loads must be reduced by 13% and 27%. In the Cukang Galih subsegment, BOD and COD pollutant loads must be reduced by 16% and 15%. In the Curug Kulon subsegment, BOD and COD pollutant loads must be reduced by 71% and 59%. Pollutant load reductions can be applied by controlling pollution from industrial and domestic wastewater disposal in The Cirarab River. These pollutant load reductions are not only implemented in the study area with a rationale that inflow pollutants from upstream are dominant to the water quality of The Cirarab River-Curug District segment. Hence, a sustainable pollution control strategy from upstream to downstream is mandatory.

4. Conclusion

TMDL values obtained from water quality modeling QUAL2Kw were 2234.30 kgBOD/day and 18619.20 kgCOD/day. The highest amount of existing pollutant loads were given in Curug Kulon subsegment of 8258.36 kgBOD/day and 28661.85 kgCOD/day, followed by Kadu Jaya subsegment of 1887.21 kgBOD/day and 12843.54 kgCOD/day. Cukang Galih subsegment gave the least amount of pollutant load compared to the other subsegments. The existing pollutant loads that entered each subsegment had exceeded TMDL values, that they must be reduced. The highest pollutant load reductions were in Curug Kulon subsegment with a reduction of 6951.99 kgBOD/day (71%) and 17775.45 kgCOD/day (59%).

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References

1. UNWater, Policy Brief: Water Quality, Retrieved from www.un.org. (2011)
2. B.I. Amalia, A. Sugiri, Jurnal Teknik PWK 3(2), 295 (2014) (in Bahasa)
3. U. Suriawiria, Air dalam Kehidupan dan Lingkungan yang Sehat (PT. Alumni, Bandung, 2005) (in Bahasa)
4. L.T. Hadgu, J.K. Mwangi, P.M. Kibetu, B.B. Mehari, Computational Water, Energy, and Environmental Engineering 3, 162 (2014)
5. WHO/UNICEF, 2015 ANNUAL REPORT WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, Retrieved from https://washdata.org/sites/default/files/documents/reports/2017-07/JMP-2015-Annual-Report.pdf (2015)
6. Suwari, Model Pengendalian Pencemaran Air Pada Wilayah Kali Surabaya (Disertasi, Institut Pertanian Bogor, 2010) (in Bahasa)
7. KLH, Atlas Status Mutu Air Indonesia Tahun 2015 (Direktorat Jenderal Pengendalian Pencemaran Kerusakan Lingkungan Kementerian Lingkungan Hidup, Jakarta, 2015) (in Bahasa)
8. KLHK, IKLH 2017 Indeks Kualitas Lingkungan Hidup Indonesia 2017 (KLHK, Jakarta, 2018) (in Bahasa)
9. A.T. Agrarini, Kualitas Perairan Pesisir Cituis Kabupaten Tangerang, Banten (Skripsi, Institut Pertanian Bogor, 2014) (in Bahasa)
10. K. Indriyani, H.S. Hasibuan, M. Gozan, Impacts of land use and land-use change in river basin to water quality of Cirarab River, Indonesia, in Proceedings of the International Conference on Environmental Science and Sustainable Development, ICESSD, 22-23 October 2019, Jakarta, Indonesia (2019)
11. WWAP (United Nations World Water Assessment Programme), The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource. (Paris, UNESCO, 2017)
12. E. Corcoran, C. Nellemann, E. Baker, R. Bos, D. Osborn, H. Savelli, Sick Water? The central role of wastewater management in sustainable development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. Retrieved from www.grida.no (2010)
13. KLH. Peraturan Menteri Lingkungan Hidup No 1 Tahun 2010 tentang Tata Laksana Pengendalian Pencemaran Air (2010) (in Bahasa)
14. P.R. Kannel, S.R. Kanel, S. Lee, Y. Lee, T.Y. Gan, Environ Model Assess 16(2), 183 (2011)
15. I. Keupers, P. Willems, Water Research 113, 62 (2017)
16. J. Meirlaen, B. Huygebaert, F. Sfori, L. Benedetti, P. Vanrolleghem, Fast, parallel simulation of the integrated urban wastewater system using mechanistic surrogate models, in Proceedings 5th International IWA Symposium Systems Analysis and Computing in Water Quality Management WATERMATEX2000, 6.9 (2000)
17. P. Willems, Probabilistic Immission Modeling of Receiving Surface Waters (Tesis, Katholieke Universiteit Leuven, Leuven, 2000)
18. P. Willems, J. Environ. Eng. 136(3), 316 (2010)
19. V. Wolfs, M. Villazon Gomez, P. Willems, Water Sci. Technol., 68(1), 167 (2013)
20. A. Fonseca, C. Botelho, R.A. Boaventura, V.J. Vilar, Sci. Total Environ. 485–486, 474 (2014)
21. E.J. Lee, T.G. Kim, K. Choi, Journal of Civil Engineering, 1 (2018)
22. H. Yao, X. Qian, H. Yin, H. Gao, Y. Wang, Risk Anal. 35(2), 265 (2015)
23. G.T. Parker, R.L. Droste, C.D. Rennie, Ecohydrology. Published online in Wiley Online Library (wileyonlinelibrary.com). doi: 10.1002/eco.1308 (2012)
24. R.D. Camargo, M.L. Calijuri, A.D. Santiago, E.D. Couto, MDFM Silva, Acta Limnologica Brasiliensia, 22(4), 486 (2010)
25. R. Zhang, X. Qian, X. Yuan, R. Ye, B Xia, Y. Wang, International Journal Environment Research Public Health, 9(12), 4504 (2012)
26. G.J. Pelletier, S.C. Chapra, H. Tao, Environmental Modeling & Software, 21, 419 (2005)
27. X. Fang, Z. Jiangyin, C. Yingxu, X. Xiangyang, Water Environment Research, 80(11), 2125 (2008)
28. D. Sharma, A. Kansal, Rev Environ Sci Biotechnol, 12, 285 (2013)
29. P. Reichert, P. Vanrolleghem, Water Science and Technology, 43(7), 329 (2001)
30. N. Broekhuizen, J.B.K. Park, G.B. McBride, G.B., R.J. Craggs, Water Research, 46(9), 2911 (2012)
31. T.T. Nguyen, P. Willems, Water Resources Management, 30(9), 3043 (2016)
32. H. Wang, F. Sun, J. Xia, W. Liu, Hydrology Earth System Science, 21, 1929 (2017)
33. G. Pelletier, S. Chapra, QUAL2Kw User Manual (Version 5.1): A Modeling Framework for Simulating River and Stream Water Quality (Department of Ecology Publications Distributions Office, Washington, 2008)
34. M.A. Hossain, I.M. Sujaul, M.A. Nasly, Research Journal of Recent Sciences, 3(6), 6 (2014)
35. A. Aliffia, N. Karnaningroem, IOP Conf. Series: Earth and Environmental Science, 259, 1 (2019)
36. H. Taherisoudejani, E. Racchetti, F. Celico, M. Bartoli, J. Limnol. 77(3), 452 (2018)
37. Baherem, Suprihatin, N.S. Indrasti, Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan, 4(1), 60 (2014) (in Bahasa)
38. DLHK Kabupaten Tangerang, Laporan Pendahuluan Kegiatan Penentuan Daya Dukung Daya Tampung Sungai Cisadane, Cirarab, dan Cimanceuri (2018) (in Bahasa)
39. BPS Kabupaten Tangerang, Kecamatan Panongan dalam angka (2017) (in Bahasa)
40. BPS Kabupaten Tangerang, Kecamatan Curug dalam angka (2018a) (in Bahasa)
41. BPS Kabupaten Tangerang, Kecamatan Cikupa dalam angka (2018b) (in Bahasa)
42. UN, International Standard Industrial Classification of All Economic Activities. Rev. 4. (United Nations Publication, New York, 2008)