The improvement of Cipunagara River quality (BOD parameter) based on pollution load analysis of domestic, agriculture, farming and industrial activities

I Juwana* and D P Nugroho

Environmental Engineering Department, Institut Teknologi Nasional, Bandung

E-mail: juwana@itenas.ac.id

Abstract. In many regions in Indonesia, rivers play a very important role to support the life activities of the communities. One of the rivers in West Java – Indonesia is Cipunagara River, which supports the biggest catchment in Subang Regency, West Java. Past research has shown that growing activities in the catchment area of the river has caused the quality deterioration of Cipunagara River. The importance of the river is multiplied because the river will also be used as the source of water for Sadawarna and Cilame Reservoirs. This paper aims at analyzing the pollution load on Cipunagara River, for the water quality parameter of BOD, from various activities. The analysis was undertaken by selecting the most important segment of the river using several criteria. Once the segment was selected, both existing and projected pollution loads were calculated based on the guidance from the Ministry of Environment and Forestry of Indonesia. Results show that total pollution loads of BOD from livestock, domestic, agriculture and industrial sectors exceed the maximum pollution level in Cipunagara River. The calculated pollution load for BOD parameter is: 6,391.21 kg/d with the maximum pollution load (based on PP 82/2001 Kelas 1) is 2,355.26 kg/d. These results were then used as the inputs in the BOD Model simulations to analyze possible strategies in improving the quality of Cipunagara River.

1. Introduction

In many regions in Indonesia, rivers play a very important role to support the life activities of the communities [1-3]. One of the rivers in West Java – Indonesia is Cipunagara River, which supports the biggest catchment in Subang Regency, West Java. This river originates from Cipunagara spring at the south of Subang Regency and ends at the Java Sea [4, 5]. Currently, the land uses of Cipunagara catchment include forestry, agriculture, domestic, livestock, and industry.

As the population in Cipunagara catchment grows, it has impacted the environmental quality in Cipunagara catchment. According to the statement from the Governor of West Java, Cipunagara Catchment is one of the three catchments vulnerable to natural disasters, particularly erosions and floods. Other problems pointed out by the Major of Subang Regency are the soil sedimentation and pollutions from industries along the river [6-8].

On the other hand, the need for reliable clean water from Cipunagara River increases due to the development plan of Sadawarna and Cilame dams to be used for clean water sources [5, 8]. Thus, further prevention of the pollution, as well as integrated water management in the river, is utmost
important. In order to properly implement the integrated water management initiatives, information on the river carrying capacity, daily and maximum pollutant load is crucial [9-11]. This paper discusses the importance of such information, and how the information can be used to support the management of Cipunagara River, in particular, the prevention of further river pollution.

2. Methodology
The methodology of this study includes data collection, river segment selection, river status assessment, pollution load calculation and BOD simulation.

2.1. Data selection
Both primary and secondary data were collected for this study. The primary data includes the topography of the catchment, river flow and social conditions surrounding Cipunagara River. As for the secondary data, it includes water quality, map of Cipunagara Catchment, data related to point-source and non-point source pollutants and population in the catchment.

2.2. Segment selection
Cipunagara River covers a very large area (Figure 1), thus to improve the accuracy of the study, the focus was limited to one out of four segments in Cipunagara River. The selection was based on activities in the segments from different sectors, development plan in the area and respective water quality.

Figure 1. Map of segments in Cipunagara catchment
2.3. Water quality assessment
This assessment is required to determine water quality status of river segment. The assessment was undertaken using the Pollution Index method as stated in the Environmental Ministry Decree 115/2003 [12].

2.4. Calculation of Maximum Pollutant Load (MPL)
The calculation of maximum pollutant load was done using the following equation:

\[ MPL = River \ Flow \times Maximum \ Allowed \ Concentration \]

The maximum allowed concentration was obtained from the Government Regulation on Water Quality Management No. 82/2001 [13-17].

2.5. Calculation of Existing Pollutant Load (PL)
This assessment is required to determine water quality status of river segment. The assessment was undertaken using the Pollution Index method as stated in the Environmental Ministry Decree 115/2003.

2.5.1. Livestock.
The existing pollutant load from the livestock sector, shown in Figure 2, was calculated using the following equation [18]:

\[ PL = \sum_{cattles} \times \text{emission factor} \times 20\%

Figure 2. Map of livestock sector of segment 3 in Cipunagara catchment
2.5.2. Domestic
Similar to the livestock sector, the domestic pollutant load was also obtained using the emission factor. However the calculation follows the equation below [18]:

\[ PL = \sum \text{population} \times \text{emission factor} \times \text{equivalent ratio} \times \alpha \text{ coefficient} \]

Where the equivalent ratio represents the city characteristics. It is assumed that if an area follows the city characteristics, then the area will discharge more pollutants to the river. As for the alpha coefficient, it represents the proximity of the pollutant sources to the river. The closer the sources to the river, the higher the alpha coefficients are. The locations of the domestic sector in Segment 3 of Cipunagara Catchment are illustrated in Figure 3.

![Figure 3. Map of housings of segment 3 in Cipunagara catchment](image)

2.5.3. Agriculture
Similar to previous sectors, the agriculture pollutant load was also obtained using the emission factor. However the calculation follows the equation below [18-20]:

\[ PL = \sum \text{area} \times \text{emission factor} \times 10\% \]

The 10% value represents the estimation of runoff entering the river from the agricultural sector. The locations of agricultures in Segment 3 of Cipunagara Catchment are illustrated in Figure 4.
2.5.4. Industry

The industrial sector, unlike other sectors, has a different calculation method due to the availability of data from the industrial sector. There is a certain hierarchy of calculating the pollutant load, as follow [19-21]:

- If monitoring data for concentration and flow of the pollutant is available, the pollutant load is calculated using the concentration and flow data.
- If concentration data is available but the flow is not, then maximum flow data from the government is used
- If concentration and flow are not available, the emission factor approach is used
- If concentration, flow, and emission factor data is not available, then the pollutant load is calculated from similar industry type

The locations of the industries in Cipunagara Catchment are illustrated in Figure 5.

2.6. BOD Model Simulation

Model simulation of BOD was undertaken considering pollutant sources along the river in Segment 3 of Cipunagara Catchment, as illustrated in Figure 6 below. The model simulation was only done to the parameter of BOD due to availability of data, using the Streeter-Phelps approach [22]. This simulation was used to analyze BOD concentration level along the river, as well as the basis to propose strategies for managing pollution in Cipunagara River. Data used for the simulation is shown in Table 1 below.
Figure 5. Map of industries of segment 3 in Cipunagara catchment

Table 1. Data used for simulation.

| No | Data/Information          | Approach Taken                                | Source                                      |
|----|----------------------------|-----------------------------------------------|---------------------------------------------|
| 1  | Flow of pollutant sources | *Domestic* 80% of the domestic needs on clean water | Ministry of Public Works                    |
| 2  | River flow                | *Agriculture* Estimation from agriculture area, 1 Ha = 1 lt/d | Iskandar, 2017                             |
| 3  | Distance between pollutent sources | *Livestock* 80% of total clean water needs for livestock (1.000 lt/d) | Padjadjaran University, 2017                |
| 4  | River temperature         | Direct sampling                               |                                             |
| 5  | River velocity            | Direct sampling                               |                                             |
| 6  | Deoxigenation constant    | 0.35 (/day)                                   | Metcalf & Eddy, 1972                       |
| 7  | Temperature coefficient   | 1.047                                         | Metcalf & Eddy, 1972                       |
Figure 6. Schematic maps of pollutant source of segment 3 in Cipunagara catchment

3. Results and Discussion
The methodology of this study includes data collection, river segment selection, river status assessment, pollution load calculation and BOD simulation.

3.1. Segment Selection
As mentioned earlier, the selection of the segments is required to provide better accuracy of the study. The criteria used for selecting the segments were the total area of the segment, number of population, number of industries, area of agriculture and existing water quality [22].

For each criterion, a 1-5 scale was given based on the ranking for each segment on the criteria, as there are five segments in Cipunagara River. Thus, at the end of the selection, each segment received five values representing all the criteria. The results from the assessment are shown in Table 2 and Table 3.

Based on the comparison in Table 2, the selected segment to be further studied is Segment 3 of Cipunagara River, which catchment includes 13 regions in Subang, Sumedang and Indramayu Regencies, as illustrated in Figure 1.

This segment dominates other segments to be prioritised in this study. It is also important to be noted that in Cipunagara Catchment, the government plans to build Sadawarna dan Cilame Resevoirs which requires the better river quality. These reservoirs will be used as the source of raw water to supply water needs of some cities and regencies in Cipunagara Catchment.
Table 2. Segments comparison based on the identified criteria

| Segment  | 1      | 2      | 3      | 4      |
|----------|--------|--------|--------|--------|
| Segment (Ha) | 3,835 (3) | 1,125 (2) | 38,406 (5) | 19,397 (5) |
| Population  | 19,887 (3) | 5,683 (2) | 216,316 (5) | 164,737 (4) |
| Number of Industries | 8 (3) | - (1) | 14 (4) | 68 (5) |
| Agriculture area (Ha) | 672 (3) | 229 (2) | 11,230 (5) | 12,877 (4) |
| Water Quality | Lightly Polluted (2) | Highly Polluted (5) | Highly Polluted (5) | Highly Polluted (5) |
| Total Value for Each Segment | 14 | 12 | 24 | 23 |

*Note: The values in the bracket is the assessment values for each criteria and segment*

3.2. Calculation of Maximum Pollutant Load

The maximum pollution load was calculated by multiplying the maximum concentration for respective parameter with its flow. The results of the calculation are shown in Table 3.

Table 3. Maximum pollutant load for segment 3 of Cipunagara River.

| No | Parameter | Unit | Threshold Class I | Maximum Pollutant Load (kg/d) |
|----|-----------|------|------------------|-------------------------------|
|    |           |      |      | Juli | Agustus | Oktober |
| 1  | TSS       | mg/liter | 50   | 207,792 | 58,881.6 | 738,720 |
| 2  | BOD       | mg/liter | 2    | 8,311.68 | 2,355.26 | 29,548.8 |
| 3  | COD       | mg/l | 10   | 41,558.4 | 11,776.32 | 147,744 |
| 4  | Total fosfat as P | mg/l | 0.2 | 831.16 | 235.52 | 2,954.88 |
| 5  | Nitrat (NO₃-N) | mg/l | 10 | 41,558.4 | 11,776.32 | 147,744 |
| 6  | Amonia (NH₃-N) | mg/l | 0.5 | 2,077.92 | 588.81 | 7,387.2 |
| 7  | Nitrit (NO₂-N) | mg/l | 0.06 | 249.35 | 70.65 | 886.46 |
| 8  | Flow      | m³/s | -    | -    | -    | -    |

3.3. Existing Pollutant Load

The example for calculating of existing pollutant load of BOD from the Domestic Sector (Ciater District, Subang Regency) is as follow:

\[
PL = \sum \text{population} \times \text{emission factor} \times \text{equivalent ratio} \times \text{alpha coefficient}
\]

\[
= 1,905 \times 40 \frac{gr}{day} \times 0.001 \times 0.8125 \times 1 = 61.92 \frac{kg}{day}
\]

Using similar approaches, existing pollutant load for other districts and regencies, as well as for other parameters and sectors in Segment 3 was calculated. The results of the calculations are shown in Table 4.
Table 4. Pollution loads from all sectors

| Sector   | BOD (kg/d) | COD (kg/d) | TSS (kg/d) | Total-N (kg/d) | Total-P (kg/d) |
|----------|------------|------------|------------|----------------|----------------|
| Domestic | 1,361.35   | 1,871.86   | 1,293.29   | 66.37          | 7.15           |
| Agriculture | 1,265.59  | -          | 2.03       | 112.47         | 56.23          |
| Livestock | 1,668.76   | 4,053.74   | -          | 8.72           | 1.75           |
| Industry | 2,095.50   | -          | -          | -              | -              |
| Total    | 6,391.12   | 5,925.6    | 1,295.32   | 187.55         | 65.13          |

3.4. Comparison of Calculated Pollutant Load with Respective Maximum Pollutant Load

The calculated pollutant loads from all sectors are then compared with their respective maximum pollutant load, as shown in Figure 7.

In general, the chart shows that for the parameters of BOD, the pollution load in Segment 3 of Cipunagara Catchment in August was above the maximum pollution load. This shows that combination of all the sectors (namely domestic, livestock, industry and agriculture) has given contribution to the pollution of Cipunagara River. Thus, the government and other stakeholders should work together for preventing the pollution in the future.

The figure also shows that in the month of October the pollution to Cipunagara River was below the maximum threshold. This is caused by the fact that during October, there is more rainfall compared to August. Therefore, the maximum threshold is higher as the maximum level was determined by the flow of the river. As the rainfall is higher, the flow of the river also increases.

3.5. BOD Simulation Model

Modeling simulation is carried out by observing the flow of pollutants in every pollution source points for BOD parameters. This modeling use is limited to BOD parameters. After data requirements are
completed, a schematic description of river pollutant sources is necessary. Figure 8. 26 describes the main river, namely Cipunagara, with 62.7 km in length, has several pollutant sources, contributing to the pollution of the river in every certain distance.

The pollutant sources are from 4 sectors: the domestic, agriculture, farming, and industry sectors. However, due to the limited data/information on pollutant debit and concentration from the industry sector, this pollutant source is not analyzed in this modeling. The model predicts the pollution condition in 2021, that without control, the river will have pollutant burden that exceeds the capacity, similar to the existing condition in 2016. Only 5 from 15 BOD mixing points correspond with Class 1 water standard. This prediction will be used in pollution control considerations in surrounding areas in which pollution is still exceeding the capacity.

![Figure 8. BOD model of segment 3 Cipunagara catchment](image-url)

**3.6. Proposed strategies**

In general, the proposed strategies to improve the conditions of Cipunagara River are presented in Table 5. Due to limited space, the strategies presented in this paper are related to domestic pollution, while strategies related to other sectors will be discussed in other papers.

| No | Issues                                      | Strategies | Programs                                                                 |
|----|---------------------------------------------|------------|--------------------------------------------------------------------------|
| 1  | The discharge of domestic waste to the river | Preventing households to discharge wastewater to river without treatment | - Enacting regulations related to river pollution                        |
|    |                                             |            | - Dissemination of river awareness to communities surrounding the river  |
| 2  | There is no wastewater treatment plant (WWTP) in place | Encouraging the cooperation of government and households to build WWTP | Initiating community-based project on WWTP |
3 River banks are used for settlements (Tanjung Siang Cibogo and Gantar Regencies) | Law enforcement to restore the river banks | Design the river banks to support the river quality, as well as for recreation areas

4 The rapid growth of population, thus increasing the discharge to the river | Control the population growth, particularly in the areas where pollution is already high | Relocation of population to less-densed areas

4. Conclusion
Segment 3 of Cipunagara Catchment was chosen to be studied in depth, based on several key criteria. The segment has the most livestock compared to other segment, and also considering the plan to build Sawadarma dan Cilame reservoirs in this segment. Based on the pollution index, this segment was identified as the most polluted segment.

The parameter exceeding its maximum pollution load was BOD, while other parameters (COD, TSS and Total-P) were still below their maximum thresholds. The government and other stakeholders in Cipunagara Catchment should initiate programs to prevent the river from further pollution. Some of the programs might include wastewater treatment plant, relocation of housings on river bank and controlling population growth in the catchment.

References
[1] Herawati H, Suripin S, Suharyanto S and Hetwisari T 2018 Analysis of river flow regime changes related to water availability on the Kapuas river, Indonesia *Irrigation and Drainage* 67 66-71
[2] Seta A R, Solikha B M, Fu'adil M H and Putranto T W C 2017 Water quality and fish diversity in the Brantas River, East Java, Indonesia East Java, INDONESIA *Journal of Biological Researches* 22 44
[3] Adji T N 2017 Upper catchment of Bribin underground river hydrogeochemistry (Gunung Sewu Karst, Gunung Kidul, Java, Indonesia)
[4] Budhi G S and Aminah M 2016 Pattern of Farmers’ Participation: Lessons from Pump Irrigation Project *Analisis Kebijakan Pertanian* 7 351-68
[5] Kikuyama S, Suzuki T, Sasaki J, Achiari H, Soendjoyo S, Higa H and Wiyono A A Study on Coastal Erosion and Deposition Processes in Subang, Indonesia
[6] Munibah K, Iswati A and Tjahjono B 2016 Pemanfaatan Citra Quick Blrd Untuk Verifikasi Peta Berbasis Kepemilikan Lahan (Studi Kasus: Delta Cipunagara, Kabupaten Subang, Jawa Barat) *Jurnal Ilmu Tanah dan Lingkungan* 14 37-43
[7] Purnomo M 2017 Membangun Semangat Kewirausahaan Dalam Pengelolaan Sampah di Desa Jati Kecamatan Cipunagara Kabupaten Subang *Dharmakarya* 5
[8] Sutikno S 2017 Pengelolaan Sumberdaya Air Terpadu (Integrated Water Resources Management, IWRM) *Jurnal MESA* 19-8
[9] Juwana I, Perera B J C and Muttil N 2009 Conceptual framework for the development of West Java water sustainability index. In: *18th World IMACS/MODSIM Congress*, (Cairns, Australia pp 3343-9
[10] Juwana I, Muttil N and Perera B 2016 Uncertainty and sensitivity analysis of West Java water sustainability index—a case study on Citarum catchment in Indonesia *Ecological indicators* 61 170-8
[11] Juwana I, Muttil N and Perera B 2016 Application of west java water sustainability index to three water catchments in west java, Indonesia *Ecological indicators* 70 401-8
[12] Sopeana S, Ibrahim E and Faizal M 2017 Water pollution evaluation as consequent of old wells oil exploration *Indonesian Journal of Fundamental and Applied Chemistry* 2 62-5
[13] Herlambang A 2018 Pencemaran air dan strategi penggulangannya. *Jurnal Air Indonesia* 2

[14] Suhardiman D and Project Muse. 2015 Bureaucracy and development reflections from the Indonesian water sector. (Singapore: Institute of Southeast Asian Studies,) pp 1 online resource (xii, 281 pages)

[15] West Java Environmental Protection Agency 2009 Monitoring Kualitas Air 2008 (Water Quality Monitoring 2008). (Bandung: West Java Environmental Protection Agency)

[16] Juwana I, Perera B J C and Muttil N 2009 Application of Delphi Technique for Development of a Water Sustainability Index for West Java, Indonesia. In: *32nd Hydrology and Water Symposium*, (Newcastle, Australia)

[17] Syarief R 2008 Pengelolaan Sumber Daya Air (Water Resources Management).

[18] Yusuf I A 2017 Emisi Hewan Ternak Acuan Untuk Menghitung Potensi Beban Pencemaran Limbah Hewan *Jurnal Sumber Daya Air* 10 85-96

[19] Macbub B 2018 Model perhitungan daya tampung beban pencemaran air danau dan waduk *Jurnal Sumber Daya Air* 6 129-44

[20] Widyastuti M and Marfa'i M A 2016 Kajian Daya Tampung Sungai Gajahwong terhadap Beban Pencemaran *Majalah Geografi Indonesia* 18 81-97

[21] Indriani V S, Hadi W and Masduqi A 2016 Identifikasi Daya Tampung Beban Pencemaran Air Kali Surabaya Segmen Jembatan Canggu-Tambangan Bambe dengan Pemodelan QUAL2Kw *Jurnal Teknik ITS* 5 A857-A61

[22] Wijaya D and Juwana I 2018 Identification and Calculation of Pollutant Load in Ciwaringin Watershed, Indonesia: Domestic Sector. In: *IOP Conference Series: Materials Science and Engineering*: IOP Publishing) p 012049