Determination of load capacity of BOD pollutant in Cisadane River with Qual2kw model & its effect on DO parameters

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Abstract. The research to determine the carrying capacity of pollutant loads in the middle to downstream Cisadane River segment started from Jl. Teuku Umar, Tangerang and ends at Muara Tanjung Burung, Tangerang Regency with a research time starting from March – June 2021. Increased land-use change due to human and industrial activities so that population growth and limited residential land make watersheds a target for land conversion. The purpose of this study is to identify sources of pollutants that have the potential to contaminate the Cisadane River in the middle to downstream segments, analyze water quality and pollutant load capacity, the Cisadane River in the middle to downstream segments along 34 km. The method used for identification of pollutant sources is carried out by conducting field surveys, water quality analysis is carried out by SNI and compared with quality standards according to Peraturan Pemerintah No. 22 of 2021, as well as analysis of the Pollutant Load Capacity (PLC) BOD and DO using the QUAL2Kw model. The results of identifying potential pollutant sources in the middle to a downstream segment of the Cisadane River are dominated by settlements, agriculture, industry, and other domestic activities, namely restaurants and stalls. The results of water quality analysis for BOD parameters ranged from 2.51 mg/L – 5.1 mg/L, and DO range from 5.4 mg/L – 7.2 mg/L. BOD parameters from all points 1-2 meet the quality standard class 2 (3 mg/L) & points 4-6 do not meet the quality standard. The DO parameter is still in good condition because the more significant the DO value, the waters are in good condition. The high levels of BOD in the Cisadane River are influenced by domestic waste that enters the river, and the land is dominated by built-up spaces as settlements, schools, hotels and malls. Land use around the river is very influential on the load of pollutants that enter the river. The lowest DTBP of the Cisadane River for BOD is 22497.9 kg/day, and the highest is 33201.6 kg/day. The decrease in the concentration of BOD load must be lowered in the Cisadane River by 29% - 42%.

1. Introduction
Cisadane River crosses West Java and Banten provinces. The river's upstream reaches are located in Mount Pangrango, bypassing on the west side of Bogor Regency, towards Tangerang regency and downstream to Tanjung Burung. Cisadane River water quality the lower the decrease with the higher the pollution level. Source pollution from various activities in the Cisadane watershed from households, agriculture and industry [1].

Cisadane River is a body of water that can recover and perform self-cleaning within certain limits. This capability occurs in conditions where the pollution does not exceed the threshold or environmental carrying capacity. The high pollutant load that enters the river body can interfere with the river's ability
to recover itself self-purification and reduce the carrying capacity of the river's pollutant load. The water quality of the Cisadane River is decreasing downstream with higher levels of pollution. Sources of pollution from various activities in the Cisadane watershed are households, agriculture and industry. The results of human activities that are not utilized are discharged into the Cisadane River, and Cisadane River tributaries and the level of pollution is most severe in rivers that pass through big cities [2].

Therefore, in this study, the determination of the BOD Pollutant Load Capacity of the Cisadane River use the Qual2kw Model, and its effect on the DO Parameter was carried out. In designing water quality programs, the application of the Qual2Kw method can be used to see the pattern of pollutant behaviour trends along the river. The water quality modelling aimed to 1) Identify sources of pollutants that can contaminate the Cisadane River in the middle to downstream segments. 2) Analyzing the pollutant load capacity in the middle to downstream Cisadane River segment using the Qual2Kw model. 3) Provide alternative scenarios in reducing pollutants in the Cisadane River in the middle to downstream segments.

2. Methodology

2.1. Study area
This research was conducted from February-June 2021 in the Cisadane River Kota Tangerang starts from the Teuku Umar Bridge to the Tanjung Burung estuary 34 km long. The scope of the study area is along the Cisadane Rivers, and Exsitu testing was carried out at the Trisakti University Environmental Engineering Laboratory. Point sampling is in Table 1.

| Reach | Location                  | Longitude | Latitude | Distance (Km) |
|-------|---------------------------|-----------|----------|---------------|
| 1     | Teuku Umar street         | 106°37'33.9"E | 6°11'44.8"S | 0             |
| 2     | Karol Satsuut Tubun bridge | 106°37'59.1"E | 6°10'06.6"S | 4.60          |
| 3     | Marselal Suraya Dorna street | 106°36'50.5"E | 6°07'40.6"S | 6.4           |
| 4     | Keduang Banat street      | 106°38'07.8"E | 6°06'24.6"S | 3.41          |
| 5     | Kali Baru street          | 106°37'59.6"E | 6°03'42.5"S | 6.47          |
| 6     | Tanjung burung estuary    | 106°38'40.82"E | 6°09'20.66"S | 7.39          |

2.2. Method sampling
The determination of the sampling location was carried out based on previous field surveys in the study area. Namely, the location was quite representative of input from the surrounding area that affected the water quality of the Cisadane River, such as residential activities, land use and industrial activities while still considering the ease of access and cost. River sample taking was determined from river debit, and it was knowns that the debit of Cisadane River was ranged 86.79-128.09 m³/s, and the sample was taken from two points ½-⅓ of river width from half the depth of the river or using an integrated sampler tool to obtain even sample from surface to bottom and then to be mixed [3].
2.3. **Qual2Kw model**

In this study, the analysis of the calculation of the pollutant load capacity using the Qual2Kw method. This analysis determines the Pollutant Load Carrying Capacity (PLCC) referring to the regulation of the Peraturan Menteri Negara Lingkungan Hidup No.110 Tahun 2010 concerning Water Pollution Control Management [4]. The following are the main steps in the calculation/analysis of the water pollution load capacity using the Qual2Kw method, as follows:

1. **Input Data**
   - The modelling input consisted of river segment borders, hydrological data and river morphometry, climatological data, water quality data, and pollutant potentials.

2. **Model Running**
   - Model running was performed after data entry, and the Qual2Kw program was executed through qual2kw.exe.

3. **Calibration and Reliability Test**
   - The result of the Qual2Kw model running was calibrate using trial and error and adding or reducing the pollutant load to produce the closest estimated value to the observed pollutant load [5]. Afterwards, the result of the trial and error was validated using this formula:
     \[
     \% \text{Error} = \frac{\text{BOD Data (mg/L)} - \text{BOD Model (mg/L)}}{\text{BOD Data (mg/L)}} \times 100\% \tag{2.1}
     \]

   A validation value equal to 50% indicates that the model's suitability with field data is very poor. If the validation value is below 20%, it can state that the model is acceptable. If the validation value on the model is wrong, it is necessary to re-calibrate until the model matches or is close to the data in the field.
2.4. Simulation techniques
Scenarios of reducing the pollutant load can be done by simulation based on the target to be achieved, namely by water quality standards according to Peraturan Pemerintah No. 22 Tahun 2021 Kelas II on water quality management and water pollution control. The scenario of reducing the pollutant load is carried out so that the pollutant load does not exceed the capacity of the Cisadane River [6].

As for the determination of the pollutant load reduction scenario that can be done, one of the potential sources of pollution in the middle-downstream segment of the Cisadane River is domestic waste from settlements. With the WWTP communal for each section that exceeds the quality standards that have been set, it can reduce the pollutant load that enters the river body.

3. Results and discussion

3.1. Calibration and validation
The model calibration result for the water quality data at six locations is shown in Figure 2. The model calibration results are conformed to be measured data because model data has been similar to the input data (black box). The calibrated parameters values in the model are presented in Table 2. The relative mean error between the simulated and observed for BOD and DO are 9% and 8% when the result is below 20% error value. It can be accepted.

| Reach | BOD (mg/L) | Model Data | % Deviation |
|-------|------------|------------|-------------|
| 1     | 2.63       | 2.51       | 4.6%        |
| 2     | 2.23       | 2.09       | 6.3%        |
| 3     | 4          | 3.84       | 4%          |
| 4     | 4.75       | 5.05       | 5.9%        |
| 5     | 5.76       | 5.03       | 12.7%       |
| 6     | 3.94       | 3.23       | 18%         |
| **Average** | **3.89** | **3.63** | **9%** |

Table 2. BOD model simulation verification.

| Reach | DO (mg/L) | Model Data | % Deviation |
|-------|-----------|------------|-------------|
| 1     | 5.30      | 5.74       | 7.7%        |
| 2     | 5.76      | 6.19       | 6.9%        |
| 3     | 5.66      | 6.07       | 6.8%        |
| 4     | 5.63      | 6.76       | 16.7%       |
| 5     | 5.97      | 5.97       | 0%          |
| 6     | 5.35      | 5.84       | 8.4%        |
| **Average** | **5.61** | **6.10** | **8%** |

Table 3. DO model simulation verification.

The results of the DO model simulation compared with the field analysis data will produce the percentage deviation, which can be seen in Table 3. The average deviation percentage from the DO model simulation results is 8% so that the model simulation results can be accepted and are considered to be able to describe DO parameters in the middle to a downstream segment of the Cisadane River.

3.2. Simulation result
The model that has been run will produce a simulation graph of the modelled parameters of the Cisadane River in the middle to downstream segments. In the model simulation results graph, the black box is the data from the field analysis, while the black-red straight line is the result of the model simulation.
Figure 2. (a) The Simulation results of the Cisadane River BOD, (b) DO model for the middle-downstream segment.

From Figure 2a, the BOD content in the Cisadane River in the middle to downstream segment increases at km 20. It is indicated by the trend line (model), which seems to have followed the trend of the black box point (data). The greater the BOD content in the river, the smaller the DO content because BOD and DO are inversely proportional to waters. Even though there was a difference between the measurements and the simulation model, the analyzed BOD concentrations remained in the same 2-5.1 mg/L range. When compared with the quality standard with model simulation results and existing field data, the water quality of the Cisadane River for the BOD parameter exceeds the quality standard for points 3-6.

From the model simulation results and measurements, it can be seen that the BOD quality in the middle to a downstream segment of the Cisadane River has exceeded the river water quality standard of class II according to PP No. 22 of 2021, so that a pollutant load reduction scenario is needed for these parameters. Before determining the pollutant load reduction scenario, the calculation of the pollutant load from the simulation model results is carried out. The calculation of the pollutant load from the simulation model can be seen in Table 4 below:

Table 4. Overload of BOD pollutants in the Cisadane River middle- downstream segment.

| Reach | Location        | Upstream (km) | Downstream (km) | Debit m³/s | Model BOD Load kg/day | BOD Capacity kg/day | Difference kg/day | % BOD to be lowered |
|-------|----------------|---------------|-----------------|------------|-----------------------|---------------------|-------------------|------------------|
| 0     | JL.BSD Boulevard | 34            | 34              | 86.80      | 21297.99              | 22497.88            | 1199.89           | 0%               |
| 1     | JL. Teuku        | 34            | 28              | 96.54      | 21936.64              | 25022.79            | 3086.14           | 0%               |
|       | Jembatan Karel   | 34            | 28              | 96.54      | 20124.23              | 27072.96            | 6948.73           | 0%               |
| 2     | JL. Satsuit      | 28            | 23,6            | 104.45     | 38944.49              | 29208.37            | -9736.12          | 25%              |
| 3     | JL. Marsekal Surya | 23,6        | 22,6            | 112.69     | 48190.15              | 30435,88            | -17754.26         | 37%              |
| 4     | JL. Kedaung Barat | 22,6         | 16,45           | 117.42     | 60608.67              | 31567,02            | -29041.66         | 48%              |
| 5     | JL. Raya Kali Baru | 16.45      | 7,25            | 121.79     |                       |                     |                   |                  |
From Table 4, it can be seen that the difference between the capacity and the pollutant load has a negative value. This negative capacity value means that the Cisadane River in the middle to the downstream segment has no pollution load capacity for the BOD point because the BOD pollution load that enters the river exceeds the allowable pollution load by class II water quality standards. Therefore, the BOD pollutant load along the middle to a downstream segment of the Cisadane River must be reduced, especially on sections 4, 5, 6, which are the highest pollutant loads. It is caused by dense residential activities that dump organic waste into the Cisadane River.

### 3.3. Pollutant load reduction scenario

Scenarios of reducing the pollutant load in the middle to downstream Cisadane River segments need to be carried out so that the river does not exceed the maximum limit of incoming pollution loads. From the data analysis of the pollutant load capacity of the Cisadane River, it is seen that points 4-6 have an overload for the BOD parameter. The results of the pollutant's load reduction scenario model with the installation of WWTP communal can be seen in Table 5 as follows:

#### Table 5. BOD pollutant load calculation results with communal WWTP application scenarios.

| Reach        | Location          | Upstream (km) | Downstream (km) | Debit (m³/s) | Model BOD Load Scenarios (mg/L) | BOD Load Capacity (kg/day) | Difference (kg/day) | % BOD to be lowered |
|--------------|-------------------|---------------|-----------------|--------------|---------------------------------|---------------------------|---------------------|---------------------|
| 0            | Jl.BSD Boulevard  | 34            | 28              | 2.84         | 21927.99                        | 22497.88                  | 1199.89             | 0%                  |
| 1            | Jl. Teuku Umar    | 28            | 23.6            | 2.63         | 21936.64                        | 25022.79                  | 3086.14             | 0%                  |
| 2            | Jembatan Karel Satsuit Tubun | 23.6 | 22.6 | 2.23 | 20124.23 | 27072.96 | 6948.73 | 0% |
| 3            | Jl. Marsekal Surya Darma | 22,6 | 16,45 | 2.80 | 27222.92 | 29208.37 | 1985.45 | 0% |
| 4            | Jl. Kedaung Barat | 16,45 | 7,25 | 2.90 | 29451.46 | 30435.88 | 984.42 | 0% |
| 5            | Jl. Raya Kali Baru | 7,25 | 0 | 2.62 | 28957.34 | 33201.58 | 4244.25 | 0% |

**Description:** negative BOD difference

**Figure 3.** (a) Decrease in BOD in the Cisadane River middle-downstream segment result of scenario with implementation of communal WWTP.
From Figure 3, it can be seen after the reduction scenario with the application of communal WWTP with BOD concentration at points 3-6 in the Cisadane River, the middle to downstream segment, has met the quality standard of PP No. 22 the Year 2021 class II. The results of the calculation of the BOD pollutant load obtained the lowest BOD load value of 20124.23 kg/day and the highest of 29451.46 kg/day with the largest BOD load capacity of 33201.58 kg/day so that the average BOD percentage that must be reduced is there is no more. Therefore, when the concentration of BOD decreases, the DO value in the middle to a downstream segment of the Cisadane River increases because the pollutant load entering the river body is processed first with communal WWTPs.

4. Conclusion
Potential sources of pollution in the middle to downstream Cisadane River segments at points 1-3 are dominated by settlements, industry, offices, schools and shopping centers. Meanwhile, points 4-6 are dominated by settlements, agriculture, rice fields and restaurants. In addition, the Cisadane River has irrigation canals that can affect water quality. The pollutant’s load reduction scenario results by applying WWTP communal use of anaerobic-aerobic biofilter has the lowest BOD load of 20124.23 kg/day, and the highest was 29451.46 kg/day. After the done scenario with the installation of the Cisadane River communal WWTP in the middle to downstream segments in good condition for the pollutant load capacity of the BOD parameter.

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