The study on the linkage between pollution load and water quality index of the Cidurian river - a case study of Serang District segments

L Pemulasari1*, B Kurniawan2 and Y Maryani3

1 Master Degree of Chemical Engineering, Universitas Sultan Ageng Tirtayasa, Serang, Indonesia
2 Ministry of Environment and Forestry, Jakarta Timur, Indonesia
3 Department of Chemical Engineering, Universitas Sultan Ageng Tirtayasa, Cilegon, Indonesia

liapemulasari@gmail.com

Abstract. The increasing population and activities carried out on the Cidurian River banks impact increasing pollutants that enter the river to decrease river water quality. This study aims to determine the effect of the river's pollution load from domestic, agricultural, and livestock sectors on the Cidurian river water quality index. Calculation results show that the Cidurian River Water Quality Index ranges from -59 to -14, heavily polluted to moderately polluted with heavily polluted locations in Kopo District. Likewise, with the calculation of pollution load, the highest value of pollution load is in Kopo District, with the domestic sector's ratio 56%, agriculture 16.54%, and livestock 27.46%, respectively. Based on these calculations, it can be concluded that the Cidurian River Water Quality Index in the Serang Regency segment is strongly influenced by pollution load from the domestic sector compared to the agricultural sector and livestock sector in all monitoring locations. Hence, it is necessary to construct and operate a domestic wastewater treatment plant in densely populated areas, especially in Kopo District, to reduce the domestic sector's pollution load, which is expected to increase the Cidurian River Water Quality Index.

1. Introduction
The Cidurian River is one of the strategic rivers in Banten Province as a raw water source for industries and agriculture that flows through 2 (two) Provinces, Banten dan West Java [1]. Along with the increase in population and the kinds of activities carried out along the river, it has resulted in increased water needs consumption, and a potential impact is the occurrence of river pollution [2]. Based on the analysis of the results of water quality monitoring carried out by the Environmental and Forestry Service of Banten Province, it shows that the trend in the quality status of the Cidurian River in the Binuang, Cikande, Jawilan, and Kopo locations ranges from moderate to severe pollution with a score range of -14 to -59 [3].

The results of previous research in the Cidurian River area showed that the largest pollution load in the Cidurian River in the Serang Regency segment came from the domestic sector, with the highest value occurring in Cikande District (BOD 2,187.02 g/day) then agriculture (BOD 552.82 g/day), but this study has not considered other sectors like the livestock sector [1].
Other research conducted by the Environmental Agency of Tangerang Regency shows that the source of pollution in the Cidurian River is dominated by the domestic sector with a BOD parameter value of 85.55% and COD parameter value 82.38%. Then from the industrial sector with values in Serang Regency respectively 11.39% and 15.71% for BOD and COD parameters. Furthermore, the industrial sector in Tangerang Regency contributed 0.77% and 0.56%, respectively, for BOD and COD parameters. The livestock sector and the agricultural sector also contribute as sources of pollution, but the value is less than 1%. [4]. This research's weakness is that it has not calculated the pollutant load that enters the Cidurian River from the domestic sector in the Serang Regency segment.

Therefore, to complement previous studies, this study was conducted. The objectives of this study are (1). determine the estimated size and type of pollutant sources from within the country, agriculture, and livestock; (2). Knowing the relationship between water quality data and pollution load; (3). determines the pollution load effect from the domestic, agricultural, and livestock sectors. In other words, land use affects river water quality. Meanwhile, this research's benefit is that it can be used as a reference for formulating policies and pollution control activities carried out by the Government of both the Banten Provincial Government and the Regency/City Government, which can then become a reference for further research.

2. Methodology

2.1. Data source

The water quality data used in this study were obtained from the Cidurian River water quality monitoring result in the Serang Regency segment conducted from 2016-2018 by the Banten Province Environment and Forestry Service. The watershed map and demographical data per sub-district within riverbanks of the Cidurian river, agricultural-related data, and livestock data were derived from the Central Statistics Agency of Serang Regency.

In the study, the land use data and land use map were used to inventory the river pollution source and determine pollution load contribution, particularly from non-point pollution sources such as domestic, agricultural, and livestock sectors.

2.2. Pollution load calculation

Geographical Information systems and emission factors were used in estimating the pollutant load from non-point pollution sources. ArcGIS is used to determine the population's distribution along riverbanks and estimate the pollution load from the agricultural sector [5].

The pollution load is calculated based on the Minister of Environment Regulation No. 01 of 2010 concerning Water Pollution Control Procedures. The stages of implementing the calculation of pollution load are as follows. First, identifying the source and number of pollutants from the domestic, agricultural, and livestock sectors from spatial data, then calculating the pollution load from each source by multiplying the data on the number of sources of pollution by the emission factor for each sector. The formula and calculation method for each sector are listed below [6,7].

2.2.1. Domestic sector. The domestic sector's pollution load is calculated using a formula developed by the Water Resources Research and Development Center of the Ministry of Public Works, which multiply the population along the riverbanks by the emission factor. This emission factor is determined based on the distance between the settlement to the river bank. The formula and calculation method can be seen below.

\[ DPL = \alpha \times \lambda \times \sum_{i} \varepsilon_i \times CER \]  

(1)

where: 
- DPL : Domestic Pollution Load (kg/day)
- \(\alpha\) : unit conversion (0.001) from gram to kg
- \(\lambda\) : load transfer coefficient over distance (0.3 – 1.0) based on the source distance to the river water body (RWB)
for $\lambda = 0.3$ : source distance to RWB is more than 500 m
$\lambda = 0.85$ : the source distance to RWB is 100 - 500 m
$\lambda = 1$ : the source distance to RWB is 100 - 500 m

$\Sigma$ : Total Population (person), based on population density x area
$\epsilon i$ : emission factor (BOD 0.04 kg/day; COD 0.055 kg/day; TSS 0.038 kg/day; total N 0.00195, total P 0.00021)

CER : city equivalent ratio, based on the difference between location and value
Value 1 = for urban areas
Value 0.8125 = for suburban area
Value 0.625 = for inland area

The coefficient is a description of the magnitude of the impact of the distance between residential areas and the potential pollution load, namely the closer the distance between residential areas and riverbanks, the greater the coefficient value. The distance between the distribution of settlements and riverbanks is obtained based on the GIS method approach.

2.2.2. Agricultural Sector. The pollution load from the agricultural sector is calculated based on the formula below. So that estimation of agricultural land area, the number of planting seasons, the length of the growing season data are needed. At the same time, the emission factors from agricultural types are shown in table 1.

$$x = \frac{a \times b \times \epsilon i}{d}$$

which:
$x$ = Agricultural pollution load (kg/day)
$\epsilon i$ = emission factor
$a$ = agricultural land area (ha)
$b$ = number of growing seasons
$d$ = the length of the growing season (days)

Table 1. Agricultural emission factor.

| Type of Agriculture   | Emission factor based on the parameter (kg/ha/ growing season) |
|-----------------------|---------------------------------------------------------------|
|                       | TSS    | BOD    | T. PO4 | N     | Pestisida |
| Rice Fields           | 0.04   | 225    | 10     | 20    | 0.16      |
| Palawija              | 2.4    | 125    | 5      | 10    | 0.08      |
| Other Plantation      | 1.6    | 32.5   | 1.5    | 3     | 0.024     |

The runoff ratio for paddy fields is 10%, while the runoff for other crops and plantations is 1%. In general, only the TSS and BOD parameters are used in the pollutant load [10]. For the planting season once a year, the length of the planting season is 365 days, while for the planting season 2 (two) times a year, the planting season is 182.5 days [8].

2.2.3. Livestock sector. The livestock sector's pollution load is calculated by multiplying the number of livestock per type by their respective emission factors as the formula below. Meanwhile, the Livestock Emission Factor is shown in table 2.

$$x = a \times \epsilon i \times 20\%$$

which:
$x$ = potential animal pollution load (kg/day)
$a$ = number of growing seasons (head)
$\epsilon i$ = emission factor
$20\%$ = the runoff ratio for the livestock sector
Table 2. Livestock emission factor.

| Types of Livestock | Emission factor based on parameter (gram/head/day) |
|--------------------|-----------------------------------------------------|
|                    | BOD | COD | NO₃ | T. Fosfat |
| Cow                | 292 | 716 | 0.933 | 0.153 |
| Buffalo            | 207 | 530 | 2.6 | 0.39 |
| Sheep              | 55.68 | 136.23 | 0.027 | 0.063 |
| Goat               | 34.1 | 92.9 | 1.624 | 0.063 |

In calculating the livestock sector's pollution load, the pollution load from the types of chickens and ducks is not included in the calculation because there are no large chicken or duck farms with a distance of 2-3 km from the riverbank [14].

3. Result and discussion

Based on the calculation results, the Cidurian river quality status in the Serang Regency segment is shown in table 3.

Table 3. Water quality status data.

| Location | 2016 | 2017 | 2018 |
|----------|------|------|------|
| Binuang  | -32  | Heavy Polluted | -56 | Heavy Polluted | -14 | Medium Polluted |
| Cikande  | -32  | Heavy Polluted | -56 | Heavy Polluted | -20 | Medium Polluted |
| Jawilan  | -32  | Heavy Polluted | -57 | Heavy Polluted | -18 | Medium Polluted |
| Kopo     | -32  | Heavy Polluted | -59 | Heavy Polluted | -20 | Medium Polluted |

Table 3 above shows that the quality conditions of the Cidurian River in 2016-2018 were on average, in a heavily polluted state. This shows that the water quality of the Cidurian River is not in accordance with its allocation based on Government Regulation no. 82 of 2001 concerning Quality Management and Water Pollution Control, which is class II, respectively. The condition of the Cidurian River, which is heavily polluted, is due to the very high pollution load that enters the river. In order to find out the most dominant sector that polluted the river, the contaminant calculations are carried out on three sectors (domestic, agriculture, and livestock).

3.1 Calculation for the domestic sector

The area of settlement and the number of population in the Binuang, Cikande, Jawilan, and Kopo areas for the calculation of the pollution load from the domestic sector is obtained from the spatial map as indicated in figure 1, while pollution load from the domestic sector in 2016 - 2018 based on the distance between settlements and riverbanks is presented in table 4.

Table 4. The pollution load from the domestic sector in 2016-2018 based on the distance between settlements and riverbanks.

| Sub-district | Binning | Cikande | Jawilan | Kopo |
|--------------|---------|---------|---------|------|
| 0 – 100 m    | 2016    | 2017    | 2018    | 2016 | 2017 | 2018 | 2016 | 2017 | 2018 | 2016 | 2017 | 2018 |
| TSS          | 33.25   | 33.51   | 33.69   | 113.57 | 113.73 | 108.73 | 36.32 | 36.54 | 36.11 | 170.62 | 170.62 | 172.57 |
| BOD          | 35.35   | 35.28   | 35.46   | 119.55 | 119.72 | 114.45 | 38.23 | 38.46 | 38.01 | 179.60 | 179.60 | 181.65 |
| COD          | 48.12   | 48.5    | 48.76   | 164.38 | 164.61 | 157.37 | 52.56 | 52.88 | 52.26 | 246.95 | 246.95 | 249.77 |
| T.PO₄        | 0.18    | 0.19    | 0.19    | 0.63   | 0.63   | 0.63   | 0.2   | 0.2   | 0.2   | 0.94   | 0.94   | 0.95   |
| T. Nitrogen  | 1.70    | 1.72    | 1.73    | 5.83   | 5.84   | 5.84   | 1.86  | 1.87  | 1.85  | 8.76   | 8.76   | 8.86   |
| 100 – 500 m  | 125.28  | 126.3   | 126.96  | 346.14 | 346.78 | 333.01 | 106.45 | 107.1 | 106.1 | 670.84 | 670.84 | 678.52 |
| TSS          | 131.87  | 132.95  | 133.64  | 364.36 | 365.04 | 350.54 | 112.05 | 112.73 | 111.68 | 706.15 | 706.15 | 714.23 |
### Table 5. Pollution load from the domestic sector in 2016 - 2018.

| Year | Parameter (kg/day) | TSS | BOD | COD | T.PO4 | T.Nitrogen |
|------|--------------------|-----|-----|-----|-------|------------|
| 2016 | 3,058.68           | 3,220.02 | 4,427.04 | 16.91 | 156.94 |
| 2017 | 3,066.62           | 3,228.02 | 4,438.52 | 16.95 | 157.37 |
| 2018 | 3,037.71           | 3,197.56 | 4,396.66 | 16.79 | 155.88 |
| Total| 9,163.11           | 9,794.67 | 13,262.67 | 50.65 | 470.19 |

Figure 1. Settlement map in the Cidurian watershed segment, Serang Regency.
After calculating the amount of pollution load in the domestic sector based on the riverbank's distance, it is then compiled into the domestic sector's total pollution load per district. The calculating results of the domestic pollution load in 2016 - 2018 can be seen in table 5.

Kopo Sub-district is a sub-district with the highest level of pollution load from the domestic sector, followed by the Cikande Sub-district, Jawilan Sub-district, then Binuang Sub-district. It can be noted that an increase in population can cause pollution due to the rise in the number and variety of activities.

### 3.2 Calculation for the agricultural sector

Data on wetland and non-rice fields from the BPS Serang district from 2016 to 2018 and then result from a calculation using the formula and emission factors, the pollution load from the agricultural sector is presented in table 6.

| Type of land And Area (ha) | Sub-district | Parameter (kg/ha/season) |
|----------------------------|--------------|--------------------------|
|                            | Binuang      | Cikande                  | Jawilan | Kopo | TSS  | BOD   | T.PO4 | T.Nitrogen |
| 2016 Rice Fields           | 2345.5       | 3,240                    | 1,294.74| 1,374| 3.62 | 2,035.29 | 76.09 | 180.91     |
| Palawija                   | 903.34       | 117                      | 290     | 527  | 0.48 | 25.17 | 1.01  | 2.01       |
| Plantation                 | 0            | 87                       | 29      | 298  | 0.02 | 0.37  | 0.02  | 0.03       |
| 2017 Rice Fields           | 2,345.5      | 3,660                    | 1,294.74| 1,374| 3.80 | 2,138.83 | 76.09 | 190.12     |
| Palawija                   | 903.34       | 58                       | 290     | 527  | 0.47 | 24.36 | 1.75  | 1.95       |
| Plantation                 | 0            | 76                       | 29      | 298  | 0.02 | 0.36  | 0.02  | 0.03       |
| 2018 Rice Fields           | 1239         | 3,545                    | 1,344.74| 1,356| 3.77 | 2,118.36 | 68.88 | 188.30     |
| Palawija                   | 1736         | 69                       | 232     | 513  | 0.46 | 23.85 | 0.95  | 1.91       |
| Plantation                 | 0            | 60                       | 53.5    | 298  | 0.02 | 0.37  | 0.02  | 0.03       |
| TOTAL                      | 12.65        | 6,366.96                 | 224.83  | 565.30 |

From the calculations in table 6 above, it is known that Binuang Sub-district is a sub-district with the largest area of agricultural land. The most significant pollution load from the agricultural sector comes from the BOD parameter, followed by Nitrogen and Phosphate. This shows that fertilizers are a source of pollution from the agricultural sector because BOD, Nitrogen, and Phosphate are the decay of fertilizers.

### 3.3 The calculation for the livestock sector

Data on livestock population on the banks of the Cidurian river segment of Serang Regency from 2016 - 2018 obtained from the BPS Serang Regency and then multiplied by each of livestock's emission factors with the calculation results shown in are table 7.

| Parameter (kg/head/day) | Cow  | Buffalo | Sheep | Goat | TOTAL |
|-------------------------|------|---------|-------|------|-------|
| 2016                    |      |         |       |      |       |
| BOD                     | 0.64 | 184.64  | 57.28 | 186.19| 428.76|
| COD                     | 1.58 | 472.76  | 140.15| 507.25| 1,121.74|
| Total Nitrogen          | 0.002| 2.32    | 0.03  | 44.34| 46.69 |
| T. PO4                  | 0.0003| 0.35   | 0.06  | 0.34 | 0.76  |
| 2017                    |      |         |       |      |       |
Parameter (kg/head/day) | Cow | Buffalo | Sheep | Goat | TOTAL  
--- | --- | --- | --- | --- | ---  
BOD | 0.58 | 174.29 | 56.47 | 187.02 | 418.37  
COD | 1.43 | 446.26 | 138.16 | 509.52 | 1,095.38  
Total Nitrogen | 0.002 | 2.19 | 0.03 | 44.53 | 46.75  
T. PO4 | 0.0003 | 0.33 | 0.32 | 0.34 | 0.74  
2018  
BOD | 0.70 | 175.49 | 63.11 | 179.96 | 419.26  
COD | 1.72 | 449.33 | 154.40 | 490.27 | 1,095.73  
Total Nitrogen | 0.002 | 2.20 | 0.03 | 42.85 | 45.09  
T. PO4 | 0.0004 | 0.33 | 0.07 | 0.33 | 0.73  

Based on the calculation results in table 7, it is known that buffalo and goats are the livestock that contributes to the largest pollution load from the livestock sector. As one of the big ruminants, buffalo produces a large amount of manure so that the highest pollution load comes from this species. COD and BOD parameters are the biggest contributing factors for pollution load because livestock manure is organic waste that decomposes quickly and can be used as organic fertilizer.

The BOD parameter is the only parameter that exists in each sector. Therefore, the BOD parameter is used to compare the percentage of pollution load between sectors. The results of the calculations are shown in table 8 below.

**Table 8.** BOD comparison per pollution source.

| Year | BOD (%) | Domestic | Agricultural | Livestock |
|------|---------|----------|--------------|-----------|
| 2016 | 56.40   | 36.09    | 7.51         |
| 2017 | 55.56   | 37.24    | 7.20         |
| 2018 | 55.52   | 37.20    | 7.28         |

Based on table 8 above, it is clear that the domestic sector is the largest contributor to the pollution load that enters the Cidurian River, followed by the agricultural sector and the livestock sector. However, in 3 years (2016-2018), there is no significant difference in percentage, so it can be interpreted that the population, agricultural land area, and the number of livestock in the three years are relatively stable.

From the calculation of water quality and pollution load status, comparisons are made, as shown in table 9 below. In the table, it can be seen that the value of the water quality status is directly proportional to the value of the pollution load. In 2018, the water quality status showed that the data is moderately polluted, and the value of the pollutant load has decreased slightly. Therefore, to improve the water quality status so that it is according to its designation, integrated efforts are needed to manage and improve the water quality of the Cidurian River continuously so that the pollution load that enters the Cidurian River decreases.

**Table 9.** Comparison of quality status with pollution load per location.

| Year | Location | Quality status | Domestic | Agricultural | Livestock |
|------|----------|----------------|----------|--------------|-----------|
| 2016 | Binuang  | -32 (heavy polluted) | 44.87 | 47.08 | 8.05 |
|      | Cikande  | -32 (heavy polluted) | 50.52 | 36.26 | 13.22 |
|      | Jawilan  | -32 (heavy polluted) | 56.31 | 38.74 | 4.95 |
|      | Kopo     | -32 (heavy polluted) | 55.40 | 17.12 | 27.48 |
| 2017 | Binuang  | -56 (heavy polluted) | 45.04 | 46.94 | 8.03 |
Some efforts that can be made to improve the quality of the Cidurian River are constructing a communal domestic wastewater treatment plant in highly populated locations. Like other studies, water quality is affected by various non-point source pollutants that are scattered from upstream to downstream [8,9,10]. Then, implementing environmentally friendly cropping and maintenance patterns on agricultural land by using fertilizers that are appropriate and not excessive, thus minimizing excess fertilizer that enters the water body. And makes a sewage treatment installation for integrated livestock and uses the waste manure as fertilizer.

4. Conclusion

Based on the calculation results, it is obtained that the quality of river water in the Cidurian Segment of Serang Regency is influenced by the pollution load originating from the domestic sector, the agricultural and livestock sectors with the percentage of 56%, 37%, and 7% respectively. Therefore, policy steps are needed in the form of strategies, programs, and action plans. Such as the socialization of the importance of a clean and healthy lifestyle and the existence of a domestic wastewater treatment plant in densely populated areas. It can reduce the domestic sector's pollution burden to improve the Cidurian River Water Quality Index, especially in the Serang Regency segment.

Acknowledgment

The Authors would like to express profound gratitude to The Department of Environment and Forestry of Banten Province for providing valuable data and support.

References

[1] Kartika I W, Riani E and Kurniawan B 2012 Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan 7(3) 204
[2] Gaol M L L, Riani E and Kurniawan B 2017 Institut Pertanian Bogor
[3] Kabupaten Tangerang DLHK 2019 Laporan Akhir Kajian Penentuan Daya Dukung dan Daya Tampung Sungai
[4] Asdak C 2010 Gadjah Mada University Press (Yogyakarta)
[5] Iskandar 2007 Panduan Pelatihan Pengelolaan Kualitas Air (Jakarta: Puslitbang Sumberdaya Air Kementerian Pekerjaan Umum)
[6] Komarudin M, Haryadi S and Kurniawan B 2015 Jurnal Pengelolaan Sumberdaya Alam dan Jurnal 5(2) 121
[7] EPA U 2018 Polluted Runoff: Nonpoint Source (NPS) Pollution an Official website of the United States Government
[8] Rezagama A and Hadiwidodo M 2016 ICSBE 332–341
[9] Sarminingsih A and Rezagama A 2019 J. Phys. Conf. Ser. 1217(1) 012134
[10] Rezagama A, Sarminingsih A, Zaman B and Handayani D S 2019 J. Phys. Conf. Ser. 1217(1) 012159