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Pollution load of Cisangkan River: The domestic sector

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Abstract. Cisangkan Sub-watershed is one of the watersheds located in Cimahi City and is part of the Citarum Watershed. In 2018, the water quality of Cisangkan Sub-watershed was in severe condition. The domestic sector is one of the sectors which has the potential to contribute to the pollution of the river. These conditions explain that a study is needed to calculate the pollution load from the domestic sector in Cisangkan Sub-watershed. The purpose of this research was to study the pollution load from the domestic sector of Cisangkan Sub-watershed based on its existing population condition and projection for the next 5 years. The pollution load calculations used domestic waste emission factor, city equivalent ratio, and load transfer coefficient. The results show that the pollution load of the Cisangkan Sub-watershed in existing conditions are 5967.92 kg/day BOD; 8205.89 kg/day COD; 5669.52 kg/day TSS; 290.94 kg/day Total-N; and 31.33 kg/day Total-P and as for the projected conditions are 6149.94 kg/day BOD; 8456.17 kg/day COD; 5842.45 kg/day TSS; 299.81 kg/day Total-N; and 32.29 kg/day Total-P.

1. Introduction

The Cisangkan Sub-watershed is one of the watersheds located in Cimahi City, West Java, Indonesia and is part of the Citarum Watershed. Based on regular monitoring by the West Java Environmental Protection Agency (EPA), most water quality parameters of the rivers in West Java are below the standard values set by provincial and national governments [1]. The quality of surface water in West Java mostly polluted by domestic, agricultural, and industrial activities [2], while water in rivers is often used to fulfil human needs and other living things [3]. Currently, many rivers become the disposal sites for domestic, agricultural, livestock and industrial sectors that causing pollution [4], which consequently causes the degradation of water quality [5]. Naturally, there is a self-purification process in water bodies, but its capacity can be exceeded due to the heavy pollution load [6].

Based on the Information Document of Environmental Management Performance of Cimahi City in 2018, the water quality of Cisangkan Sub-watershed is classified as class II (water for which the designation can be used for recreational infrastructure/facilities, cultivation of freshwater fish, livestock, water to irrigate crops) according to the Government Regulation No. 82 of 2001 on Management of Water Quality and Water Pollution Control. However, the results of a study conducted by the Cimahi City Environmental Agency in 2017 indicate that the water quality in the Cisangkan Sub-watershed has exceeded class IV (water for which the designation can be used to irrigate crops) of the quality standard, so it is concluded to be in a severe polluted condition.

The pollution that occurs in Cisangkan Sub-watershed has the potential to contribute to the pollution of Citarum Watershed of Dayeuh Kolot-Nanjung segment [7]. The Citarum Watershed supplies water to three reservoirs which were built to supply water for domestic, agricultural, power plant, and fishery [8]. That explanation shows the importance of Citarum Watershed for living creatures in West Java because there exist domestic, agricultural, livestock, and industrial activities that are sources of pollution. The domestic sector is predicted to be the main source of pollution due to the dominant domestic area as compared to the other sources.

The above-mentioned conditions provide enough reasons to study the pollution load from the domestic sector. The pollution load could be calculated by taking into account the domestic waste emission factor, city equivalent ratio, and load transfer coefficient on existing population condition and projection for the next 5 years. In this way, the acceptable pollutant load to Cisangkan Sub-watershed from domestic sector can be known.

2. Methodology

2.1. Data collection
The data used in this research were secondary data, namely data on population, the map of Cisangkan Sub-watershed, the quality of water in Cisangkan Sub-watershed, distribution of domestic sector activity, and document of the spatial and regional plan of Cimahi City. All of the data were obtained from the Environmental Agency of Cimahi City.

2.2. Calculation of the pollutant load
The existing pollutant load was obtained from the domestic sector data of 2017, which was calculated using the following formula [9]:

The domestic sector pollutant load =
Σ Population x Emission factor x City equivalent ratio x Load transfer coefficient

The domestic waste emission factor can be seen in Table 1. City equivalent ratio (Cer) can be seen in Table 2.

Table 1. The domestic waste emission factor.

Parameter	Emission (g/person/day)
TSS	38
BOD	40
COD	55
Total-N	1.95
Total-P	0.21

Table 2. City equivalent ratio.

Area	Cer value
City	1
Suburbs	0.8125
Rural	0.6250

Table 3. Value of load transfer coefficient (α).

Value of α	Distance to the river (m)	Sanitary pattern
1	0-100	Direct disposal to the river
0.85	100-500	Open canal
0.3	>500	Septic tank

The load transfer coefficient (α) of each sub-district was calculated by the approach method. The approach was done by calculating the percentage of settlements included in the range of 0-100 m, 100-500 m, and > 500 m. The range was the distance between settlements and rivers. Load transfer coefficient can be seen in Table 3.

Pollutant load of Cisangkan Sub-watershed from domestic sector could be calculated using population data and emission factors for key parameters such as BOD, COD, TSS, Total-N, and Total-

P. The key parameters were water quality parameters that caused pollution with an occurrence probability of ≥80% [9]. In addition to these two data, the city equivalent ratio and the load transfer coefficient also had to be determined.

The potential pollutant load was calculated with the same principle as the existing pollutant load. The difference laid in the use of population data, which need to be projected every 5 years as described in Government Regulation No. 82 Year 2001 Chapter III Article 23 Paragraph 2. The projection was done by choosing one of the best methods among arithmetic, geometry, and least square, based on the last 10-years data.

3. Results and analysis

3.1. Existing pollutant load

The data used were population data of each sub-district. The approach method was used to calculate the area of settlement, the percentage of settlements in each sub-district, which could be found using ArcGIS software.

The results of the calculation of population in the Cisangkan Sub-watershed area of 2017 can be seen in Table 4.

Table 4. The recapitulation of total population in Cisangkan Sub-watershed area of 2017.

Sub-district	Total area of settlements (km^2)	Area of settlement of Cisangkan Sub-watershed (km^2)	% area of settlements	Total population (person)	Total population in Cisangkan Sub-watershed (person)
South Cimahi (Downstream)	7.11	2.90	40.78	257417	104985
Central Cimahi (Center)	6.91	3.56	51.59	172591	89033
North Cimahi (Upstream)	7.11	1.25	17.59	163218	28712

Percentage of settlements in each range in the Cisangkan Sub-watershed area for each sub-district can be seen in Table 5.

Table 5. The percentage of settlements in Cisangkan Sub-watershed.

Sub-District	Area of settlement of Cisangkan Sub-watershed (km^2)			Total area of settlement of Cisangkan Sub-watershed (km^2)	The total area of settlement (%)		
	0-100 m	100-500 m	>500 m		0-100 m	100-500 m	>500 m
South Cimahi (Downstream)	0.02	1.77	1.12	2.90	0.63	60.88	38.49
Central Cimahi (Center)	0.68	1.34	1.54	3.56	19.13	37.65	43.22
North Cimahi (Upstream)	0.35	0.85	0.05	1.25	27.96	68.28	3.76

The higher the alpha value, the higher the level of water pollution by the domestic sector that could occur. The calculation of load transfer coefficient for each sub-district can be seen in Table 6.

Table 6. Load transfer coefficient.

Sub-District	Area of settlement (%)			α			Total α
	0-100 m	100-500 m	>500 m	0-100 m	100-500 m	>500 m	
South Cimahi (Downstream)	0.63	60.88	38.49	1	0.85	0.3	0.64
Central Cimahi (Center)	19.13	37.65	43.22				0.64
North Cimahi (Upstream)	27.96	68.28	3.76				0.87

Settlement map in the Cisangkan Sub-watershed can be seen in Figure 1.

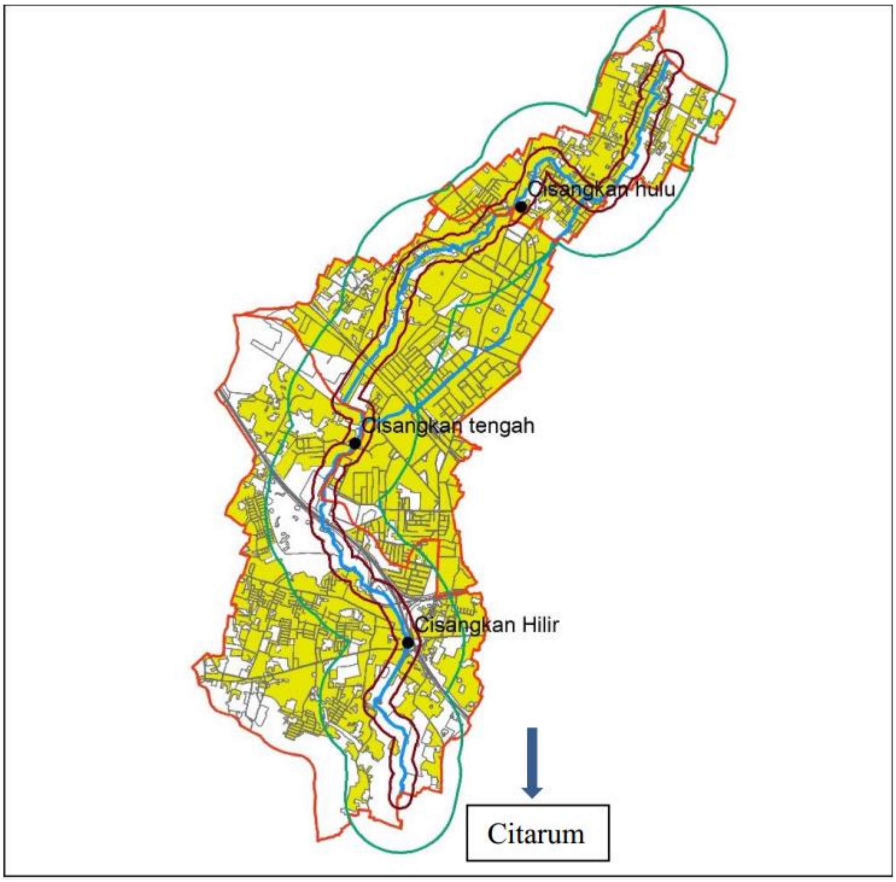

Figure 1. Settlement map of the Cisangkan Sub-watershed.

Hence the pollutant load for BOD parameter entering the river every day from the domestic sector in South Cimahi Sub-district by 2017 was 2684.58 kg/day. The result of the calculation of the domestic sector by each pollutant load parameter in 2017 can be seen in Table 7. The downstream, center, and upstream sections of the river are represented by the South Cimahi, Central Cimahi, and North Cimahi Sub-districts, respectively.

Table 7. The existing domestic sector pollutant load.

Sub-district	The domestic sector pollutant load (kg/day)				
	BOD	COD	TSS	Total-N	Total-P
South Cimahi (Downstream)	2684.58	3691.30	2550.35	130.87	14.09
Central Cimahi (Center)	2.282.73	3138.76	2168.60	111.28	11.98
North Cimahi (Upstream)	1000.61	1375.84	950.58	48.78	5.25
Total	5967.92	8205.89	5669.52	290.94	31.33

The number of population in an area is directly proportional to the pollutant load generated from the domestic sector. In addition, the amount of pollutant load value is also affected by the city equivalent ratio and the distance of the settlement to the river. The city equivalent ratio for urban areas and the distance of settlements with adjacent to streams cause the higher pollutant load generated. Based on the calculation, South Cimahi Sub-district is the area that produces the most pollutant load.

3.2. Potential pollutant load

The calculation of the potential pollutant load from the domestic sector begins with projections of the population. The best population projection method was chosen based on the standard deviation, correlation coefficient, and coefficient of variances. Comparison of the three methods of population projection can be seen in Table 8. The red color shows the best value for each factor.

Table 8. Comparison of the three methods of population projection.

Factors	Method		
	Arithmetic	**Geometry**	**Least square**
Standard deviation	14132.673	13651.235	15277.622
Correlation coefficient	0.88	0.89	0.88
Coefficient of variances	0.025	0.024	0.027

A standard deviation is a number that indicates the distribution of data in the sample. The smaller the value, the closer to the actual value, so does the coefficient of variances. A correlation coefficient is a number that indicates the strength of the relationship between variables. The greater the value (close to 1), the stronger the correlation between variables. Based on the calculation, the best method chosen to project the population was geometry method.

The same method was used to project the existing population for the domestic sector in 2022. The area of urban settlement in Cimahi City was assumed not to increase based on the Cimahi City Regulation Number 4 of 2013 on Spatial Plans and Region of Cimahi City Year 2012-2032 article 39, which explains that the development of the residential area in Cimahi City is done by building vertical residences. The recapitulation of the population in the Cisangkan Sub-watershed area in 2022 can be seen in Table 9.

Table 9. The recapitulation of total population in Cisangkan Sub-watershed area of 2022.

Sub-district	Total area of settlements (km^2)	Area of settlement of Cisangkan Sub-watershed (km^2)	% area of settlements	Total population (Person)	Total population in Cisangkan Sub-watershed (Person)
South Cimahi (Downstream)	7.11	2.90	40.78	269335	109846
Central Cimahi (Center)	6.91	3.56	51.59	171524	88482
North Cimahi (Upstream)	7.11	1.25	17.59	174940	30773

The domestic pollutant load calculation by 2022, which were done for each sub-district, can be seen in Table 10.

Table 10. The result of the domestic sector potential pollutant load calculation.

Sub-district	The domestic sector pollutant load (kg/day)				
	BOD	**COD**	**TSS**	**Total-N**	**Total-P**
South Cimahi (Downstream)	2808.86	3862.19	2668.42	136.93	14.75
Central Cimahi (Center)	2268.62	3119.35	2155.19	110.60	11.91
North Cimahi (Upstream)	1072.46	1474.64	1018.84	52.28	5.63
Total	6149.94	8456.17	5842.45	299.81	32.29

Hence, the domestic sector pollutant load for each parameter by 2022 can be seen in Table 10. For example, the value for the BOD pollutant load entering the river every day from the domestic sector in South Cimahi Sub-district by 2022 will be 2808.86 kg/day.

3.3. Comparison of the existing and potential pollutant load

The comparison of domestic sector pollutant loads by 2017 and 2022 can be seen in Table 11.

Table 11. Comparison of pollutant load from the domestic sector.

Year	**Pollutant Load (kg/day)**				
	BOD	**COD**	**TSS**	**Total-N**	**Total-P**
2017	5967.92	8205.89	5669.52	290.94	31.33
2022	6149.94	8456.17	5842.45	299.81	32.29
Difference	182.03	250.29	172.92	8.87	0.96

It can be assumed that the increase in population is directly proportional to the increase of pollutant load generated from the domestic sector. Chart of domestic sector pollutant load for the year 2017 and 2022 can be seen in Figure 2.

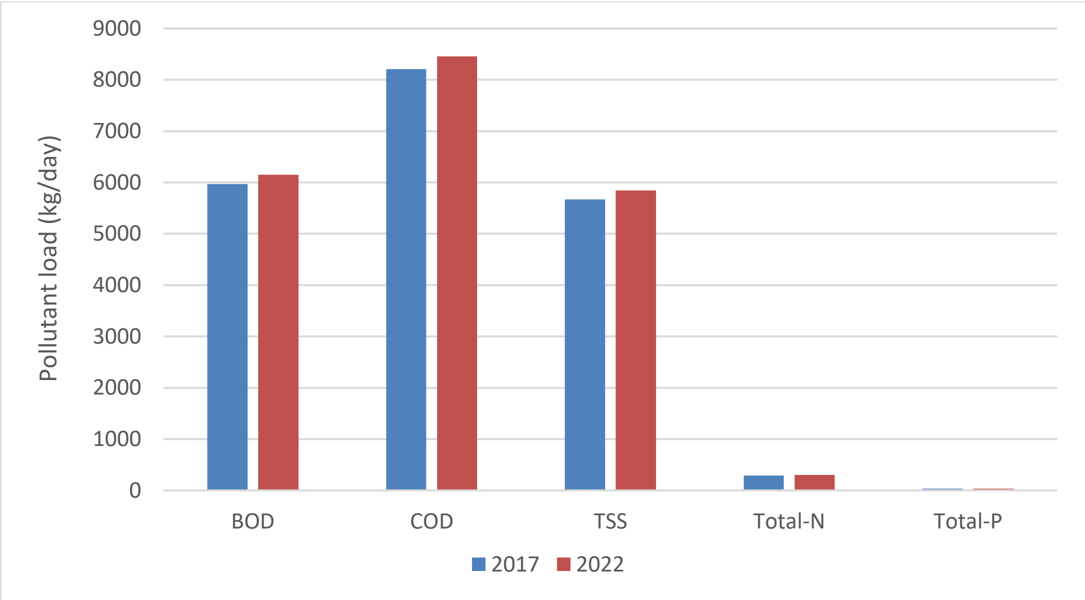

Figure 2. The chart of the pollutant load from the domestic sector.

For all parameters, pollutant loads from the domestic sector have increased from the upstream to the downstream, both for existing and projected conditions (Table 10). The increase of BOD and COD values from the upstream to the downstream indicates an increase of organic waste discharges to river bodies. The high values of BOD and COD increase the oxygen required by microorganisms to break down organic matter, resulting in a decrease of dissolved oxygen in water bodies. The low content of dissolved oxygen indicates that the water body has been contaminated. Suspended solids also increase from the upstream to the downstream, which may occur due to an increase in domestic waste. Increased suspended solids can cause water bodies to become muddy so that it will inhibit the entry of sunlight into the water column. The contents of phosphates and nitrogen that increase from the upstream to the downstream is a sign of increased decomposition of organic matter due to the increase of domestic waste. The content of phosphate may affect the fertility of algae that, if uncontrolled, can cause a decrease in dissolved oxygen.

4. Conclusion

The pollutant load from the domestic sector in the Cisangkan Sub-watershed comes from settlements that spread from the upstream to the downstream or from the North Cimahi Sub-district to the South

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Cimahi Sub-district. Results show that pollutant load of Cisangkan Sub-watershed in existing conditions from the domestic sector are 5967.92 kg/day BOD; 8205.89 kg/day COD; 5669.52 kg/day TSS; 290.94 kg/day Total-N; dan 31.33 kg/day Total-P. While in the projected conditions are 6149.94 kg/day BOD; 8456.17 kg/day COD; 5842.45 kg/day TSS; 299.81 kg/day Total-N; and 32.29 kg/day Total-P. There is an increase of pollutant load from existing condition (year 2017) to projection condition (year 2022). The increasing of population in Cisangkan sub-watershed area is one of the factors that could cause the increase of pollutant load in domestic sector.

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