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Pollution load capacity in the Downstream Citarum Watershed: 4 years after Citarum Harum Program

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Abstract. *Citarum River is one of the strategically valuable rivers in Indonesia, especially on Java Island. Since 2018, the central government has carried out the "Citarum Harum" program to revitalize the river while improving its reputation of Citarum as one of the dirtiest rivers in the world. This study aimed to see the pollution load capacity of the downstream Citarum River 4 years after the revitalization program was implemented. Downstream Citarum Watershed (Karawang Regency) was chosen as the focus of the study site because of the very high risk of contamination. This area has a high level of population, industry, and agricultural land which have a risk of contributing pollutants to water bodies. Moreover, the location of this regency is located in the downstream area of the river. So it has a high risk of having poor water quality. This research was comparing the pollution load capacity of biochemical oxygen demand (BOD) in 2022 using QUAL2Kw software and 2017 based on the data analyzed by the Ministry of Environment and Forestry. River revitalization over the last 4 years has significantly reduced the BOD value in the downstream Citarum Watershed. The success of this revitalization program can be a reference for other watershed management toward environmental improvement using the same scheme. This study is expected to provide updated information on water quality in the downstream Citarum watershed several years after revitalization and provide an overview of the important functions of river revitalization.*

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INTRODUCTION

The river is one of the most important natural resources in the world. Rivers can provide various types of ecosystem services for the community, such as provider for water, food, and habitat; water quality regulators; air temperature reducers; recreational service providers; and research sites (Khan *et al.* 2019). These various ecosystem services show that rivers can support human life from environmental, social, and economic aspects. Therefore, environmental degradation in river ecosystems can bring harm to humans and the surrounding environment. Hydrological disasters, infectious diseases, loss of biodiversity, and loss of recreational sites are some of the impacts of not being managed properly by rivers. Several factors can encourage the degradation of inland freshwater ecosystems (Chen *et al.* 2017).

In developing countries, population growth has a positive impact on increasing built-up land, especially settlements and industry (Sejati *et al.* 2018). Pollutants produced from industrial and household activities can flow into water bodies such as rivers, lakes, and the sea. Built-up areas also increase the risk of erosion entering water bodies and producing sedimentation (Spalevic *et al.* 2020). In addition, the high demand for food makes agricultural land also increase. The high use of agricultural fertilizers has an impact on the flow of nutrients to water bodies which are at risk of increasing eutrophication. If not managed properly, water quality will decrease and the development of algae and water hyacinth will increase (Spears *et al.* 2022). This condition will make river ecosystem services not optimal.

One of the most polluted rivers in Indonesia is the Citarum River. Citarum is the third biggest river on Java Island. The river is about 270 km long, flowing across an area 6.614 km^2 from Situ Cisanti, Bandung, upstream to downstream at Bekasi (Kurniawan *et al.* 2019). In 2018, no less than 20.000 tons of waste and 340.000 tons of wastewater, mostly from 2.000 textile factories, were disposed of directly into Citarum River every day. There are various activities, domestic and non-domestic, in the watershed and surrounding tributaries of this river (Idris *et al.* 2019). It is not uncommon to find large amounts of waste in the main river and tributaries of the Citarum. These caused Citarum to become the world's most contaminated river, according to a WHO statement.

In 2018, the government launched a revitalization program for the Citarum River, named citarum harum. This program was created due to the bad predicate given to the river. This restoration program involves the TNI (Indonesian National Army) as the main actor through the Citarum Harum Program. Under the command of the military command of Siliwangi III, West Java, this program became a breakthrough in Indonesia, where the TNI participated in carrying out environmental restoration programs. Several stakeholders claim that citarum harum has given tangible results in improving river water quality (Ayyasy *et al.* 2021). This can be seen in the disappearance of piles of garbage at several points on the Citarum River that previously existed (Idris *et al.* 2019). To see the performance of the program, it is necessary to monitor water quality and calculate pollution load capacity frequently.

Pollution Load Capacity (PLC) is a calculation of the maximum number of pollutants that can be accommodated by a water body. This calculation aims to keep the quality standards and allocation of pollutants amount that can be received by water bodies from pollutant sources (Singh *et al.* 2020). Thus, the river water quality does not exceed the proposed designation. In Indonesia, the results of the PLC study can be used for spatial planning and in general for the formulation of water pollution control policies (PCP). Water PLC in Water Sources is determined using the QUAL2E software. QUAL2E is a program that can calculate the load carrying capacity of pollution. The QUAL2Kw program used in this study is an upgraded version of the QUAL2E program. The purpose of the study was to obtain information on pollutant sources, both point sources (PS) and non-point sources (NPS) that enter the watershed, and obtain information on the amount of pollutant load that is permitted to be discharged into the river or the number of pollution load carrying capacity in the Citarum River.

METHODS

Study Location

The Citarum River is one of the strategically valuable rivers on the island of Java. Citarum is the biggest river in West Java (Hidayat *et al.* 2022). Citarum watershed is divided into 9 segments spread from the upstream to the downstream. This segmentation is divided by administrative area and becomes the baseline for sampling points for water quality monitoring by the government. From various administrative areas, Karawang Regency has the highest level of pollution potential. This area has a high level of population, industry, and agricultural land which have a risk of contributing pollutants to water bodies. Moreover, the location of this regency is located in the downstream area of the river. So it has a high risk of having poor water quality. Because of those reasons, segments 7 and 8 are selected from the 9 segments as our study location.

The selection of sampling points was carried out by considering the confluence of the main river and its tributaries. Although segment 9 is also included in the Downstream Citarum River, we did not use it in this study considering that most of the land cover in that segment is an agricultural area, mangroves, and fish ponds. Between the two segments (7 and 8), 8 water quality sampling points were selected. The location points of 8 sampling locations can be seen in Figure 1 and Table 1.

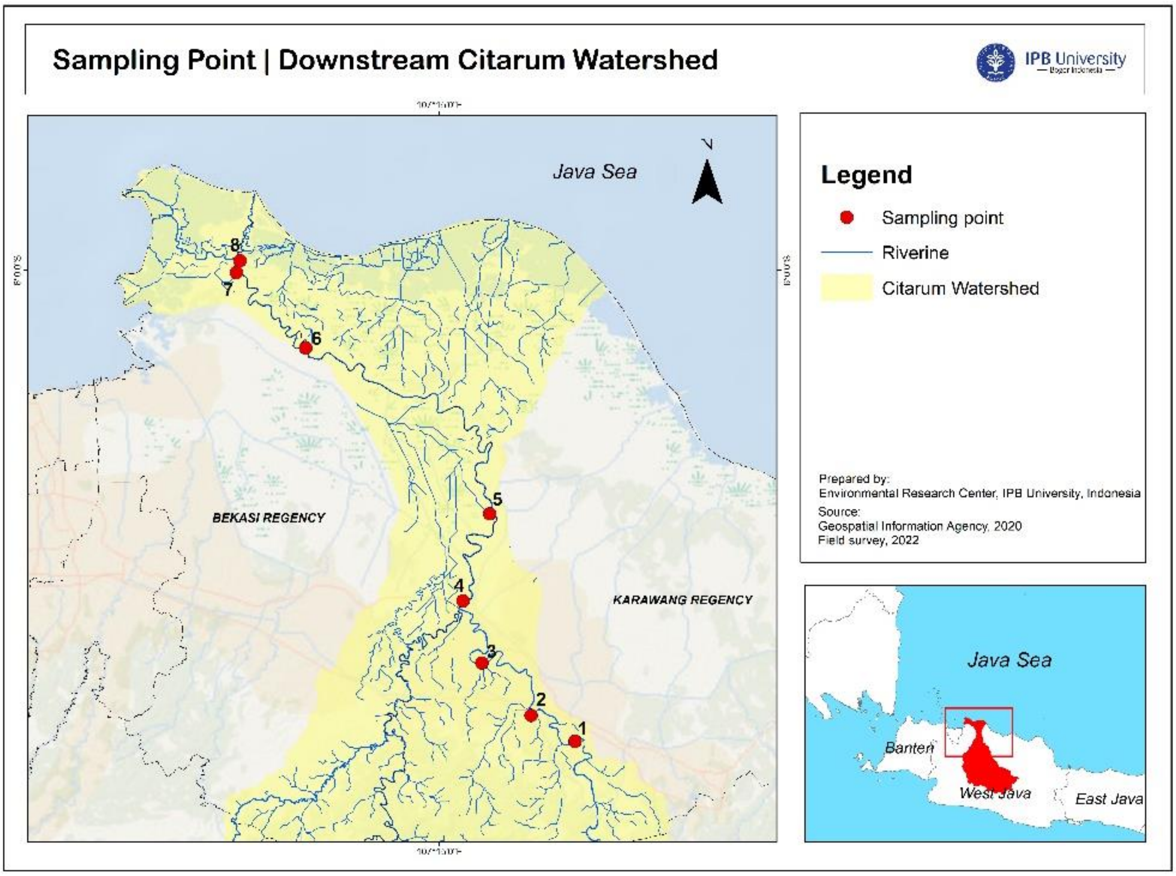


Figure 1 Sampling location

Table 1 Sampling points coordinate

No	Segment	Location	Dominant landuse	X	Y
1	7	Walahar Dam	Paddy field	107°21'45,303" E	6°22'58,324" S
2	7	Boat Bridge H. Endang	Dryland farming	107°19'20,557" E	6°21'44,985" S
3	7	Pakuncen	Paddy field	107°17'4,4" E	6°19'11,5" S
4	8	Tanjung Pura Bridge	Settlements/built-up land	107°16'08,8" E	6°16'18,8" S
5	8	Rengasdengklok	Settlements/built-up land	107°17'27,2" E	6°11'53,6" S
6	8	Telukbuyung	Settlements/built-up land	107°08'27,4" E	6°03'47,3" S
7	8	Jayasakti	Paddy field	107°05'03,6" E	6°00'05,7" S
8	8	Pakisjaya	Paddy field	107°05'14,1" E	5°59'31,2" S

Data Collecting

Data collecting consists of primary data and secondary data. Primary data were obtained from field observations while secondary data was obtained from government agencies and research reports that had been carried out previously. The data needed in this study can be seen in Table 2. In-situ data collection was carried out at 8 sampling points that represented the overall condition of the study location. The water quality parameters for data collection can be seen in Table 3. Water samples at 8 sites were collected and located with a global positioning system (GPS) receiver. The samples were taken at a depth of 30 cm using a Van Dorn water sampler (Alpha Bottle Kit - 2.2L Horizontal, Wildco, Yulee, FL, USA), preserved in 1-L cleaned, dark-colored bottles, and then refrigerated.

Table 2 Research data

No	Data	Type of data	Source
1	Water quality (BOD, COD, TSS, DO, Turbidity, pH, Temperature)	Primary	Field survey (in situ data collection)
2	Non-point source pollutants in the downstream area of Citarum Watershed	Secondary	Data projection from the previous study
3	Point source pollutant in the downstream area of Citarum Watershed	Secondary	Ministry of Environment and Forestry
4	Land use map	Secondary	RBI map, Geospatial Information Agency
5	Topographic map	Secondary	Ministry of Environment and Forestry
6	Meteorological, climatological, and hydrological data	Secondary	Ministry of Environment and Forestry

Water Quality Sampling

Water quality sampling was held in certain points covering each segment of the study area, Sampling was conducted in the dry season (May 2022). Water quality parameters analyzed are chemical and physical parameters. The chemical parameters analyzed were pH, DO, BOD, and COD, while the physical parameters analyzed were temperature, turbidity, and TSS. The analytical method or tool used for the analysis of each chemical and physical parameter is equipped with quality standards based on Government Regulation No. 22/2021 concerning water quality management and water pollution control, and their units are shown in Table 3.

Table 3 Analyzed water parameter based on Government Regulation No 22/2021

No.	Parameters	Methods	Unit	Water class (*)			
				1	2	3	4
Physical Parameters							
1.	Temperature *)	SNI 06-6989.23-2005	^oC	Dev 3	Dev 3	Dev 3	Dev 3
2.	TSS *)	SNI 06-6989.3-2004	mg/L	40	50	100	400
Chemical Parameters							
3.	pH *)	SNI 06-6989.11-2004		6,0-9,0			5,0-9,0
4.	DO	Winkler Modf	mg/L	6	4	3	1
5.	BOD *)	SNI 6989.72:2009	mg/L	2	3	6	12
6.	COD *)	SNI 6989.2:2009	mg/L	10	25	40	80

River Pollution Load Capacity Analysis and Pollutant Load Allocation

In calculating the river's PLC using Qual2kw software (version 5.1), several work steps were carried out, such as determining river segments and collecting river length data in each segment to the distance of each segment. The distance of each segment is calculated from downstream of the river. Water quality data for each segment is also input into the program. BOD is one of the most commonly used water quality parameters in PLC studies (Nugraha *et al.* 2022). Beside water quality data, the Qual2Kw program requires inputting climatological data such as dew point, temperature, wind speed, cloud cover, and topography and vegetation shade. River water quality data that is input into the program not only comes from point sources but also from non-point sources. The flow diagram of this analysis can be seen in Figure 2.

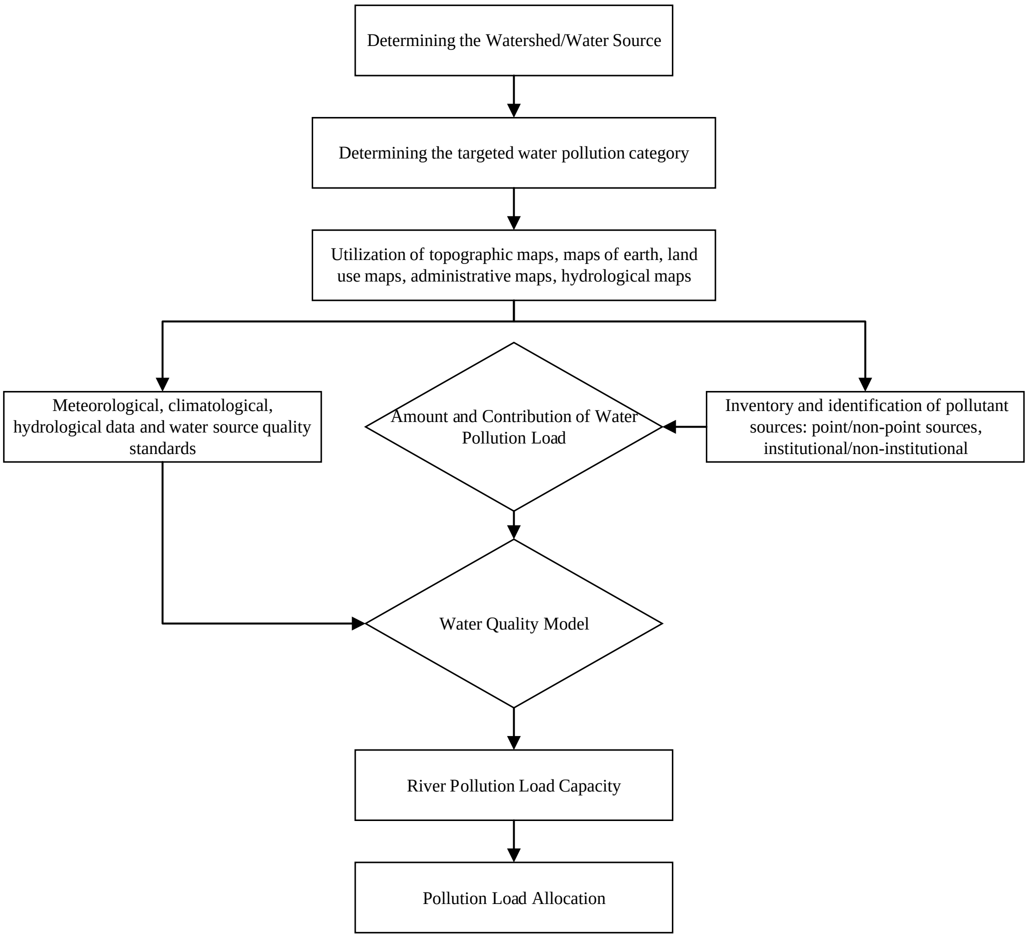


Figure 2 The flow diagram of river's PLC analysis

RESULTS

Estimated NPS Pollutant

Based on the projected non-point source pollutant data (NPS), Karawang district is the administrative area with the largest potential pollutant load in the Citarum Watershed. Based on their activities, the sources of NPS pollutants are divided into several sources such as households, agriculture, industry, livestock, etc (Table 4). Based on Figures 4, 5, and 6, households are the sectors that produce the highest BOD, COD, and TSS with percentages of 57,92%, 54,98%, and 82,02%, respectively. The high population in Karawang Regency is one of the triggers for the high potential for pollutants originating from households/domestic waste. The high number of NPS pollutants in the Karawang Regency is caused by several factors. Karawang Regency is an administrative area in the Citarum Watershed with the second largest population after Bandung Regency. The high population in the area makes the potential for NPS pollutants from households to be high. The potential for NPS pollutants originating from the industrial and agricultural sectors in this region is also quite high. Based on statistical data for 2021, the largest income in Karawang Regency comes from the manufacturing sector (70,05%), trade (9,83%), and agriculture, forestry, and fisheries (4,34%).

Table 4 Projected NPS Pollutant potential in Karawang Regency

No	Sectors	BOD		COD		TSS	
		Kg/Day	(%)	Kg/Day	(%)	Kg/Day	(%)
1	Industries	19.149,81	13,01	35.983,68	16,01	10.371,12	13,56
2	Hospitals	29,44	0,02	67,43	0,03	38,24	0,05
3	Hotels	1.633,84	1,11	2.382,43	1,06	1.193,14	1,56
4	Households	85.254,20	57,92	123.571,69	54,98	62.731,49	82,02
5	Livestock	19.782,74	13,44	51.739,18	23,02	-	0,00
6	Agricultures	15.131,44	10,28	-	0,00	22,94	0,03
7	Fisheries	220,79	0,15	359,61	0,16	-	0,00
8	Small Scale Enterprises (SSE)	4.945,69	3,36	9.012,78	4,01	2.126,23	2,78
9	Wastes	1.045,07	0,71	1.640,73	0,73	-	0,00
	Total	147.193,02	100,00	224.757,53	100,00	76.483,17	100,00

Source: Estimated from MoEF data in 2017

Land Use (Karawang Regency has Various Types of Land Use)

In the southern region bordering Purwakarta Regency, the Karawang Regency area has diverse industrial areas (Figure 3). Money printing, automotive, textiles, medicine, and chemicals are some of the industrial sectors in the region. There are even several industries located in an area called Karawang International Industrial City (KIIC). In the north of the industrial area is the city center, which is dominated by residential and commercial areas. Several hotels, restaurants, and business districts dominate the area. In the further north, agricultural land dominates the land use. Karawang Regency is one of the rice granaries in West Java Province. The flat topography and irrigation flow from the Citarum River also support the development of agricultural land in this region. In the northern coastal area, fish, shrimp, and salt ponds dominate land use. The economic value generated from pond cultivation is a driving factor for the community to convert agricultural land on the coast into ponds. Area and percentage of each land use can be seen in Table 5.

Table 5 Landuse in Downstream Citarum Watershed in 2020

Landuse	Karawang		Bekasi	
	Area (ha)	Percentage	Area (ha)	Percentage
Water Body	959,25	1,17	481,31	0,91
Shrubs	62,73	0,08	0	0,00
Secondary dryland forest	2.577,37	3,14	0	0,00
Forest	3.972,22	4,84	0	0,00
Built up area	10.000,00	12,19	7.571,26	14,33
Plantation	512,39	0,62	0	0,00
Mining area	15,52	0,02	0	0,00
Dryland farming	10.000,00	12,19	2.125,66	4,02
Mix farming	10.000,00	12,19	2.079,97	3,94
Paddy field	30.000,00	36,56	30.000,00	56,77
Pond	10.000,00	12,19	8.699,39	16,46
Bare land	3.963,56	4,83	1.891,76	3,58
Total	82.063,04	100,00	52.849,35	100,00

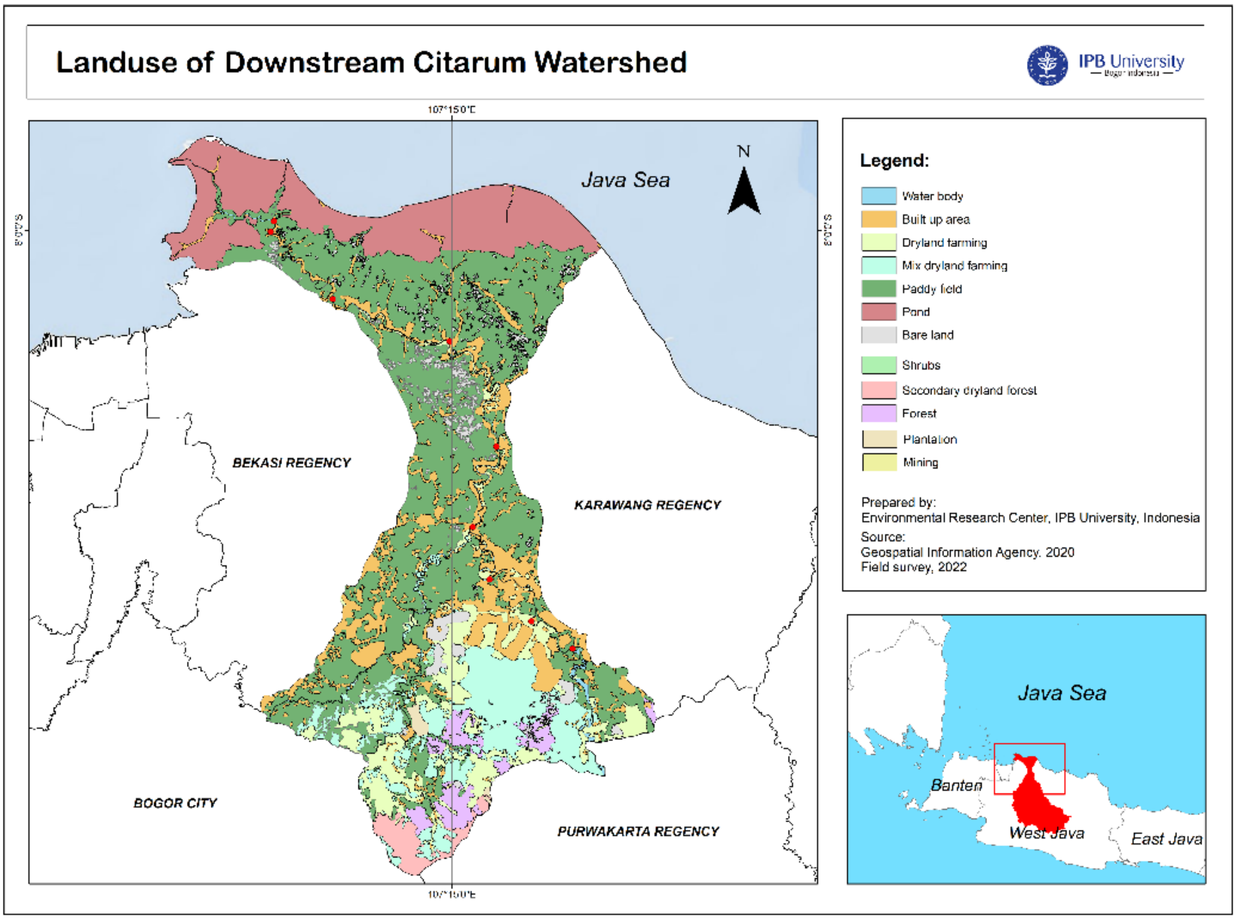


Figure 3 Landuse map of Citarum Watershed in Karawang and Bekasi Regency

Water Quality

Water quality parameters consist of temperature, pH, DO, turbidity, TSS, BOD, and COD (Table 6). Some parameters (temperature, pH, DO, and turbidity) were tested directly in the field using several instruments to prevent changes in water conditions. The remaining parameters were tested in the laboratory. To maintain the validity of the measurement results, the instrument is calibrated periodically. In general, in situ water quality shows a deteriorating trend from upstream to downstream. This can be seen from the dissolved oxygen parameter which shows a decrease from points 1 to 8. In addition, turbidity is increasing in the downstream area. At point 8 there is high sedimentation, so that the turbidity at that point reaches a value of 909 NTU.

Table 6 Water quality

Sampling point	Temperature (°C)	pH	DO	Turbidity	TSS (mg/L)	BOD (mg/L)	COD (mg/L)
1	29,6	7,74	5	24,9	20	1,1	7,82
2	32,3	7,78	3	20,3	28	2,2	15,57
3	30,3	7,43	3,2	24,92	40	3,4	21,08
4	31,9	7,9	4	41,9	52	3,8	25,81
5	32,7	7,74	3,6	55	84	3,8	28,54
6	30,6	6,99	3,1	848	110	2,8	31,59
7	31	6,89	2,3	101	78	2,5	18,32
8	29,5	7,23	2,6	909	126	2,8	33,85

In general, the TSS value from upstream to downstream has increased. The presence of sedimentation in the downstream area makes the TSS value higher in the downstream area, especially at point 8 which reached 126 mg/L. The presence of runoff water due to high rainfall in urban areas poses a great risk of soil sedimentation entering the water body. When sediment accumulates in water bodies, the downstream area has a high vulnerability to high TSS (Kurniawan *et al.* 2019). The TSS value is strongly associated with turbidity. The higher the TSS value, the higher the turbidity value. A study states that turbidity can describe the potential for TSS, COD, and total phosphate (Liu *et al.* 2020). This can be seen in the turbidity value at point 8, which has the highest value compared to other points. TSS and turbidity parameters are closely related to the quality of drinking water and the aesthetics of water bodies. Therefore, water bodies with high TSS are difficult to use for drinking water sources and tourism sites.

Similar to TSS, COD shows an increase from points 1 to 8. This result also indicated that COD, TSS, and turbidity have a strong relationship. Turbidity is an in situ water quality parameter that can predict other parameters that require laboratory tests such as TSS and COD (Kurniawan *et al.* 2019). An increase in COD value indicates an increase in chemicals from upstream to downstream areas. In some industrial areas, COD values show an increase due to waste released into water bodies (Swati and Faruqui 2018). Based on the land cover map, industrial areas in Karawang Regency are concentrated in the upstream (South) area of Karawang Regency. However, in the upstream area, the COD value still meets class 1. This increase can be caused by the accumulation of chemicals in the downstream area so that the sampling point in the downstream area shows a high value.

In contrast to TSS and COD, BOD at points 4 and 5 has the highest value. Points 4 and 5 are located in Karawang City Center. Karawang City Center is dominated by built-up areas such as settlements and other commercial areas. The high occurrence of BOD within commercial land use types may be attributed to the discharge of organic wastes such as wastewater, human and animal excreta, and detergents released directly into the water, which uptake the oxygen level in the water body. BOD increases due to the biodegradation of inorganic materials which exerts oxygen tension in water bodies (Fashae *et al.* 2019).

Based on the results of the analysis of settlement density in 2003 and 2014, Telukjambe District is one of the most densely populated residential areas in Karawang. This area continues to develop from year to year due to the growing population and economic activity in the region Telukjambe is the village with the highest regional development index. This is related to the high BOD pollutant potential around the area (points 3, 4, and 5).

Pollution Load Capacity

The study location was divided into 2 segments (Figure 4), segment 7 and segment 8. Segment 7 has a segment length of 29,74 km located in Karawang Regency, which crosses 5 districts: Ciampel, Klari, Teluk Jambe Timur, West Karawang, and East Karawang District. Segment 8 has a length of 66,48 km across 2 regencies, Bekasi and Karawang regencies, with a total of 9 (nine) districts. In the Bekasi Regency area, it is included in 4 (four) Districts, Kedungwaringin, Pebayuran, Cabangbungin, and Muara Gembong District, while in Karawang Regency it is included in 5 (five) Districts: West Karawang, Rengasdengklok, Jayakerta, Batujaya, and Pakisjaya District.

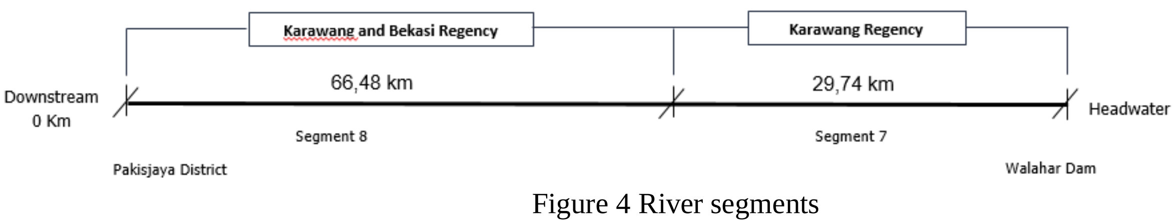


Figure 4 River segments

The Qual2Kw water quality model applies simulations in two different scenarios. Scenario 1 was carried out by using the water quality from upstream, then inputting the pollutant load from the measurement results for the PS pollutant, while the NPS pollutant load was inputted by trial and error until the simulation results approach the water quality data sampled in the entire study area. The inputted pollutant loads from PS and NPS were then summed and analyzed. Meanwhile, scenario 2 was executed using the same upstream water quality data as scenario 1, but the input of the pollutant load was carried out so that the simulation results approach class 2 water quality in all segments of the Downstream Citarum River modeled using the scenario (Table 7). In the 2020-2024 period, the Ministry of Environment and Forestry set the Citarum river area from the Jatiluhur reservoir to the coastal estuary at class 2 water quality. This is the reason why in scenario 2 the simulation results should approach class 2 water quality.

Table 7 Scenario Model calculation of pollution load capacity

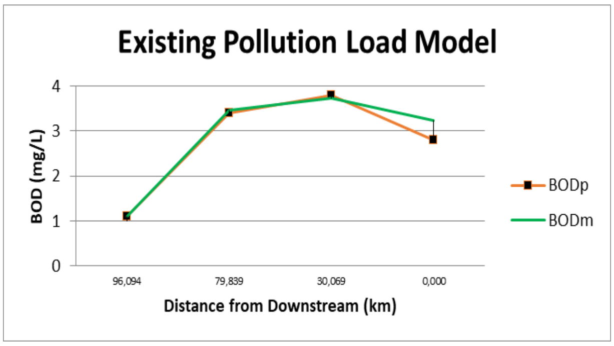
Scenario	Treatment in headwater			Output
	Debit	Water quality	Pollution load	
1 Existing pollution load	Based on measurement	Based on measurement	Input Model PS: MoEF 2017 NPS: Trial and error Model	Existing Pollution Load Model
2 Pollution Load Capacity	Based on measurement	Class 2	Input Model PS: MoEF 2017 NPS: Trial and error Model	Pollution Load Capacity for Class 2

Although we use 3 water quality parameters (BOD, COD, TSS) for PLC monitoring, MoEF data in 2017 only used BOD parameter for PLC analysis. Thus, in this research, we can only compare the BOD data. Based on calculations using the QUAL2Kw water quality model, the results of the existing pollution load and the calculation of the pollution load carrying capacity for BOD parameter are presented in Table 8.

Table 8 Recapitulation of BOD pollution load capacity of the Downstream Citarum River

Segment	Existing pollution load (kg/day)	Percentage (%)	Pollution load capacity (kg/day)	Excess pollutant (kg/day)
7	11.380	47	4.177	7.203
8	38.448	53	30.370	8.078
Total	49.828	100	34.546	15.282

The results of the calculation of the PLC (Table 8) illustrate the relationship between the existing/actual pollutant load both originating from certain sources and unspecified sources entering the river with the pollutant load carrying capacity of the Downstream Citarum River. Furthermore, when the value of the incoming pollutant load is greater than the value of carrying capacity, it means that the pollution load has exceeded the pollution load capacity. The total pollution load of existing BOD entering the Downstream Citarum river body is 49 828 kg/day for BOD. Based on the results of the calculation of the existing pollutant load, it is indicated that the most influential PS pollutant is coming from companies that have not been identified by the wastewater treatment plant (WWTP) Companies that dispose of liquid waste into the Citarum river body especially the area before Walahar Dam. The next thing that affects the downstream area is the NPS pollutant. The study location limits the administrative areas of Bekasi Regency and Karawang Regency, so it is indicated that Bekasi Regency contributes to the load that enters the downstream area of Citarum.



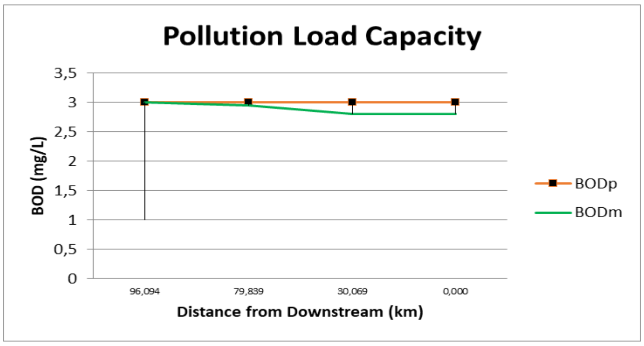


Figure 4 Graphics of the BOD model in the Downstream Citarum River:
scenario 1 (above) and scenario 2 (below)

The BOD parameter is a special parameter to see the content of Biochemical Oxygen Demand on a surface which is an indicator for determining water quality. BOD is a parameter measuring the amount of oxygen needed by bacteria to break down almost all dissolved and suspended organic substances in wastewater. It is necessary to calculate the pollution load to find out how much daily pollutant load is in main rivers and tributaries (kg/day). The following pictures are a graphics of the relationship between BOD parameters and the value of the quality standard and the pollution load capacity, based on the Qual2Kw water quality model in the study location as shown in Figure 5.

Table 9 Actual and ideal pollution load from point source pollutant

No	Point source	Distance (Km)	Debit	Actual		Ideal	
				BOD concentration (Mg/L)	BOD pollution load (Kg/Day)	BOD concentration (Mg/L)	BOD pollution load (Kg/Day)
1	PT. PD II	93,635	0,17361	48	720,00	48	720,00
2	PT. CS	93,38	0,00463	21	8,40	21	8,40
3	PT. APF I*	92,63	0,00023	5.210	104,20	260	5,20
4	PT. APF II*	92,63	0,00058	1.025	51,25	400	20,00
5	PT. APF III	92,63	0,00463	499	199,60	499	199,60
6	PT. MKT	92,52	0,00289	23	5,75	23	5,75
7	PT. MS	85,28	0,92592	23	1.839,99	23	1.839,99
8	PT. PF	84,31	0,00006	95	0,47	95	0,47
9	PT. WIT	83,47	0,00009	95	0,76	95	0,76
10	PT. DIC	82,82	0,00556	102	48,96	102,00	48,96
11	PT. CI	73,74	0,00289	324	81,00	324,00	81,00
12	PT. FSJ	73,54	0,00289	41	10,25	41	10,25
13	PT. SMD	71,48	0,00209	324	58,56	324	58,56
14	PT. PD I	69,29	0,03472	47	141,00	47	141,00
	TOTAL				3.270,18		3.139,93

*Industry that needs to reduce BOD concentration

The simulation results using scenario 1 show that in all segments, the BOD concentration has exceeded the class 2 water quality. This condition means that the Downstream Citarum River can no longer carry water pollutant loads for BOD. The complete results of the PLC calculation for the BOD parameter based on Qual2Kw (with RMSE 0.078) are presented in Tables 9 and 10. From scenario 1 we can see the existing BOD pollution load ranged from 1,1 - 3,8 mg/L. From scenario 2, the green line shows the ideal condition to be achieved to fulfill the water quality class 2. The orange line in scenario 1 indicates the existing water quality, in scenario 2 indicates the quality standard. The green lines in both images indicate the model achieved if it follows the existing pollutant and quality standards.

To fulfill the pollution load capacity, it is necessary to reduce pollutants both from PS pollutants (industry) and NPS pollutants. In Table 9, there is a comparison of pollutant loads from PS and NPS and their ideal conditions. Based on the table, it can be seen that the existing PS pollutant from the industry was not much different from its capacity of 130,25 kg/day. However, to meet the quality standards of river water quality, it is still necessary to reduce the concentration of BOD from some industries so that the pollutant load fulfills its carrying capacity. Some industries that need to reduce BOD concentrations include PT APF I and PT APF II. All PS pollutants are in segment 7, so all pollutants in segment 8 are NPS pollutants.

Unlike PS pollutant, NPS pollutant has a big difference between actual and ideal conditions. The difference reached 15.250 kg/day or more than 100 times PS Pollutant (Table 10). This indicated that maximum efforts are needed to reduce the NPS pollutant concentration. In NPS pollutants, all points need to reduce BOD concentrations so that ideal conditions can be fulfilled. NPS 1 - 8 is located in segment 7, and NPS 9 - 10 is located in segment 8. This shows that the pollutants in segment 7 come from PS and NPS while in segment 8 only come from NPS.

Table 10 Actual and ideal pollution load from non-point source pollutant

No	Non point source	Distance (Km)	Debit	Actual		Ideal	
				BOD concentration (Mg/L)	BOD pollution load (Kg/Day)	BOD concentration (Mg/L)	BOD pollution load (Kg/Day)
1	NPS 1	94,819	0,50000	8	346	3	130
2	NPS 2	88,728	0,50000	8	346	3	130
3	NPS 3	87,836	0,50000	8	346	3	130
4	NPS 4	77,085	0,50000	8	346	3	130
5	NPS 5	76,425	0,50000	8	346	3	130
6	NPS 6	67,054	0,50000	50	2.160	3	130
7	NPS 7	63,545	0,50000	50	2.160	3	130
8	NPS 8	62,095	0,50000	50	2.160	3	130
9	NPS 9	54,775	0,50000	840	36.288	700	30.240
10	NPS 10	40,435	0,50000	50	2.160	3	130
	TOTAL				46.656		31.406

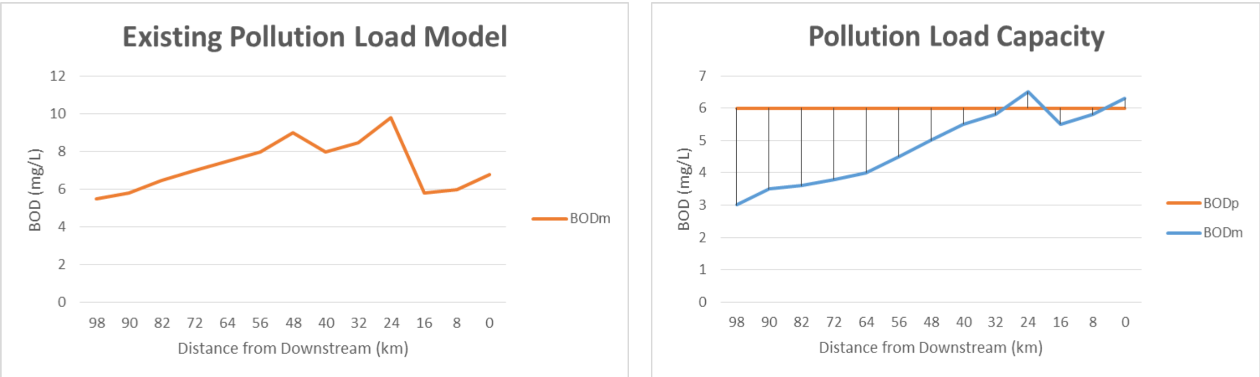


Figure 5 Graphics of the BOD model in the Downstream Citarum River: actual condition (above) and BOD 75% reduction scenario (below) in 2017 (MoEF 2017)

In the same scenario, the 2017 data from MoEF is presented in Figure 6. The 2017 data shows higher BOD values which range from 5,5 to 9,8 mg/L. Thus, the data in 2022 shows a better condition from 2017, or 4 years after the Citarum Harum Program water quality shows many improvements. In 2017, the target class for Citarum River water is class 3 with a BOD concentration of 6 mg/L. To meet this target, a scenario of reducing the pollution load by up to 75% is required. However, in the scenario used in 2017, the government chose to reduce the pollutant load in the downstream Citarum by up to 50%. The total pollutants in the Citarum watershed in Karawang Regency, which must be reduced in 2017 are around 49.761,79 kg/day so that the targeted water quality of the Citarum River in that period can be met. This amount was much larger than the conditions in 2022, which only needed a decrease of 15.282 kg/day to reach class 2.

Citarum Harum Effect

The improvement in water quality in the Lower Citarum River shows the positive influence of the revitalization program organized by the government. Usually, environmental revitalization programs are initiated by the local government and supported by various related institutions in the region. However, the Citarum revitalization was initiated directly by the President of the Republic of Indonesia through Presidential Regulation Number 15/2018. The issuance of this regulation became the fastest President Regulation to deal with the environment in the history of Indonesia. In general, this regulation contains the Acceleration of Pollution and Damage Control of the Citarum River (Chandra *et al.* 2019).

Because of the command that comes from the president, many stakeholders contribute to the realization of this program. There is a steering board and task force to help run the program. The steering board consists of several ministers while the task force is commanded by the Governor of West Java. In carrying out his duties, the governor of West Java is assisted by the regional military commanders from the provinces of West Java and Jakarta and the regional police chiefs from the same regions. The Task Force has high authority in controlling pollution, inspecting industries around the Citarum River, and prohibiting residents from constructing buildings on river borders.

This program is planned to run for approximately 7 years. To facilitate implementation and supervision, the Citarum River is divided into several sectors. Each sector has a member of the task force who monitors this program. This program also involves people from community organizations, philanthropy, religious organizations, enterprises, academics, and other stakeholders. Each ministry also contributes to this program. For example, the ministry of environment and forestry plays a role in providing plant seeds, planting programs, and managing waste around rivers.

The contribution from various elements of the government and the government makes the Citarum Harum Program feel very special. The involvement of the military and police in supervising this program made the river revitalization process run effectively (Ayyasy *et al.* 2021). The involvement of the military in this program has also made the community respect the program and reluctant to do environmental damage. This program is a breakthrough in Indonesia. If this program can bring success to the improvement of the Citarum River, it is not impossible to carry out a similar scheme to other environmental revitalization programs.

CONCLUSION

Water quality and pollution load capacity in the Citarum Hilir River show a significant increase in 2022. This can be seen from the decrease in pollution load capacity at the study site. In 2022, the reduction of BOD pollutants of 15.282 kg/day is needed to fulfill targeted water class 2 in the Downstream Citarum River. In the same location, a reduction of 49.761,79 kg/day of BOD pollutants was needed to reach targeted class 3 water quality in 2017. Data of existing pollution load also show that in 2022, BOD level in Downstream Citarum Harum ranged from 1,1 - 3,8 mg/L while in 2017 BOD level ranged from 5,5 - 9,8 mg/L. The "Citarum Harum" revitalization program initiated by the central government in 2018 is estimated to be one of the factors that have made the water quality in downstream Citarum increase. The military involvement in river revitalization makes the river cleaning process more effective. This program also changed the mindset of the community to participate in protecting the environment and avoiding throwing garbage in the river.

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