ISSN 2541-223X
Volume 4 2022

WATER POLLUTION AND SEDIMENT INDEX OF THE CIMANUK RIVER BEFORE DEVELOPMENT OF RAW WATER INTAKE OF DRINKING WATER

E Wardhani[1*], M R Pratama[1]

[1] Environmental Engineering Study Program, Faculty of Civil Engineering and Planning, National Institute of Technology, Bandung, Indonesia

ABSTRACT

Cimanuk River water is the main raw water source in West Java Province. The quality of the water must be maintained so that it can be useful in the long term. Cimanuk River water is planned to be a source of raw water for clean water services in the West Java Region. Based on this, it is necessary to know the quality of this river water. This study aims to calculate the water and sediment pollution index considering that there is a strong relationship between the water column and sediment in the river. The research method uses the Pollution Index method to determine the water pollution index and the Contamination Factor and Metal Pollution Index to assess the quality of sediment due to heavy metal pollution. . There are 6 (six) parameters that do not meet the quality standards, namely: BOD_5, COD, Total Ammonia (NH_3-N), Sulfur as H_2S, Free Chlorine (Cl_2), and Copper (Cu). Sources of pollution are predicted to come from domestic and agricultural activities in the Cimanuk river basin. The results of the analysis of sediment quality using the Contamination Factor method showed that the sediment of the Cimanuk River was polluted with heavy metals Cadmium and Copper with a very high category. Based on the results of calculations using the Metal Pollution Index method, it was concluded that the sediment of the Cimanuk River was polluted with heavy metals.

Keywords: Cimanjuk, River, Sediment, Water, Quality

1. INTRODUCTION

This study aims to determine the quality of water and sediment of the Cimanuk River which will be used as a source of raw water for clean water services in the West Java Province. The intake location is in Kadujaya Village, Jatigede District, Sumedang Regency at an elevation of 121.7 m above sea level. The planned water intake discharge at the intake is 1,500 liters/second. Based on this, research is needed on the quality of raw water that will be taken to be processed at the water treatment plant. Many researches on river water quality have been carried out in Indonesia. The results showed that rivers in Java have been polluted by domestic, non-domestic, industrial, and agricultural wastes. Research on river water quality continues to grow because the pollution that occurs continues to increase and the need for raw water sources continues to grow along with population growth. Rivers are the aquatic environment most at risk of being affected by pollution from human activities in the watershed.

[1*] Corresponding author's email: ekawardhani08@gmail.com
DOI: https://doi.org/10.20885/icsbe.vol2.art18

The decline in the quality of river water as a source of raw water for drinking water continues to occur in Indonesia, this makes it increasingly difficult to find sources of raw water. Heavy metal pollution is very important to take into account because it is non-degradable, persistent, and can accumulate in the body of living things. Heavy metals in waters are usually found in low concentrations but human activities will increase the concentration of heavy metals in waters, causing environmental problems that must be resolved immediately. Heavy metals enter the aquatic environment from natural processes and human activities. The enrichment of heavy metals in the aquatic environment occurs through various sources, namely: industrial, agricultural, mining, and domestic waste. The main sources of natural heavy metal pollution are volcanic activity and rock weathering.

In developing countries, the rapid increase in the agricultural and industrial sectors has contributed to an increase in the content of heavy metals in the air, water and soil. Pollutants that enter the river will accumulate in the sediment which at some point will be released back into the water column and become a secondary pollutant in these waters. Sediments play an important role in the movement and accumulation of heavy metals which in the long term have the potential to cause toxicity to humans.

This study aims to determine the index of water and sediment pollution in the Cimanuk River adjacent to the location of the raw water intake. Water pollution is calculated using the Water Pollution Index method referring to the Decree of the Minister of the Environment Number 115 of 2003 concerning guidelines for determining the status of water quality using the pollution index method. The sediment pollution index uses the Contamination Factor (CF) and Metal Pollution Index (MPI) methods. Researchers in several countries have used both sediment pollution indices because the formula is simple so it is easy to use. The sediment quality assessment method has been applied in several countries, such as assessing the sediment quality in the canal adjacent to the domestic waste landfill area in Qayen City, Iran using the Igeo, CF and MPI methods for Cd, Ni, Pb, Zn, and Cr metals. The water pollution index method has been applied to determine the quality of river water in several places such as the Cimahi River and several rivers in Central Java Province. The results showed that the quality of river water had deteriorated as evidenced by the index value of lightly to heavily polluted water.

2. RESEARCH METHODS

2.1. Research Time and Location

The location of the research was carried out on the Cimanuk River which is the location for the construction of raw water intake for drinking water services in the Cirebon and surrounding areas. The coordinates of the sampling point are before Intake S 06˚83'75.69" and 108˚97.00" and after Intake S 06˚49'59.00" and E 108˚06'27.12". Water quality sampling locations in the Cimanuk River are presented in Figure 1.

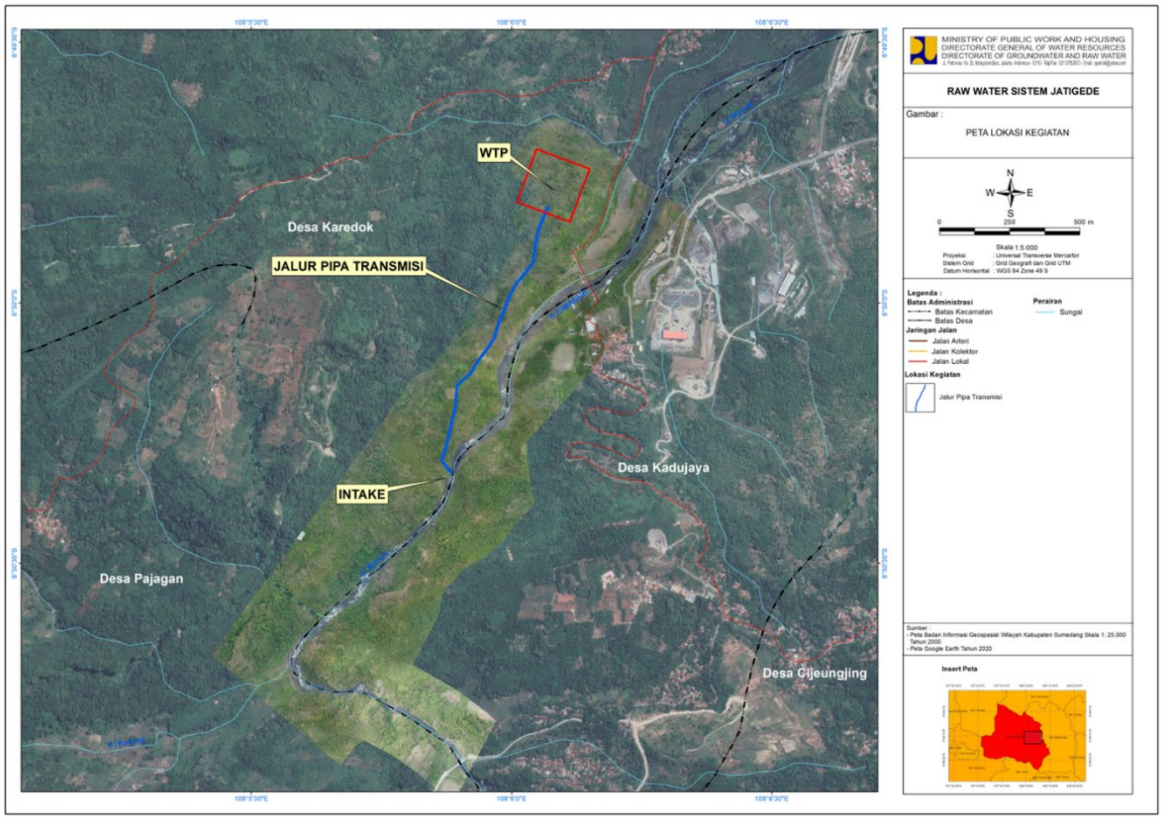

Figure 1 Location of sampling points for water quality inspection of the Cimanuk River

2.2. Data Analysis Method

The water sampling method refers to the Indonesian National Standard Number 6989.57-2008 concerning water and wastewater-section 57: surface water sampling method Water and sediment quality checks were carried out on: January 24 -07 February 2022. The quality standard used refers to the Government Regulation of the Republic of Indonesia No. 22 of 2021 concerning the Implementation of Environmental Protection and Management Annex VI Class 1, namely water whose designation can be used for drinking water raw water, and or other uses that require the same water quality as that use.

The sediment sampling method refers to the Indonesian National Standard No 8520:2018 regarding the procedure for sampling the solid phase toxic and hazardous waste. The quality standard of heavy metal concentration in sediment is compared with the quality standard based on Government Regulation no. 101 of 2014 concerning Management of Hazardous and Toxic Waste. Determination of water quality status is based on the Decree of the Minister of the Environment Number 115 of 2003 concerning guidelines for determining water quality status using the pollution index method. The table of water quality values based on the pollutant index is presented in Table 1.

Table 1 Water Quality Based on Water Pollutant Index Value

Score	Water Quality Status
$0 \leq IP \leq 1,0$	Meets Quality Standards (good condition)
$1,0 < IP \leq 5,0$	Lights Pollution
$5,0 < IP \leq 10$	Lights Pollution
$IP > 10$	Heavy Polluted

Source : (Keputusan Menteri Lingkungan Hidup Nomor 115 Tahun 2003)

a. Contamination Factor (CF)

The level of sediment contamination by heavy metals is often expressed by the contamination factor or CF which is calculated by the following equation:

$$CF = \frac{Cm}{Cb}$$

Where Cm is the metal concentration in the sediment sample (mg/g) and Cb is the background metal concentration (mg/kg). This assessment method compares the concentration of one type of heavy metal with the background heavy metal which is the original heavy metal concentration from the earth's crust. The sediment quality assessment method using the CF and MPI methods is a development of geology in the field of environmental pollution. The principle of calculation is to compare the total concentration of heavy metals measured with the total concentration of background heavy metals (background concentration/Cb). Cb is the concentration of heavy metals contained in sediments originating from the erosion process of the rock that formed it which is not affected by human activities. Cb is very specific to the location and geological conditions of the study area [16]. This study uses the background concentration of the results of research conducted in the Citarum River watershed. Background concentrations for Cd were 0.34 ± 0.10 mg/kg, Cr 110.57 ± 28.61 mg/kg, Cu 49.93 ± 9.28 mg/kg, and Pb 18.62 ± 9.83 mg/kg [17]. The results of the calculations using the CF method are compared with several classes of pollution levels as presented in Table 2.

Table 2 Values and Categories of Sediment Quality Assessment with the CF Method

Nilai CF	**Pollution category**
CF < 1	*Low*
1 ≤ CF ≥ 3	*Moderated*
3 ≤ CF ≥ 6	*Considerable*
CF > 6	*Very high*

Source : (Thomilson D. C. et al., 1980)

b. Metal Pollution Index (MPI)

MPI is a sediment quality assessment method related to heavy metal pollution that uses data from more than one measurement point. This method has the formula presented in equation 2.

$$MPI = (CF_1 \times CF_2 \times CF_3 \ldots\ldots\ldots \times CF_n)^{1/n}$$

Where n is the amount of metal studied and CF is the value of the contamination factor calculated using equation 1. This MPI method is a simple way to assess the quality of sediment in waters. The results of the calculation using the MPI method are presented in Table 3.

Table 3 Values and Categories of Sediment Quality Assessment with the MPI Method

MPI Value	Pollution Category
< 1	Sediment has not been polluted

>1	Sediment has been polluted

Source : (Thomilson D. C. et al., 1980)

3. RESULT AND DISSCUSSION

Based on the results of the analysis of laboratory results compared with quality standards, it was concluded that there were 6 (six) parameters that did not meet the quality standards, namely: BOD5, COD, Total Ammonia (NH3-N), Sulfur as H2S, Free Chlorine (Cl2), and Copper (Cu). The following description will explain the parameters that do not meet the quality standards. BOD5 is one of the parameters used to determine the content of organic matter that is easily decomposed in water bodies. The quality standard for the BOD5 parameter is based on Government Regulation Number 22 of 2021 class I of 2 mg/L. Based on the results of the analysis, the concentration of BOD5 before the intake location was 10.5 mg/L and after the intake was 10.06 mg/L. The high concentration of BOD5 in the Cimanuk River is predicted to come from domestic and agricultural activities in the watershed. The concentration of BOD5 at the activity site is presented in Figure 2. COD is a parameter that is always juxtaposed with BOD5 to determine the content of organic matter in water. The quality standard for COD parameters is based on the quality standard of 10 mg/L. Based on the analysis results, the COD concentration before the intake location was 32.821 mg/L and after the intake was 32.457 mg/L. The same as BOD5, the source of COD is predicted to come from domestic and agricultural activities in the watershed. The COD concentration at the activity site is presented in Figure 3.

The quality standard for the parameter Ammonia (NH3-N) is set at 0.10 mg/L. The quality standard for the parameter Ammonia (NH3-N) is set at 0.10 mg/L. Based on the analysis results, the total Ammonia (NH3-N) concentration before the intake location was 0.281 mg/L and after the intake was 0.469 mg/L. The high concentration of this parameter in the Cimanuk River is predicted to come from domestic and agricultural activities in the watershed. The total concentration of Ammonia (NH3-N) at the activity site is presented in Figure 4. The high content of H2S in the river is the impact of the high content of organic matter in the water. The anaerobic decomposition process produces this compound. The quality standard for Sulfur as H2S parameter is 0.002 mg/L. Based on the results of the analysis the concentration of Sulfur as H2S before the location of the intake was 0.03 mg/L and after the intake was 0.03 mg/L. The concentration of Sulfur as H2S at the activity site is presented in Figure 5. The quality standard for the Free Chlorine (Cl2) parameter is based on the quality standard of 0.03 mg/L. Based on the analysis results, the concentration of Free Chlorine (Cl2) before the location of the intake was 0.08 mg/L and after the intake was 0.09 mg/L. The high concentration of Free Chlorine (Cl2) in the Cimanuk River is predicted to come from domestic and agricultural activities in the watershed. The concentration of Free Chlorine (Cl2) at the activity site is presented in Figure 6. The quality standard for the Copper (Cu) parameter is 0.020 mg/L. Based on the results of the analysis of the concentration of Copper (Cu) before the location of the intake of 0.02 mg/L and after the intake of 0.034 mg/L. The high concentration of total copper (Cu) in the Cimanuk River is predicted to come from agricultural activities whose waste residue accumulates in the river. The concentration of Copper (Cu) at the activity site is presented in Figure 7.

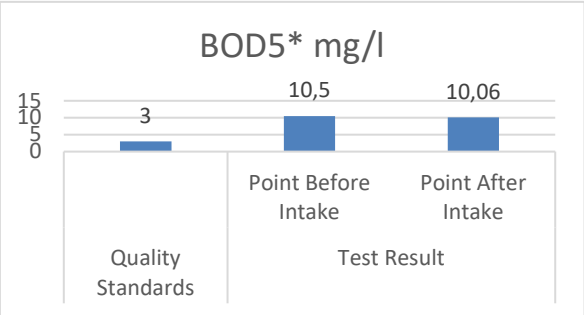

Figure 2. BOD5 Pollution Profile

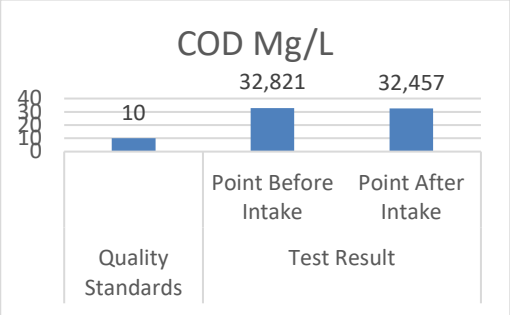

Figure 3. COD Pollution Profile

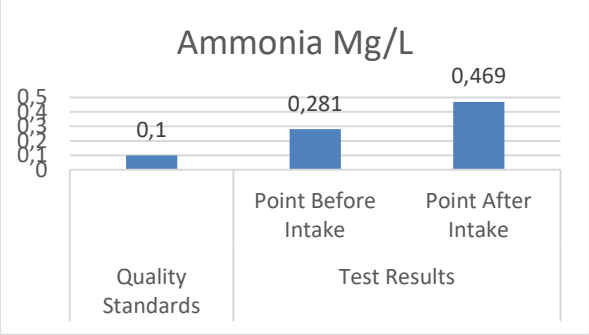

Figure 4. Ammonia Pollution Profile

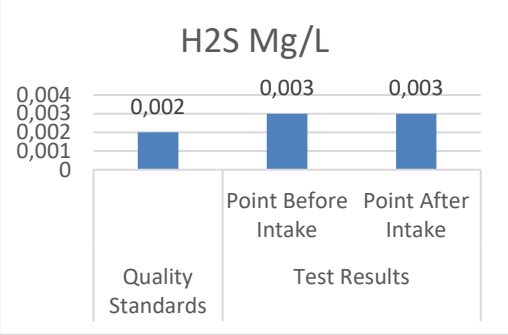

Figure 5. H2S Pollution Profile

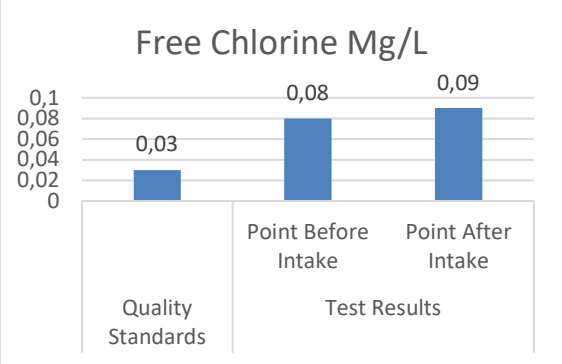

Figure 6. Free Chlorine Pollution Profile

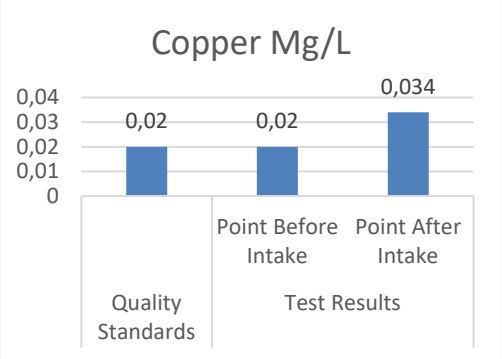

Figure 7. Pollution Profile of Copper (Cu)

Based on the calculation results, the water quality of the Cimanuk River is included in the category of light pollution with an index value of 1.81-1.86. Cimanuk River water must be treated first before being used as a source of raw water. The processing carried out depends on six parameters that exceed the quality standard. The results of the study were compared with water quality in several areas. Table 4 presents a comparison of research results with similar studies that have been conducted in Indonesia. Based on Table 4, the water quality of the lightly polluted Cimanuk River is relatively the same as other rivers in Indonesia such as the Blukar River, Kendal Regency, Percut River, Percut Sei Tuan District, Deli Serdang Regency, Jaing River, Tabalong Regency, and Lesti River, Batu City.

ISSN 2541-223X
Volume 4 2022

Table 4 Comparison of Water Quality of Several Rivers in Indonesia

Name	Parameter Not Meetings Quality Standards	Water Quality	Status	Source
Blukar River Kendal Regency	BOD and COD	0,49-3,28.	Lightly Polluted	(H. S. Huboyo et.al., 2009)
Percut River, Percut Sei Tuan District, Deli Serdang Regency	BOD	2,21-3,55	Lightly Polluted	(Machairiyah et.al., 2020)
Jaing River Tabalong Regency	DO, BOD, COD, Fecal coliform and Total Coliform	4,027-4,173	Lightly Polluted	(Yuniarti, Danang Biyatmoko, 2019)
Lesti River Batu City	BOD, COD, nitrate and fosfat	< 5	Lightly Polluted	(Bambang Rahadi Widiatmono et.al., 2019)
Cimanuk River	BOD_5, COD, Amonia (NH_3-N) total, Belerang sebagai H_2S, Klorin Bebas (Cl_2), dan Tembaga (Cu)	1,81-1,86	Lightly Polluted	Research Results 2022

The high concentration of copper heavy metal in the water was analyzed again for its content in the sediment to find out how the quality of the sediment was. This is done to determine whether copper has accumulated in the sediment or not. The high concentration of copper in the sediment indicates that the heavy metal pollution has been going on for a long time (Eka, W. et.al., 2018) (Wardhani, E. et.al., 2021). The results of heavy metal concentrations in sediments are presented in Table 5. Considering that the Government of Indonesia has not yet issued a quality standard for sediment, the quality standard used is Government Regulation no. 101 of 2014 concerning Management of Hazardous and Toxic Waste.

Table 5 Heavy Metal Concentration in Citarum River Sediment (mg/L)

No	Parameter	Unit	Quality Standards		Test Result	
			TCLP-A	TCLP-B	1	2
1	Cadmium (Cd)	mg/L	0,90	0,15	0,04	0,12
2	Copper (Cu)	mg/L	60,00	10,00	8,91	9,86
3	Lead (Pb)	mg/L	3,00	0,50	0,22	0,13
4	Chromium (Cr)	mg/L	-	-	0,11	0,22

TCLP is Toxicity Characteristic Leaching Procedure)

Based on Government Regulation No. 101 of 2014 concerning Management of Hazardous and Toxic Waste, waste is identified as Category 1 B3 waste if the waste has a concentration of pollutant substances greater than the TCLP-A quality standard. Waste is identified as category 2 B3 waste if the waste has a concentration of pollutant substances greater than or less than the TCLP-A quality standard and greater than the TCLP-B quality book. Category 1 B3 waste is B3 waste that has an acute (sudden/sudden) impact on humans, as well as a negative impact on the environment. Category 2 B3 waste

is B3 waste that has a non-acute (delayed) effect and has an indirect impact on humans and the environment. This category of B3 waste has a toxicity that tends to be sub-chronic or chronic (long term). Based on the results of the examination, it was concluded that the concentration of heavy metals in the sediment of the Cimanuk River did not include B3 waste categories 1 and 2.

Concentrations of heavy metals in sediments were made in mg/kg and compared with quality standards based on heavy metal quality standards in sediments prevailing in Australia and New Zealand as presented in Table 6. Based on the results of the comparison, it is concluded that Cadmium and Copper have exceeded the quality standards set by these quality standards so that their presence in sediments must be watched out for. Heavy metals contained in sediments if environmental conditions allow will be released and dissolved in water.

Table 6 Heavy Metal Concentration in Cimanuk River (mg/kg)

No	Parameter	Test Result		Quality Standards	
		1	2	Low	High
		mg/kg	mg/kg	mg/kg	mg/kg
1	Cadmium (Cd)	5,57	14,87	1,5	10
2	Copper (Cu)	1.113,70	1.232,31	65	270
3	Lead (Pb)	27,69	15,66	50	220
4	Chrome (Cr)	14,07	27,81	80	370

The results of the sediment quality analysis using the CF method are presented in Table 7. Based on the table, the sediment of the Cimanuk River was polluted with heavy metals Cadmium and Copper with very high categories in two measurement locations. Lead polluted in the low to moderate category and total chromium polluted in the low category. Based on the results of calculations using the MPI method, it was concluded that the sediment of the Cimanuk River was contaminated with heavy metals because the MPI value was 13.67 at point 1 and 2.88 at point 2.

Table 7 Value of CF in Cimanuk River Sediment (mg/kg)

No	Parameter	Test Results (mg/kg)		C_b	Value Of CF		CF Category	
		1	2	(mg/kg)	1	2	1	2
1	Cadmium (Cd)	5,57	14,87	0,34	16,38	43,73	*Very High*	*Very High*
2	Copper (Cu)	1.113,70	1.232,31	49,93	22,30	24,68	*Very High*	*Very High*
3	Lead (Pb)	27,69	15,66	18,62	1,49	0,84	*Moderate d*	*Low*
4	Chrome (Cr)	14,07	27,81	110,57	0,13	0,25	*Low*	*Low*
	MPI				13,67	2,88		

Many studies on sediment quality using CF have been carried out. The results show that the value is almost the same as the sediment quality in the Cimanuk River where the CF value is in the low-very high category. Sediment quality research in Sagara Anakan has a CF value of 10.8 with a very high contamination category with heavy metals analyzed, namely Pb, Cd and Cr (Hartono Nuning et.al., 2014). The CF value is between 2.41-32.88 with the very high contamination category for the analyzed parameters, namely Cd, Ni,

Pb, Cu, Zn, Cr based on the results of research in areas adjacent to the landfill (Sayadi M. H., Rezaei M. R., Rezaei A., 2015). The CF value is between 0-4.50 with the Low-considerable contamination category for the analyzed parameters, namely Cr, Fe, Mn, Co, Ni, Cu, Zn, Cd, and Pb based on the results of research in the Chaibasa Mining area of India (Jayakumar, 2006) . Based on the results of calculations using the MPI method, it was concluded that the sediment of the Cimanuk River was contaminated with heavy metals because the MPI value was 13.67 at point 1 and 2.88 at point 2. Based on the MPI value, the sediment conditions in the Cimanuk River were the same as in several locations as presented in Table 8.

Table 8. Summary of Research on Sediment Quality Assessment with MPI Method

Location	Value of MPI	Catagori	Source
Kampala Uganda River	1,09-3,87		[9]
Buringanga Bangladesh River Dry Season	13,5		[23]
Buringanga Bangladesh River Rainy Season	15,5		[23]
Tigris Turki River	1,88		[23]
Kurang Nallah Pakistan	2,03		[23]
Pakistan Rawal Lake	2,03	Polluted	[5]
Areas Close to a Domestic Waste Landfill in Egypt	3,37-12,89		[8]
Mangrove India	0,78-1,57		[3]
Saguling Reservoir	26,10-57,70		[17]
Cimanuk River	2,88-13,67		Research Results, 2022

Heavy metals can accumulate in the sediments which in time will become a secondary pollutant source for the river. The concentration of Cu in the water will be influenced by the Cu content in the sediment. Based on the results of this study, efforts to identify and inventory sources of pollutants, especially heavy metals, must be carried out so that they do not cause significant impacts in the future.

4. CONCLUSION

Research on the water quality of the Cimanuk River shows that the quality of river water is in the category of lightly polluted with an index value of 1.81-1.86. There are 6 (six) parameters that do not meet the quality standards, namely: BOD5, COD, Total Ammonia (NH3-N), Sulfur as H2S, Free Chlorine (Cl2), and Copper (Cu). Sources of pollution are predicted to come from domestic and agricultural activities in the Cimanuk river basin. The results of the analysis of sediment quality using the CF method showed that the sediment of the Cimanuk River was polluted by heavy metals Cadmium and Copper with very high categories in the two measurement locations. Lead polluted in the low to moderate category and total chromium polluted in the low category. Based on the results of calculations using the MPI method, it was concluded that the sediment of the Cimanuk River was polluted with heavy metals. Cimanuk River as one of the sources of raw drinking water requires good treatment considering that there are parameters that do not meet quality standards, especially heavy metals which are toxic, persistent and have an impact on public health.

ISSN 2541-223X
Volume 4 2022

5. REFERENCES

Detail Engineering Report Cimanuk Raw Water System Balai Besar Wilayah Sungai Cimanuk Cisanggarung

Wardhani, E., Primalaksono, Y. (2022). Pollutant Index Method in Determining the Water Quality Status of the Cimahi River in West Bandung Regency. IOP Conference Series: Earth and Environmental Sciencethis link is disabled, 2022, 999(1), 012025

Dhanakumar S, G. Solaraj, R. Mohanraj. (2015): Heavy metal partitioning in sediments and bioaccumulation in commercial fish species of thre emajor reservoirs of river Cauvery delta region, India, Ecotoxicology and Environmental Safety, 113:145-151.

Eka, W., Suprihanto, N., Dwina, R. (2018) Assessment of Heavy Metal Contamination in Saguling Reservoir Water West Java Province Indonesia. E3S Web of Conferences, 2018, 73, 06009

Zahra A, Hashmi M.Z, Malik R.N, Ahmed Z. (2013): Enrichment and geo-accumulation of heavymetals and risk assessment of sediments of the Kurang Nallah-feeding tributary ofthe Rawal Lake Reservoir, Pakistan. Sci Total Environ, 470-471C:925-33.

Wardhani, E., Roosmini, D., Notodarmojo, S. (2021). Calculation of heavy metals pollution load enters to Saguling dam West Java Province. IOP Conference Series: Earth and Environmental Sciencethis link is disabled, 2021, 802(1), 012032

Keputusan Menteri Lingungan Hidup Nomor 115 Tahun 2003 tentang pedoman penentuan status mutu air dengan metode indeks pencemaran

Sayadi M.H, Rezaei M.R, Rezaei A. (2015) Sediment toxicity and ecological risk of trace metals from streams surrounding a municipal solid waste landfill. Bull Environ Contam Toxicol.

Sekabira K, H. Oryem Origa, T. A Basamba, G. Mutumba, E. Kakudidi. (2010): Assessment of heavy metal pollution in the urban stream sediment and its tributaries, International Journal Environment Science and Technology., 7 (3) 435-446 Summer.

H. S. Huboyo, W. D. Nugraha, and R. Indah, "Analisis Penentuan Mutu Air Beberapa Sungai Di Jawa Tengah Dengan Metode Storet Dan Indeks Pencemaran," Jurnal Presipitasi: Media Komunikasi dan Pengembangan Teknik Lingkungan, vol. 6, no. 2, pp. 1-6, Sep. 2009.

Standar nasional Indonesia Nomor 6989.57-2008 tentang air dan air limbah-bagian 57: metoda pengambilan contoh air permukaan.

Peraturan Pemerintah Republik Indonesia No. 22 Tahun 2021 Tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup Lampiran VI.

Standar Nasional Indonesia No 8520:2018 tentang tata cara pengambilan contoh uji limbah bahan beracun dan berbahaya fase padat

Peraturan Pemerintah No. 101 Tahun 2014 Tentang Pengelolaan Limbah Bahan Berbahaya dan Beracun

Thomilson, D. C.; Wilson, D. J.; Harris, C. R.; Jeffrey, D. W., (1980): Problem in assessment of heavy metals in estuaries and the formation of pollution index, Helgol. Wiss. Meeresunlter, 33(1-4), 566-575.

Sakan Sanja, Devic Gordana, Relic Dubravka, Aldenovic Ivan, Sakan Nenad, Dordevic Dragana. (2015): Evaluation of sediment contamination with heavy metals: the

importance of determining appropriate background content and suitable element for normalization. Environ Geochem Health 37: 97-113

Wardhani, E., Notodarmojo, S., Roosmini, D. (2018). Stream Sediment Geochemical Survey of Selected Element in Catchment Area of Saguling Lake. MATEC Web of Conferences, 2018, 147, 08003

Machairiyah Machairiyah, Zulkifli Nasution, Bejo Slamet (2020) Pengaruh Pemanfaatan Lahan Terhadap Kualitas Air Sungai Percut Dengan Metode Indeks Pencemaran (IP). Limnotek Perairan Darat Tropis di Indonesia Vol 27, No 1 (2020)

Yuniarti Yuniarti, Danang Biyatmoko (2019) Analisis Kualitas Air Dengan Penentuan Status Mutu Air Sungai Jaing Kabupaten Tabalong. Jukung Jurnal Teknik Lingkungan Vol 5, No 2 (2019)

Bambang Rahadi Widiatmono, Bambang Suharto, Florensia Yuke Monica (2019) Identifikasi Daya Tampung Beban Pencemar dan Kualitas Air Sungai Lesti Sebelum Pembangunan Hotel. Jurnal Sumberdaya Alam dan Lingkungan Vol 6, No 3 (2019)

Australian and New Zealand Environment and Conservation Council (ANZECC). (1997): ANZECC Sediment Quality Guidelines. Report for the Environmental Research Institute of the Supervising Scientist. Sydney, Australia: AZECC ISQG-Low.

Hartono Nuning Vita Hidayati, Asrul Sahri Siregar, Lilik Kartika Sari, Gayuh Laksana Putra, Hartono, I Putu Nugraha, Agung Dhamar Syakti. (2014): Pendugaan tingkat kontaminasi logam berat Pb, Cd, dan Cr pada air dan sedimen di perairan Sagara Anakan, Cilacap, Omni Akuatika Vol XIII, hal 30-39

Sen Memet Varol dan Bulent Sen, (2012): Assessment of nutrient and heavy metal contamination in surface water and sediment of the upper Tigris River, Turkey, Catena 92.