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Analysis of Water Quality Status of Cengklik Reservoir based on Pollution Index, Boyolali Regency, Central Java, Indonesia

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Abstract: Anthropogenic activities such as fishing, fish ponds, and domestic trash contribute the most to the water quality of the Cengklik reservoir. This research aimed to analyze the water quality status and Pollution Index of the Cengklik reservoir. Water quality status was calculated by using the Pollution Index method. The results indicated that the water quality of the Cengklik Reservoir is strongly influenced by the sources of water pollutants and the surrounding area's ambient conditions. The results revealed that the water quality at the inlet is lightly polluted, with pollutant index values (Pij) of 2.56 at the inlet (CI1) and 4.02 at the inlet (CI2).

Keywords: Water quality, Pollution Index, Cengklik water reservoir, Indonesia

1. INTRODUCTION

Indonesia has various potentials for abundant natural wealth in living and non-biological natural resources. Indonesia still has a lot of natural resources that aren't being used to their full potential. One is the potential wealth of Indonesian waters, sea, or freshwater, such as lakes, rivers, and reservoirs[1]. A reservoir is one of the bodies of water that can significantly benefit people. Reservoir building serves numerous purposes, including irrigation, generating electrical energy through hydroelectric power, supplying potable water, flood control, recreation, fisheries, aquaculture, and capture. The reservoir is developed over a large region, considering the water supply used to fill the dam. Rivers and rainwater can fill reservoirs[2]. The Cengklik reservoir is one of the reservoirs in the Central Java region in Indonesia and has a dual role in ecology and economics. The Cengklik reservoir's ecological role is related to its hydrological capabilities, including the catchment area and flood control, providing water for the surrounding area, irrigation, and freshwater fish farming. Global water scarcity and the volume of wastewater effluents from industrial sites and urban agglomerations are causing considerable environmental, economic, and societal concerns[6,7]. Because of the massive volumes of contaminated water, production water can be a significant environmental hazard and a possible source of freshwater for domestic or agricultural use [2], [5].

The number of activities around the Cengklik reservoir area benefits the community in the economic field. However, the community and local government have not paid serious attention to the environmental aspect. Many land uses do not adhere to ecological principles, such as constructing food stalls on the edge of the reservoir but not equipped with wastewater treatment facilities, causing the wastewater to enter the reservoir[5], [6]. It creates a considerable risk of water pollution in the reservoir, as seen by the abundance of water hyacinth. Furthermore, the Cengklik reservoir underwent silting, which increased water levels. The substantial growth was partly due to the river silting and the vast amount of waste buried in the reservoir due to being swept away by river currents, requiring the reservoir bottom to be drained regularly by dredging [5], [7].

In practice, there are limits because the responsibility of regulating and supplying water resources services may still overlap; ineffective law enforcement and water management frameworks have yet to be established. The Citarum River in West Java is one of the world's most polluted due to insufficient government attempts to reduce pollution[8], [9]. This study provides the picture of water quality with PI for the Cengklik reservoir to support the Boyolali policymaker for ensuring water management sustainability.

2. STUDY AREA DESCRIPTION

The study was conducted at Boyolali Regency; it is located between 110° 22' - 110° 50' East Longitude and 7° 7' - 7° 36' South Latitude, Central Java Province. Boyolali has three reservoirs: Bade, Kedung Ombo, and Cengklik. Cengklik Reservoir is located between Ngargorejo and Sobokerto villages in Ngemplak Boyolali District. Three volcanoes surround this location: Merapi, Merbabu, and Lawu. The Cengklik Reservoir is located between 109°11'28"-109°14'58" east longitude and 7°1'31" - 7°2'18" south latitude. Cengklik Reservoir has a 6792.71 hectares watershed and covers 306 ha, of which 296 hectares are inundated, with an embankment length of 1693 m and a width of 750 m. In these conditions, the Cengklik reservoir may drain 1578 hectares of technically irrigated rice fields.

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Figure 1. Map of the Cengklik Reservoir area and its surroundings (Source: Boyolali Regency Regional Development Planning Agency, 2010)

3. METHODOLOGY

In this study, various types of data related to the study were collected; the type of data collected includes reservoir water quality data obtained from laboratory testing of reservoir water samples. A reservoir water sampling is carried out on the reservoir water body, the flow of river water entering the reservoir, and the flow of river water leaving the reservoir body. Laboratory testing of reservoir water samples was carried out on chemical parameters such as pH, TSS, BOD, COD, Total Phosphate, Ammonia, Total Coliform, and detergent. The instruments used in this research include pH meter, DO meter, spectrophotometer, thermometer, Gravimetric, cooler box, boat, camera, bucket, dipper, Winkler and incubation, and Reflux K2Cr2O. The Pollution Index (PIj) Method is used to determine the current state of water quality.

$$PI_j = \sqrt{\frac{(C_i/L_{ij})^2{}_M + (C_i/L_{ij})^2{}_R}{2}}$$

Note:

PIj: Pollution Index

Ci: Concentrations of water quality parameters

(i): (units adapted to Water quality parameters observed)

Lij: Standard of water quality parameters (i) designation of water (j) (unit adjusted for water quality parameters observed) (Ci/Lij)M: Maximum value

Ci/Lij (Ci/Lij)R: Average value Ci/Lij

4. RESULTS AND DISCUSSION

Based on the Law of the Republic of Indonesia Number 5 of 1990 about the conservation of biological natural resources and ecosystems, conservation aims to balance living natural resources and their ecosystems to help people improve community welfare and the quality of human life[10].

4.1 Water quality analysis of Cengklik Reservoir

Table 1 displays the results of chemical parameters from laboratory water sample analysis from various sampling sites.

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Table 1. Test Results of Cengklik Reservoir Water Laboratory.

Parameters								
Parameter	pH	TSS	BOD	COD	PO4-	NH3-N	T. Coliform	Detergent
Unit		mg/l	mg/l	mg/l	mg/l	mg/l	MPN/100ml	mg/l
RWQS	6-9	50	3	25	0,03	0,75	5000	0,2
Sample area								
CB1	6,29	4	3,82	20,35	0,0382	0,3660	460	0,0088
CB2	6,30	8	3,80	19,32	0,0250	0,3652	430	0,0043
CB3	6,32	11	4,14	20,42	0,0233	0,3856	430	0,0043
CO1	6,44	8	5,55	29,00	0,0793	0,3774	350	0,0066
CO2	6,54	14	4,39	19,01	0,0500	0,3938	540	0,0059
CI1	6,53	24	4,79	18,90	0,0936	0,3829	920	0,0043
CI2	6,60	28	3,86	16,87	0,2441	0,3633	920	0,0043

Note: RWQS: Reservoir Water Quality Standard
CB1: Reservoir Body 1
CB2: Reservoir Body 2
CB3: Reservoir Body 3
CO1: Reservoir Outlet 1
CO2: Reservoir Outlet 2
CI1: Reservoir Inlet 1
CI2: Reservoir Inlet 2

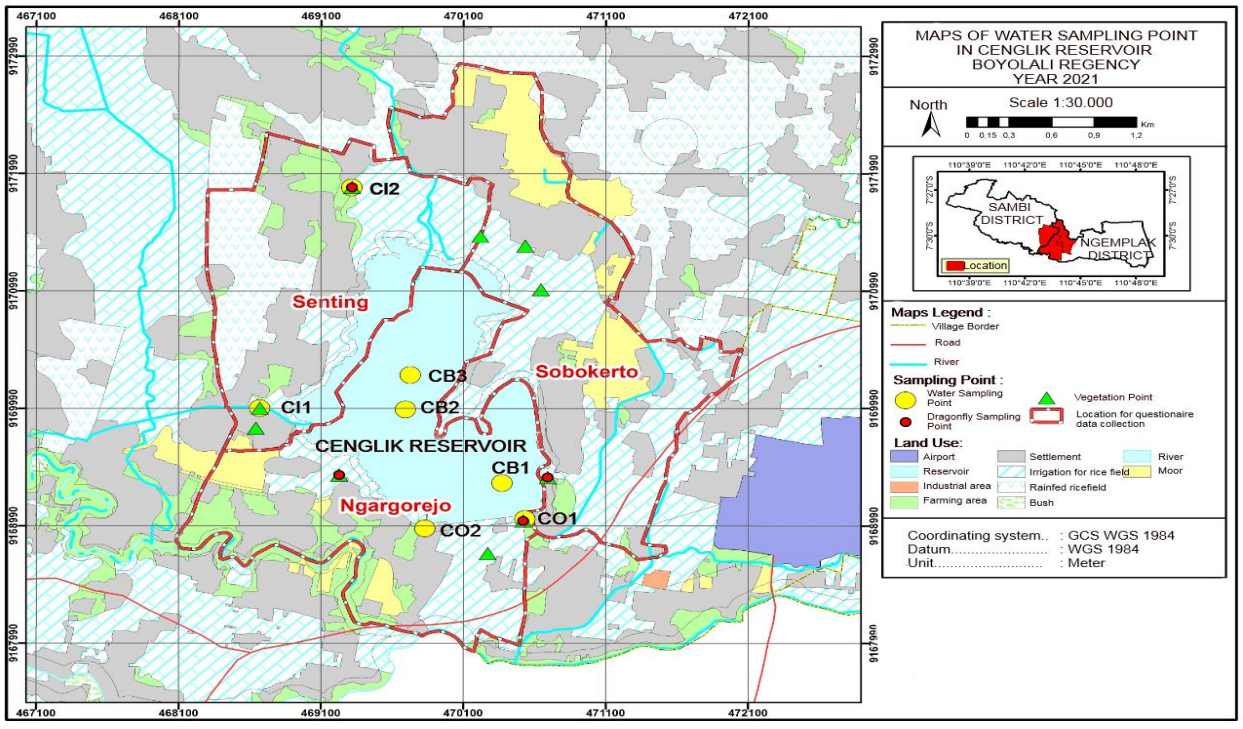

Figure 2. Map of Cengklik reservoir water sampling points and Pollutant Index (Pij) values.

The water quality of the Cengklik reservoir can be determined by comparing the results of the Cengklik reservoir quality test with the quality standards regulated by the government based on Government Regulations No. 22 of 2021 for reservoir water bodies. Based on observations, the pH value of the Cengklik reservoir water can be seen in Figure 2. The highest pH value at the CI2 sampling point (Cengklik Reservoir Inlet 2) is 6.6. In contrast, the lowest pH of the Cengklik reservoir water occurs at the sampling point CB1 (Cengklik reservoir body 1), which is 6.26. The pH value of the Cengklik

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reservoir water still meets the reservoir water quality standard according to PP 22 of 2021.

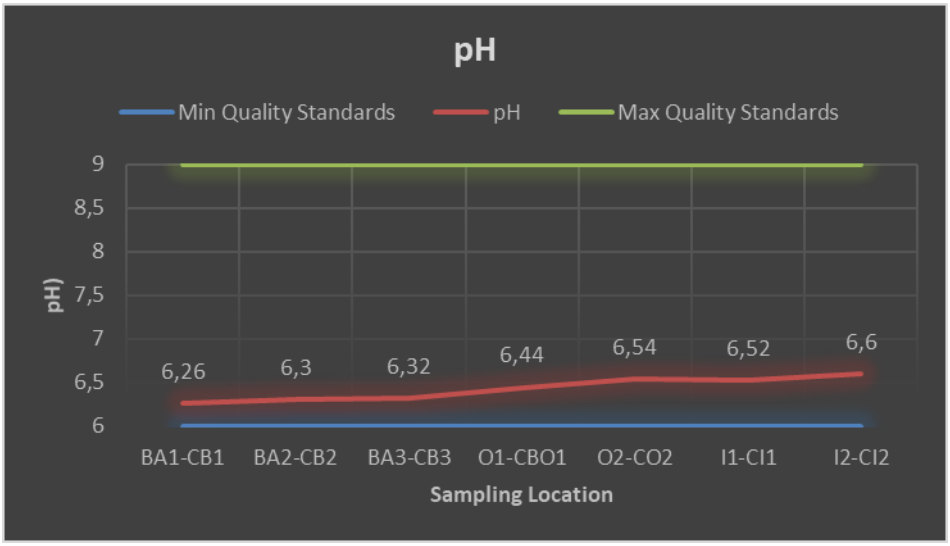

Figure 3. The pH value of the Cengklik reservoir water sample

The BOD5 value of the Cengklik reservoir water is based on observations in figure 3. The highest BOD5 value occurred at the sampling point of CB1, or Outlet 1, was 5.55 mg/L, while the lowest BOD5 of Cengklik reservoir water occurred at the sampling point of CB2 or Water Agency 2 was 3.8 mg/L. Based on the analysis results, BOD5 values in all current Cengklik reservoir water samples exceed quality standards.

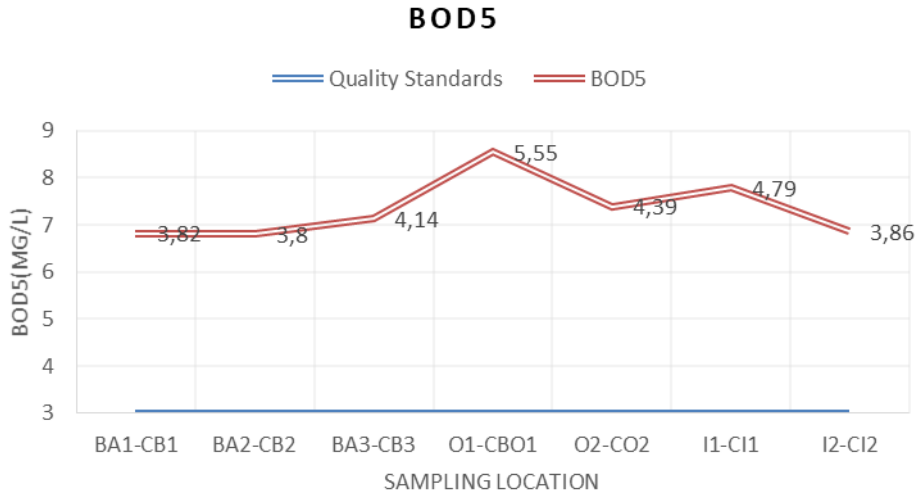

Figure 4. BOD5 value in the Cengklik reservoir water sample

COD value Cengklik reservoir water based on results observed in figure 4. The highest COD value occurred at the sampling point B01 or Outlet 1 was 29 mg/L, while the lowest COD of Cengklik reservoir water occurred at the sampling point CI2 or Inlet 2, which was 16.87 mg/L. Based on the analysis results, almost all of the COD parameters of the Cengklik reservoir still meet the quality standards, except for the sampling point at CBO1 (Waduk Water Agency 01), which is 29 mg/L, with a quality standard of 25 mg/L.

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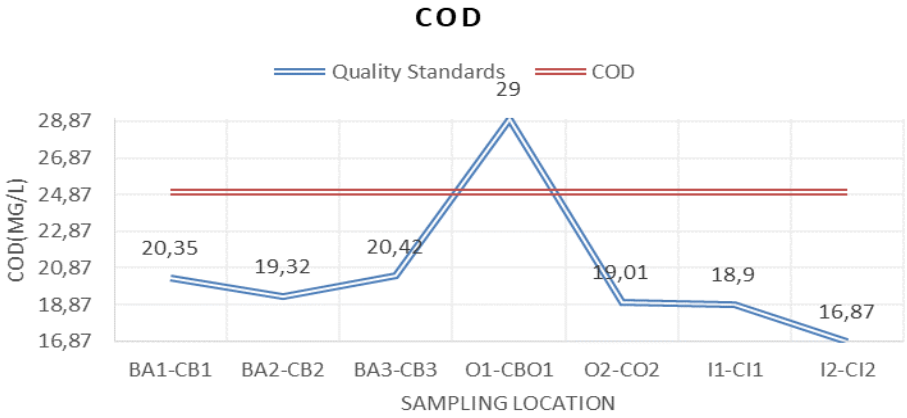

Figure 5. COD value in the Cengklik reservoir water sample

TSS parameter value of Cengklik reservoir water based on the results' observation in figure 5 showed that the highest TSS value occurred at the sampling point CI2 or Inlet 2 was 28mg/L. In contrast, the lowest TSS of Cengklik reservoir water occurred at the sampling point of CB1 or reservoir body 1, which was 4mg/L. All TSS parameter values of Cengklik reservoir water still met the quality standard.

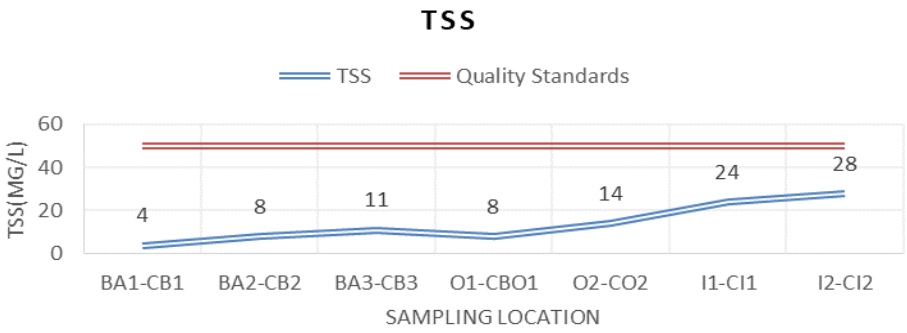

Figure 6. TSS value in the Cengklik reservoir water sample.

The parameter value results of Total Phosphate in Cengklik reservoir water in figure 6 showed that the highest PO4-P at the sampling point C12 or Inlet 2 was 0.2441mg/L. In contrast, the lowest PO4-P of the Cengklik reservoir water at the sampling point of CB3 or water body 3 was 0.0233mg/L. Only 2 (two) of the 7 (seven) PO4-P parameter values of Cengklik reservoir water meet the reservoir water quality standard, which is 0.03 mg/L, and all of them are in the reservoir body.

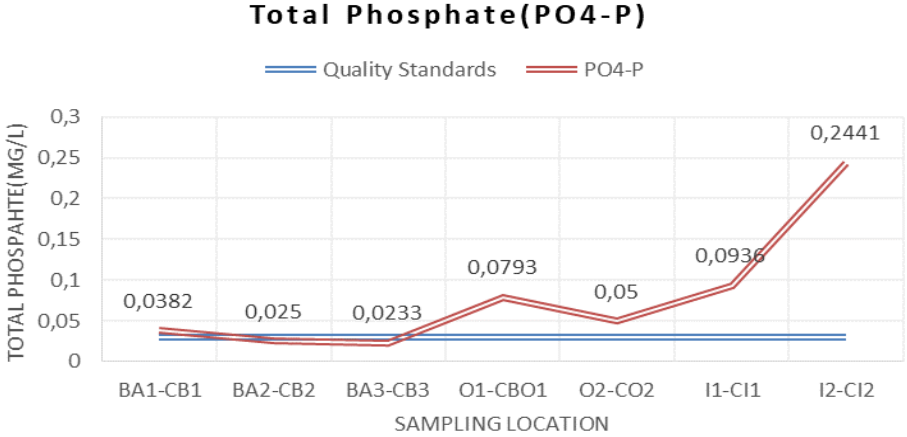

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Figure 7. PO4-P value in the Cengklik reservoir water sample

The NH3-N value of the Cengklik reservoir water in figure 7 showed that the highest NH3-N value occurred at the sampling point of CB2 or Outlet 2 was 0.3928mg/L. In contrast, the lowest NH3-N of Cengklik reservoir water occurred at the sampling point of CB2 or reservoir body 2 was 0.3652mg/L.

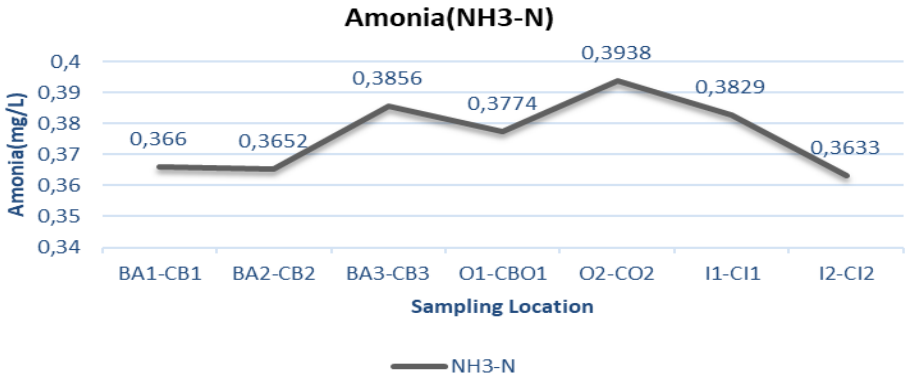

Figure 8. NH3-N value in the Cengklik reservoir water sample.

The Cengklik reservoir water detergent value in figure 8 showed that the highest detergent value occurred at the sampling point CB1 or reservoir body 1(one) was 0.0088mg/L. In contrast, the lowest detergent water from the Cengklik reservoir occurred at the sampling CB2, CB3, CI1, and CI2 are 0.0043mg/L. The current value of Cengklik reservoir water detergent still meets the quality standard of 0.2 mg/L.

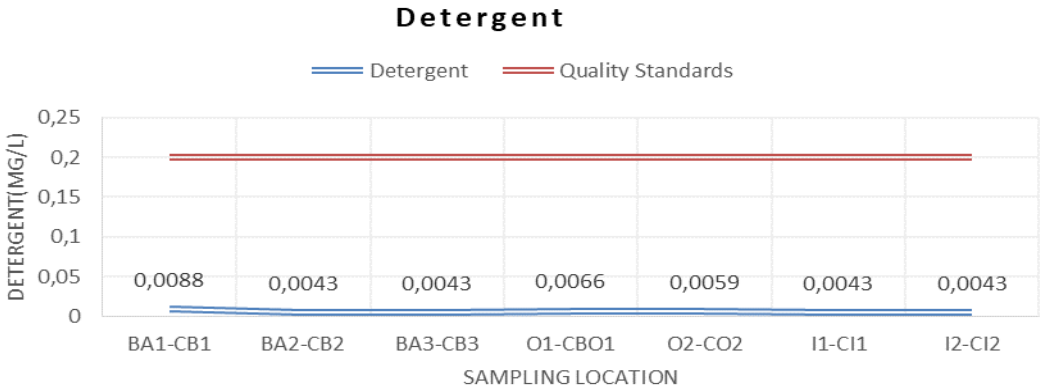

Figure 9. Detergent value in the Cengklik reservoir water sample

The results of the total coliform value of the Cengklik reservoir water in figure 9 showed that the highest Total Coliform value occurred at the sampling points CI1 and CI2 or Inlets 1 and 2 of 920 NPM, while the lowest Total Coliform water from the Cengklik reservoir occurred at the sampling point CB1 or Outlet 1, which was 350NPM. Cengklik currently still meets the quality standard, which is 5000 NPM.

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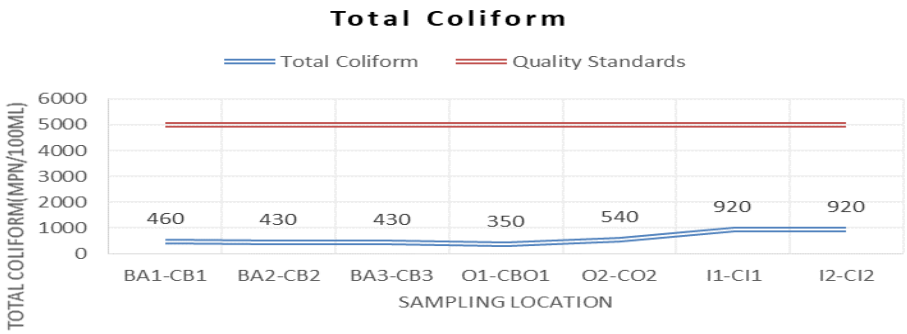

Figure 10. Total Coliform value in the Cengklik reservoir water sample

4.2 Pollution Index

The Pollution Index highlights contamination levels (Minister of the Environment Decree No. 115/2003). The Pollution Index (PI) is calculated for a specific purpose. The criteria are established following the score in Table 2.

Table 2. Criteria for assessing status water quality using the Pollution Index

Score	Criteria
$0,0 \leq PIj \leq 1,0$	Good Water Quality
$1,0 \leq PIj \leq 5,0$	Moderately Polluted
$5,0 \leq PIj \leq 10$	Polluted
$PIj > 10$	Extremely Polluted

Source: Minister of Environment 2003 [11]

The Pollution Index (PI) calculation can calculate water quality status. Table 3 shows the calculation results for the water quality status of the Cengklik Reservoir.

Table 3. Calculation of the Pollutant Index of Cengklik Reservoir water quality

Sample Code	Location	Ci/Lij, Avg	Ci/Lij, Max	Pij	Water Quality Status
CB1	R.Body 1	0.698013	1.524711	1.1857	Moderately Polluted
CB2	R.Body 2	0.586135	1.513312	1.1476	Moderately Polluted
CB3	R.Body 3	0.609976	1.699396	1.2767	Moderately Polluted
CO1	R.Outlet 1	1.098511	3.110760	2.3328	Moderately Polluted
CO2	R.Outlet 2	0.794523	2.109244	1.5938	Moderately Polluted
CI1	R.Inlet 1	1.028211	3.470773	2.5596	Moderately Polluted
CI2	R.Inlet 2	1.236723	5.552233	4.0222	Moderately Polluted

Note: R. Body: Reservoir body

R.Outlet: Reservoir Outlet

R.Inlet: Reservoir Inlet

The Pollutant index calculation results show that all water sampling locations are lightly polluted. The lightest pollution is in the reservoir body, and the most polluted site is reservoir Inlet 2 (CI2).

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Table 4. Status of Cengklik Reservoir Water Quality in 2021

Month	Pij	Water Quality Status
January	5.63	Polluted
February	9.21	Polluted
March	15.68	Extremely Polluted Extremely
April	19.83	Polluted
May	23.40	Extremely Polluted Moderately
June	3.94	Polluted
July	12.72	Extremely Polluted Moderately
August	4.41	Polluted
September	1.32	Moderately Polluted
October	3.33	Moderately Polluted

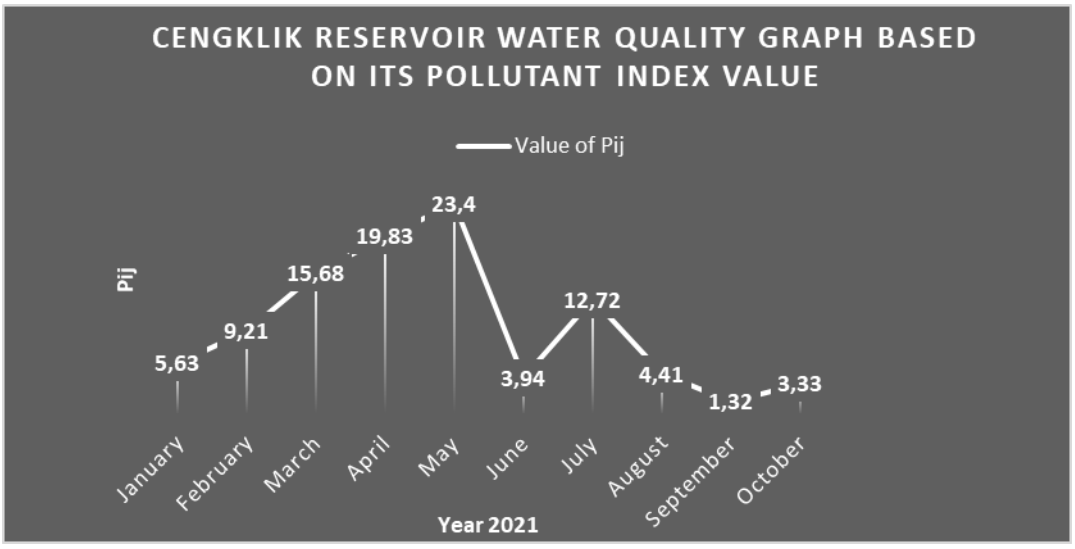

Figure 11. Graph of Cengklik Reservoir Water Quality based on its Pollutant Index value

Based on the results of monitoring the water quality of the Cengklik reservoir carried out by the Bengawan Solo River Basin Center, the reservoir water quality trend is shown in Table4 and figure 11. Based on the water quality monitoring data of the Cengklik reservoir conducted by the Bengawan Solo, it can be seen that the water quality of the Cengklik reservoir tends to be poor, especially during the rainy season, from January to May.

5. CONCLUSION

The water quality of the Cengklik Reservoir is strongly influenced by the sources of water pollutants and the surrounding area's ambient conditions. The results revealed that the water quality at the inlet is lightly polluted, with pollution index values (Pij) of 2.56 at the inlet (CI1) and 4.02 at the inlet (CI2). As a result, the water became polluted.

Furthermore, climate factors substantially impact the water quality of the Cengklik reservoir. When a large amount of water is added, it changes water flow and water conditions in the reservoir body, resulting in excessive suspended particles or pollutants in the reservoir water, leading the reservoir water quality to deteriorate. The results of this study reinforce the water quality status and Index of Pollution; the findings indicated Cengklik reservoir was polluted. However, this result is necessary for further investigation to get the whole picture. Further research can assess the environmental impact factors affecting the pollution of the Cengklik reservoir and the social-economic benefits to the surrounding community.

6. FINANCIAL SUPPORT

No public or private institution funded this study.

7. CONFLICTS OF INTEREST

There are no conflicts of interest

8. REFERENCES

[1] G. R. Barokah, F. Ariyani, and T. H. Siregar, "Comparison of Storet and Pollution Index Method to Assess the Environmental Pollution Status: A Case Study from Lampung Bay, Indonesia," *Squalen Bull. Mar. Fish. Postharvest Biotechnol.*, vol. 12, no. 2, p. 67, 2017, doi: 10.15578/squalen.v12i2.287.

[2] E. Kellner, "The controversial debate on the role of water reservoirs in reducing water scarcity," *Wiley Interdiscip. Rev. Water*, vol. 8, no. 3, pp. 1–11, 2021, doi: 10.1002/wat2.1514.

[3] I. Fischhendler and T. Heikkila, "Does integrated water resources management support institutional change? the case of water policy reform in Israel," *Ecol. Soc.*, vol. 15, no. 1, 2010, doi: 10.5751/ES-03015-150104.

[4] M. A. Fulazzaky, "Challenges of integrated water resources management in Indonesia," *Water (Switzerland)*, vol. 6, no. 7, pp. 2000–2020, 2014, doi: 10.3390/w6072000.

[5] R. Bagatin, J. J. Klemeš, A. Pietro Reverberi, and D. Huisingh, "Conservation and improvements in water resource management: A global challenge," *J. Clean. Prod.*, vol. 77, pp. 1–9, 2014, doi: 10.1016/j.jclepro.2014.04.027.

[6] W. E. Rintaka, A. W. Hastuti, E. Susilo, and N. Radiarta, "The Used of Storet Index to Assess Water Quality in Perancak Estuary, Bali, Indonesia," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 246, no. 1, 2019, doi: 10.1088/1755-1315/246/1/012012.

[7] V. G. Christensen, K. E. Lee, J. M. McLees, and S. L. Niemela, "Relations between Retired Agricultural Land, Water Quality, and Aquatic-Community Health, Minnesota River Basin," *J. Environ. Qual.*, vol. 41, no. 5, pp. 1459–1472, 2012, doi: 10.2134/jeq2011.0468.

[8] M. A. Fulazzaky, "Water quality evaluation system to assess the Brantas river water," *Water Resour. Manag.*, vol. 23, no. 14, pp. 3019–3033, 2009, doi: 10.1007/s11269-009-9421-6.

[9] M. L. Reba *et al.*, "A statewide network for monitoring agricultural water quality and water quantity in Arkansas," *J. Soil Water Conserv.*, vol. 68, no. 2, pp. 45–49, 2013, doi: 10.2489/jswc.68.2.45A.

[10] S. M. *et al.*, "Overview of forest tenure reforms in Indonesia," *Overv. For. tenure reforms Indones.*, 2017, doi: 10.17528/cifor/006402.

[11] R. M. D. Ujianti, S. Anggoro, A. N. Bambang, and F. Purwanti, "Water quality of the Garang River, Semarang, Central Java, Indonesia based on the government regulation standard," *J. Phys. Conf. Ser.*, vol. 1025, no. 1, 2018, doi: 10.1088/1742-6596/1025/1/012037.