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Regional Case Study

Water Quality Identification and Analysis of Saguling Reservoir, West Bandung Regency

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Abstract
The Saguling Reservoir in West Bandung Regency is crucial for local water supply and biodiversity. However, water quality has significantly declined due to human activities, environmental changes, and poor waste management. This degradation jeopardizes the reservoir's clean water supply and the ecological health of surrounding communities. This research used the STORET (Storage and Retrieval) method to assess water quality through purposive sampling in the most affected zones, analyzing physical, chemical, and biological parameters at multiple depths. Key indicators, such as dissolved oxygen, nutrient concentrations, and heavy metal presence, were measured. Results show severe water quality deterioration, especially in deeper sections with less sunlight and aeration. Elevated nitrate and phosphate levels, mainly from agricultural runoff and residential waste, exceeded environmental safety standards. Toxic heavy metals like lead and mercury were also detected, posing serious risks to aquatic life and human health. The study highlights that deeper water zones are critically impacted by pollutants, stressing the need for better regulatory frameworks and waste management. Immediate strategic interventions are crucial to restore and protect the Saguling Reservoir's water quality for future generations.

Keywords: Water quality; saguling reservoir; storet method

1. Introduction

Water quality assessment is a critical component of environmental management, ensuring the sustainability of water resources that are vital for ecological stability, economic development, and public health (Camara et al., 2019; Pandey, 2018; Subehi et al., 2018). The Saguling Reservoir, located on the Citarum River in Indonesia, exemplifies a significant hydrological asset whose condition directly influences various sectors including hydroelectric power generation, agriculture, fisheries, and tourism (Juliastuti et al., 2021; Subehi et al., 2018). This reservoir, managed by PT. Indonesia Power Saguling POMU (Power generation Operation and Maintenance service Unit) plays a pivotal role in the regional economy and sustains a multitude of ecological and human activities. However, the reservoir faces challenges due to environmental degradation and pollution from anthropogenic sources, necessitating a rigorous and continuous assessment of its water quality (Herfiantara and Hariadi, 2023).

The context of hydroelectric infrastructure and regional development, the Saguling Dam is a prominent feature within the cascade system of dams on the Citarum River. This system includes the Saguling Dam situated upstream, the Cirata Dam in the midstream, and the Ir. H. Djuanda Dam downstream. The construction of the Saguling Dam, which took place from 1981 to 1985, has positioned it as a significant hydroelectric power producer, with an output of approximately 2,156 GWh per year (Salsabila et al., 2023). The Saguling Reservoir, formed by the damming of the Citarum River, is characterized by its unique topography. The inundation area of the reservoir exhibits a 'fingered' landscape, with numerous water bodies extending inland. This intricate configuration results in a substantial circumference of the reservoir's edge, measuring approximately 400 kilometers (Hidayat et al., 2013; Marselina and Burhanudin, 2017). The strategic importance of the Saguling Reservoir is further underscored by its multifunctional utility, serving as a vital resource for various socio-economic activities while also presenting challenges related to environmental management and sustainability (Hidayat et al., 2013).

The strategic location of the Saguling Dam at the upstream end of the Citarum River cascade necessitates a thorough assessment of its influence on the water quality of downstream reservoirs, specifically the Cirata Dam and the Ir.H. Djuanda Dam. The land use within the Saguling Reservoir's boundary, as reported by PT. Indonesia Power Saguling POMU, indicates a significant deviation from environmental regulations. Specifically, the area comprises 16.23% residential zones, 37.49% agricultural land, and 46.27% allocated to other uses. This land use pattern is in direct violation of the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia Number 28/PRT/M 2015, which stipulates that a buffer zone of at least 50 meters from the highest recorded water level must be maintained as a safety green area around the reservoir (Salsabila et al., 2023). This non-compliance poses several risks, including increased sedimentation and pollution runoff into the reservoir, which can adversely affect the water quality downstream. The presence of residential and agricultural activities within the designated buffer zone likely contributes to nutrient loading and other contaminants entering the water body, thereby impacting the ecological balance and water quality of the Saguling Reservoir and, consequently, the downstream reservoirs.

To conduct a comprehensive assessment of the water quality of the Saguling Reservoir, the STORET (Storage and Retrieval) method is utilized. This method involves the comparison of water quality data against established standards that are specific to the reservoir's designated uses. The STORET method is instrumental in identifying which parameters are within compliance and which exceed the water quality standards, providing a detailed analysis of the water quality in accordance with the regulations in place. Such an analysis is crucial for informing sustainable water management practices and addressing the challenges faced by the Saguling Reservoir. The importance of employing the STORET method for water quality assessment is highlighted in several studies, including those assessing the water quality status of various rivers and reservoirs (Afriani et al., 2021; Ibrahim et al., 2023; Mudjiardjo et al., 2021; Utami et al., 2021). These studies underscore the utility of the STORET method as a reliable tool for environmental monitoring and decision-making in water resource management.

The innovative aspect of this research is the application of the STORET (Storage and Retrieval) method to the Saguling Reservoir, which offers a modern and region-specific evaluation of water quality, taking into account the present conditions of sedimentation and the effects of land use. This methodological approach is especially pertinent in light of the fluid interplay between terrestrial and aquatic environments, as well as the ongoing challenges introduced by human activities and climatic variations. By focusing on these contemporary issues, the study provides a critical update to the understanding of water quality dynamics within the Saguling Reservoir.

2. Methods

2.1. Time and Location of Research

The present study was conducted at the Saguling Dam, situated in the Rajamandala area of Cipatat District, West Bandung Regency, approximately 43 kilometers from Bandung City. The specific focus of the research was on the border area surrounding the Saguling Reservoir, an area critically linked to the reservoir itself. The research was structured in two distinct phases: the field survey and data collection phase, which spanned two months from September 2022 to October 2023, followed by a subsequent two-month period dedicated to data analysis. This timeline was strategically chosen to capture relevant environmental and anthropogenic influences on water quality during these months, which are representative of the region's climatic conditions.

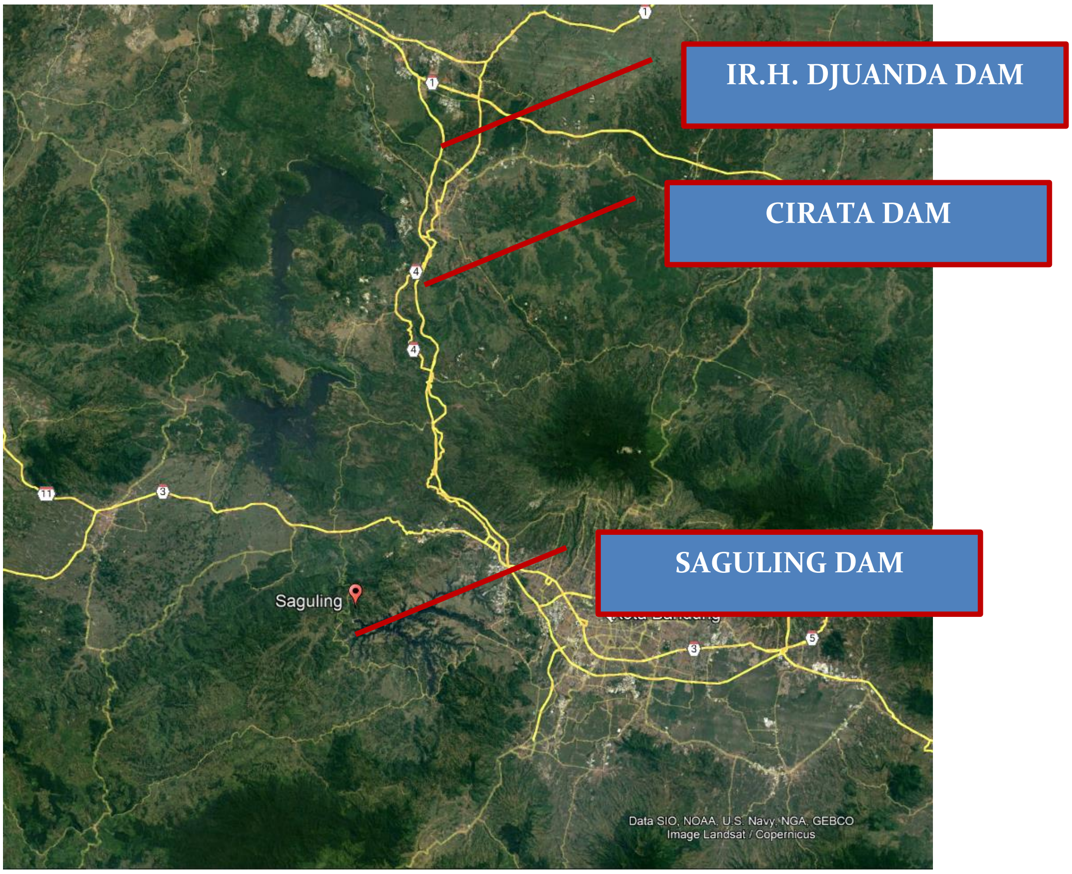

Figure 1. Map of research location

2.2. Research Methods

The research method described leverages purposive sampling for water quality testing at varying depths within the Saguling Reservoir. This non-probability sampling technique is chosen for its effectiveness in gathering data from specific areas of interest identified by researchers based on their expert judgment. Such a targeted approach is essential in studies where certain locations are expected to provide crucial insights into environmental conditions, and is often employed in studies focusing on localized environmental impacts (Tongco, 2007 & Setia, 2016).

Purposive sampling is particularly beneficial in environmental science for exploring the water quality in specific zones of a reservoir that are most affected by external factors such as industrial discharge, agricultural runoff, or population density. The sampling point is in the Cihampelas area with three depths, namely at the surface, at a depth of 5 m and 8 m (near the bottom of the reservoir). Then the reservoir water sample is subjected to laboratory testing. The method allows for a thorough investigation of the stratification and distribution of pollutants (Nufutomo et al., 2023). To investigate thermal stratification in Saguling Reservoir, temperature measurements are taken at the surface and at depths of 5 meters and 8 meters using high-precision digital thermometers.

In adherence to Indonesian regulations, the study would refer to the Decree of the State Minister for the Environment of the Republic of Indonesia No. 115 of 2003, which sets guidelines for environmental management including standards for water quality (Novita et al., 2020). Additionally, Government Regulation No. 22 of 2021 provides updated standards and management practices crucial reference that sets forth the water quality standards and management practices in Indonesia (Adnina et al., 2023;

Nufutomo et al., 2023). These standards typically dictate the permissible limits for various chemical and biological parameters in water bodies, guiding both sampling protocols and analytical procedures .

2.3 Data Analysis

Reservoir Water Quality Analysis Refers to PP No. 22 of 2021, Appendix VI. About Lake Water Quality Standards and the Like Class 2. While the reference to quality status is based on the Environmental Decree No.115 of 2003, Annex I concerning guidelines for determining water quality status. The Analysis Method uses the STORET method so that it can be known the parameters that have met or exceeded water quality standards. In principle, the STORET method is to compare water quality data with water quality standards in accordance with its designation. How to determine it using the value system with the following classification: (U.S. Environmental Protection Agency (EPA), 2017)

Class A : very good, score = 0 (meets quality standards)
Class B : good, score = -1 to -10 (mild contaminants)
Class C : is, score = -11 s/d -30 (contaminating being)
Class D : poor, score = ≥ -31 (heavy pitcher)

Determination using the STORET method is carried out with the following steps:

a) Water quality seris data
b) Compare the measurement data from each water parameter with the appropriate quality standard values Class.
c) If the results meet, give it a score of 0.
d) If it does not meet, it is scored according to Table 11 Determination of the value system to determine water quality status.

For copper parameters using the SNI 6989-84:2019 reference method. Water quality standards listed in SNI 6989-84:2019 limit the concentration of copper in water to ensure safe water quality.

Table 1. Determination of value systems to determine water quality status

Sum	Value	Parameters		
		Physics	Chemical	Biology
<10	Maximum	-1	-2	-3
	Minimum	-1	-2	-3
	Average	-3	-6	-9
≥ 10	Maximum	-2	-4	-6
	Minimum	-2	-4	-6
	Average	-6	-12	-18

Source: (Sudaryanti et al., 2023)

3. Result and Discussion

The results of the analysis of water quality samples in Saguling Reservoir are listed in detail in Table 2.

Table 2. Results of water quality analysis in saguling reservoir

No	Parameters	Unit	Criteria Class II	Test Results		
				Surface	Middle	Basis
PHYSICS						
1	Temperature	^{0}C	Deviasi 3	26.7	25.5	24.5
2	TSS	mg/L	100	7.4	8	10
	TDS	mg/L	1000	198	200	237
CHEMICAL						
1	pH		6-9	7.25	7.23	7.17

No	Parameters	Unit	Criteria Class II	Test Results		
				Surface	Middle	Basis
2	Copper (Cu)	mg/L	0.02	0.016	0.016	0.016
3	Zinc (Zn)	mg/L	0.05	0.136	0.065	0.103
4	Dissolved Oxygen (DO)	mg/L	4	1.8	1.3	1.2
5	HCO_3	mg/L	-	100.08	78.36	104. 43
6	BOD	mg/L	3	7	7	7
7	COD	mg/L	25	14.66	16.12	17.59
8	Sulfur as H_2S	mg/L	0.002	0.001	0.001	0.001
9	Nitrat (NO_3-N)	mg/L	-	0.517	0.555	1.233
10	Nitrite (NO_2-N)	mg/L	-	0.069	0.076	0.03
11	Phosphate (PO_4-P)	mg/L	-	0.127	0.132	0.143
12	Free Chlorine (Cl_2)	mg/L	0.03	1.296	1.296	1.296
13	Calcium (Ca)	mg/L	-	24	27	27
14	Flourida	mg/L	1.5	0.088	0.09	0.081
15	MBAS	mg/L	0.2	0.077	0.074	0.099
16	Fenol	mg/L	0.005	0.005	0.006	0.006
17	Fatty Oils	mg/L	1	0.1	0.1	0.1
18	Crom Heksavalen	mg/L	0.05	0.024	0.024	0.024
19	Cadmium	mg/L	0.001	0.001	0.001	0.001
20	Celenium	mg/L	0.05	0.003	0.003	0.003
21	Cobalt (Co)	mg/L	0.2	0.022	0.024	0.024
22	Lead (Pb)	mg/L	0.003	0.006	0.006	0.006
23	Cyanide	mg/L	0.02	0.001	0.001	0.00
24	Boron	mg/L	1	0.066	0.064	0.064
25	Mercury (Hg)	Ppb	0.002	0.006	0.006	0.006
26	Arsen (As)	mg/L	0.05	0.0002	0.0002	0.0002
MICROBIOLOGY						
1	Total Coliform	MPN/100 ml	5,000	2,400	24,000	2,400,000
2	E-Coli	MPN/100 ml	1,000	2,400	24,000	2,400,000

The results of laboratory analysis show that the criteria for water quality standards are divided into three, namely physics, chemistry and biology. In the physical aspect, the parameters analyzed are temperature, Total Suspended Solids (TSS), and Total Dissolved Solids (TDS). It was found that the surface temperature was 26.7 ^{0}C, the middle temperature of the reservoir was 25.5 ^{0}C and the bottom temperature of the reservoir was 24.5 ^{0}C. The temperature difference between the surface, middle, and bottom of the reservoir can be caused by changes in weather and seasons. In general, surface temperatures are higher than the middle and bottom temperatures of reservoirs due to direct exposure to sunlight. The phenomenon of thermal stratification in reservoirs is a direct result of differential heating by the sun, as described in the search results. During the summer months, the sun's rays warm the surface water, making it less dense than the cooler water below. This creates a stable stratification with distinct thermal layers: the warm upper layer known as the epilimnion, the rapidly changing temperature layer known as the thermocline, and the cooler, more stable bottom layer known as the hypolimnion (Liu et al., 2020; Wardhani and Sugiarti, 2021). The movement of water in reservoirs can also affect temperatures at various depths. Reservoirs that have water inflow and outflow, as well as circulation processes such as the presence of aeration pumps or the use of reservoirs for power generation, can affect the distribution of water temperature in various layers (Vourlitis & Kepner, 2018)

The difference in the value of Total Suspended Solids (TSS), namely the surface tss of the reservoir 7.4 mg / L, the middle tss of the reservoir 8 mg / L and the bottom tss of the reservoir 10 mg / L. In general, solid particles dissolved in water such as sediment tend to be heavier than the water itself. Therefore, at the bottom of reservoirs, TSS tends to be higher because such particles have a tendency to settle there. On the surface, TSS is usually lower because large solid particles have descended to the bottom. The movement of water in reservoirs can affect the distribution of TSS. Under some conditions, circulating water can carry solid-particles from the base to the surface or vice versa. This can change the distribution of TSS at various depths. Biological activities, such as plankton activity or organisms that disrupt sediments at the bottom, can affect TSS concentrations in different layers of water. On the surface, more sunlight can increase photosynthetic activity, which may reduce TSS because the particles are filtered out by photosynthetic organisms. External factors, such as river flow carrying sediment or sewage, can also affect TSS concentrations at various locations within reservoirs (Eneji & Onoja, 2018).

The reservoir surface TDS was 198 mg/L, the middle TDS of the reservoir was 200 mg/L, and the bottom TDS of the reservoir was 237 mg/L. One of the main factors affecting TDS is the source. TDS consists of various water-soluble compounds, including salts, minerals, and other chemical compounds. Differences in TDS concentrations at various depths can be caused by differences in TDS sources. At the bottom of reservoirs, there are more mineral deposits or sediments that can increase TDS concentrations. The movement of water within the reservoir, such as currents, vertical circulation, or mixing of water, can affect the distribution of TDS. Circulating water can carry water with different TDS concentrations from different depths to the surface or vice versa. Chemical reactions in water can change TDS concentrations in different layers of water. Processes such as precipitation or precipitation of certain chemical compounds can affect TDS. Biological activities, such as photosynthesis by aquatic plants, can affect TDS concentrations on the surface of reservoirs. Photosynthesis can reduce TDS concentrations because aquatic plants use some of the TDS compounds as nutrients (Wei, 2018).

From a chemical perspective, the analyzed parameters are quite complex. The pH at the surface of the reservoir was 7.25. The pH at the surface tends to be close to neutral, which can be influenced by factors such as the atmosphere, photosynthesis by algae, and human activities. The pH value at the center of the reservoir was 7.23. The pH at mid-depth may still be quite stable, but it may have lower fluctuations compared to the surface. While the pH value at the bottom of the reservoir is 7.17. The pH at the bottom of the reservoir may tend to be lower because of the influence of the decomposition of organic matter at the bottom and the separation of stratified layers.

Cu concentrations were generally low across all observation points, suggesting that Cu is becoming a significant problem in water quality in the Saguling Reservoir. Then zinc concentrations varied at the three observation points, but also tended to be low, indicating that zinc could be a significant problem in water quality in these reservoirs. The concentration of dissolved oxygen tends to decrease with depth, which is a common characteristic in waters. At the bottom of reservoirs, oxygen concentrations can be low due to oxygen ingestion by microorganisms involved in the decomposition of organic matter (Gudisa, 2018).

The HCO_3 content in the water varies depending on the surrounding mineral sources. At the bottom of the reservoir, a mineralization process increases the concentration of HCO_3 due to interactions with sedimentary and rock deposits at the bottom of the reservoir. BOD is a measure of the level of organic pollution in water. High BOD values, especially on the surface, are due to biological activity that produces dissolved organic substances. This can be attributed to the inflow of organic waste or biological activity at the surface. COD is also an indicator of organic pollution, but includes organic substances that can be broken down by chemical reactions. High COD values on the surface may indicate the presence of organic compounds that are difficult to break down by biological processes. Low sulfur concentrations, such as H_2S, at all observation points suggested that H_2S production may not be significant in these reservoirs. Factors such as acidity, dissolved oxygen, and biological activity can affect H_2S production. Varying concentrations of nitrates and nitrites at various depths can be affected by biological activity, agricultural use, or waste input. Higher nitrate concentrations may be due to increased nutrient input at the surface or reduced biological activity at the bottom of reservoirs (Cesar, 2018).

The concentration of phosphate in water can vary based on biological activity, fertilizer application, and waste input. Higher concentrations at the surface are associated with nutrient inputs from streams or agricultural waste. Free chlorine is used as a disinfectant in water conservancy. Higher concentrations in the middle and bottom of reservoirs are related to the use of disinfectants or water conservation processes. Calcium is a common cation in water and originates from rocks or geological activity. Stable calcium concentrations at various depths exhibit consistent water chemistry and geological characteristics in Saguling Reservoir. Fluoride concentrations are influenced by geological sources or the use of fertilizers and chemicals. The lower concentration on the surface is due to factors such as surface washing by rain. MBAS is an indicator of detergents or compounds that can form foams in water. Low MBAS concentrations at all observation points indicate that foam-forming compounds are insignificant in Saguling Reservoir water. Low phenol concentrations at all observation points indicate that phenol is a problem in water quality in these reservoirs (Pandey, 2018).

Relatively low concentrations of fatty oils at all observation points may indicate that oil leakage or waste oil input is not significant in Saguling Reservoir. Hexavalent chrome can be associated with industrial activity and the use of certain chemicals. The difference in concentration at various depths reflects inputs from different sources or interactions with sediments at the bottom of reservoirs. Cadmium is a heavy metal that can come from sources such as industrial or agricultural waste. Variations in concentration at various depths may be related to inputs from different sources or interactions with sediments. Low selenium concentrations at all observation points may indicate that selenium input is not significant in water quality in these reservoirs. Low cobalt concentrations at all observation points indicate that cobalt input does not significantly affect the water quality in the Saguling Reservoir.

Low lead concentrations at all observation points may indicate that lead leakage or lead waste input is not significant in Saguling Reservoir. Low cyanide concentrations at all observation points indicated that cyanide input did not significantly affect the water quality in these reservoirs. It should be noted that cyanide can be very toxic and that low measurements are positive. The relatively stable boron concentrations at various depths reflect the consistent chemical characteristics of water in Saguling Reservoir. Boron is usually associated with certain minerals and rocks. Low mercury concentrations at all observation points may indicate that mercury input is significant in water quality in these reservoirs. This is something that needs to be considered because mercury is a substance that is very harmful to the environment and human health. Low arsenic concentrations at all observation points indicate that arsenic inputs are not significant in water quality in these reservoirs. Arsenic is a toxic substance, and its low concentrations are beneficial for ecosystems and human health.

From a biological perspective, the parameters observed were total coliforms and E-Coli. concentration of total coliforms and E. coli (Escherichia coli) in units of Most Probable Number per 100 milliliters (MPN / 100 ml). Total coliforms are a group of bacteria that include different types of bacteria, including E. coli, which can be found in aquatic and soil environments. The total coliform concentration at the three observation points was significantly different. The concentration of total coliforms is relatively low on the surface of the reservoir, which is affected by the influence of the sun and oxygenation on the surface of the water. Total coliform concentrations in the center of the reservoir are slightly higher than the surface, but still in the low to medium range. High concentrations of total coliforms at the bottom of reservoirs may indicate a greater bacterial contamination problem at these depths. This can be associated with the decomposition of organic matter and lack of oxygen at the bottom of reservoirs.

E. coli is a bacterium normally found in the digestive tract of humans and animals. The presence of E. coli in water may indicate contamination by human or animal feces. The concentration of E. coli on the surface was relatively low, but it still indicated the presence of this bacterium. The concentration of

E. coli in the center of the reservoir was slightly higher than that on the surface, but still in the low-to-moderate range. Very high concentrations of E. coli at the bottom of reservoirs are indicative of significant pollution. This can be a serious health issue and requires more attention. High concentrations of total coliform and E. coli bacteria at the bottom of reservoirs indicate potential problems in water quality at those depths.

The results of the analysis are then adjusted to the STORET reference method. STORET (Storage and Retrieval of U.S. Environmental Protection Agency (EPA) Water Quality and Other Environmental Data (EPA) system was developed by the United States Environmental Protection Agency (EPA) for storing, managing, and sharing water quality data and other environmental data. It is one of the largest and most important data storage systems used by the EPA and various government, state, and local agencies in the United States to monitor, manage, and understand water quality and the environment. The results of the analysis using the STORET method are presented in detail in Table 3.

Table 3. Results of water quality standard analysis score based on reference method

No	Parameter	Unit	Reference Method	Max Value	Min Value	Average	Skor
PHYSICS							
1	Temperature	^{0}C	SNI 06-6989.23-2005	26.7	24.5	25.57	0
2	TSS	mg/L	SNI 6989.3:2019	9.8	7.4	8.53	0
	TDS	mg/L	SNI 6989.27-2019	237	198	211.67	0
KIMIA							
1	pH		SNI 6989.11:2019	7.25	7.17	7.22	0
2	Copper (Cu)	mg/L	SNI 6989-84:2019	0.016	0.016	0.016	-10
3	Zinc (Zn)	mg/L	SNI 6989-84:2019	0.136	0.065	0.101333	-10
4	Dissolved Oxygen (DO)	mg/L	Direct Reading	1.8	1.2	1.43	-10
5	HCO3	mg/L	SM 2310:2017	104.43	78.36	94.29	0
6	BOD	mg/L	SM 5210 B	7	6.7	6.8	-10
7	COD	mg/L	SNI 6989.2:2019	17.59	14.66	16.123	0
8	Sulfur as H2S	mg/L	SNI 6989.75:2009	0.001	0.001	0.001	0
9	Nitrat (NO3-N)	mg/L	SNI 6989.79-2011	1.233	0.517	0.76833	0
10	Nitrite (NO2-N)	mg/L	SNI 06-6989.9-2004	0.076	0.03	0.0583	0
11	Phosphate (PO4-P)	mg/L	SM 4500-P.D	0.143	0.127	0.134	0
12	Free Chlorine (Cl2)	mg/L	SM 2350:2017	1.296	1.296	1.296	-10
13	Calcium (Ca)	mg/L	SM 3500-Ca B	27	24	26	0
14	Flourida	mg/L	SNI 06-2482-1991	0.09	0.081	0.0863	0
15	MBAS	mg/L	SM 5540 C	0.099	0.074	0.0863	0
16	Fenol	mg/L	SM 5530 C	0.006	0.005	0.0056	-8
17	Fatty Oils	mg/L	SM 5220 B	0.1	0.1	0.1	0
18	Krom Heksavalen	mg/L	SM 3500-Cr A	0.024	0.024	0.024	0
19	Cadmium	mg/L	SM 3500-Cd	0.001	0.001	0.001	0
20	Celenium	mg/L	SNI 06-2475-1991	0.003	0.003	0.003	0
21	Cobalt (Co)	mg/L	SM 3500-Co B	0.024	0.022	0.023	0
22	Lead (Pb)	mg/L	SM 3500-Pb A	0.006	0.006	0.006	0
23	Cyanide	mg/L	SM 4500-CN C	0.001	0.001	0.001	0
24	Boron	mg/L	SM 4500- B B	0.066	0.064	0.064	0
25	Mercury (Hg)	Ppb	SNI 06 – 3605- 1994	0.006	0.006	0.006	-10

No	Parameter	Unit	Reference Method	Max Value	Min Value	Average	Skor
26	Arsen (As)	mg/L	SNI 06-6989-54-2005	0.0002	0.0002	0.0002	0
MIKROBIOLOGI							
1	Total Coliform	MPN/100 ml	APHA 9221-B	2,400,000	2,400	808,800	-12
2	E-Coli	MPN/100 ml	APHA 9221-E	2,400,000	2,400	808,800	-15
TOTAL STORET							-95

The use of reference methods to measure these parameters is important to ensure compliance with established water quality standards. The pollution score provided provides an overview of the level of water pollution based on a comparison between the measurement results and the permissible threshold. In the physical aspect, there is no significant pollution of water quality standards. This is evidenced by a score value of 0.

Meanwhile, from a chemical perspective, several parameters were found to have scores with indications of light to moderate pollution. A score of -10 indicates that the copper concentration exceeds the permissible threshold, indicating light pollution of this parameter. Increased Cu concentrations in water can be caused by the release of Cu from industrial activities, agricultural waste, or Cu-containing sewers. Increased copper concentrations can be toxic to aquatic organisms and aquatic ecosystems (Smriti et al., 2023). It can also potentially contaminate water sources used for human drinking water supplies. A score of -10 indicates that the zinc concentration exceeds the permissible threshold, indicating light pollution of this parameter. Zinc in water can come from a variety of sources, including industrial, agricultural, and domestic wastes. Increased zinc concentrations can poison aquatic organisms and disrupt ecosystems. In addition, heavy substances such as zinc can accumulate in the organism, which can affect the food chain (Hussain et al., 2021).

Dissolved oxygen levels in water should be high enough to support aquatic life. A score of -10 indicates that the dissolved oxygen level is very low, indicating mild pollution of this parameter using the Direct Reading reference method. A decrease in dissolved oxygen in water can be caused by the liberation of organic matter from waste, nutrient pollution, or an increase in water temperature. A decrease in DO can cause oxygen stress in aquatic organisms and reduce their survival. This condition is commonly called "hypoxia" or "anoxia" if DO is very low or absent altogether (Zeng et al., 2022). Biochemical Oxygen Demand (BOD) measures how quickly microorganisms decompose organic matter in water. A score of -10 indicates that the BOD level exceeds the permissible threshold, indicating light pollution of this parameter using the SM 5210 B reference method. The high BOD indicates that there is a lot of organic matter that needs to be broken down by microorganisms. This leads to a decrease in DO, which can adversely affect aquatic life (Zeng et al., 2022).

Free chlorine is used as a disinfectant in drinking water maintenance. A score of -10 indicates that the concentration of free chlorine exceeds the permissible threshold, indicating light pollution of this parameter. Free chlorine is typically added to drinking water as a disinfectant to kill pathogenic microorganisms. Increased concentrations of free chlorine beyond permissible limits can be irritating to humans and harmful to aquatic organisms in water.

A score of -8 indicates that the phenol concentration almost exceeds the permissible threshold, it can be categorized as light pollution on this parameter using the reference method SM 5530 C. Phenol is a chemical compound derived from industrial waste and from certain chemical processes. Increased phenol concentrations can have toxic effects on aquatic organisms and disrupt aquatic ecosystems (Zeng et al., 2023). The score of -10 indicates that the mercury concentration exceeds the permissible threshold. Mercury is a heavy metal that can come from industrial releases or mining activities. Mercury is highly toxic and can accumulate in the organism. Increased mercury concentrations can cause damage to ecosystems and are harmful to human health (Ajitha et al., 2021). In the biological aspect, the parameter indicated to trigger pollution in Saguling Reservoir is total coliform. A score of -12 indicates that the Total Coliform count exceeds the permissible threshold, indicating moderate contamination of this parameter by the APHA 9221-B method. Total Coliforms are a group of bacteria that can be found in the natural environment and drinking water. An increase in the concentration of Total Coliform, especially beyond permissible limits, may indicate contamination of water by pathogenic bacteria that are harmful to human health (Pal, 2014).

Then for conditions on the E-Coli parameter a score of -15 indicates that the amount of E. coli exceeds the permissible threshold, indicating moderate pollution of this parameter by the reference method APHA 9221-E (Clesceri et al., 2005). E. coli (Escherichia coli) is a bacterium usually found in the digestive tract of humans and animals. The presence of E. coli in water may indicate contamination by human or animal feces. A significant increase in the concentration of E. coli indicates the presence of serious contamination by human or animal feces, which can harm human health if the water is used as a source of drinking water (Rañada and Jaraula, 2023).

Table 4. Water quality classification according to storet method

Class		Score	Result
A	Very good	0	Meet quality standards
B	Good	-1 until -10	Light contaminants
C	Middle	-11 until -30	Medium containment
D	Bad	> -31	Heavy polluted

The location of the saguling reservoir shows the status of heavy polluted water quality with a total score of -95. The combination of negative scores for most of these parameters indicates that the water quality in Saguling Reservoir is heavily polluted requiring urgent corrective and management actions. This pollution can damage water ecosystems, threaten human health, and require efforts to reduce sources of pollution and restore water quality to a better condition. Further monitoring and remediation actions need to be taken to address pollution problems in this location (Marselina and Burhanudin, 2017; Salsabila et al., 2023; Subehi et al., 2018).

Agricultural activities in this region have a significant impact on the reservoir water quality. The use of chemical fertilizers and pesticides is a common practice aimed at increasing crop yields, but these substances can leach into the water system, leading to contamination. If not managed properly, the residues from these agricultural inputs introduce nitrates, phosphates, and toxic chemicals into the water, contributing to eutrophication, the potential for harmful algal blooms, and posing risks to aquatic life and human health (Eka et al., 2018; Mushfiroh and Marselina, 2021). The densely populated settlements surrounding the reservoir are another source of pollution. Domestic waste, including sewage and household waste containing detergents and other harmful substances, can enter the water system, particularly where sewage treatment is inadequate or non-existent. This can lead to increased levels of organic matter, which, in turn, reduces dissolved oxygen levels and can cause hypoxic conditions that are detrimental to aquatic organisms (Wardhani and Sugiarti, 2021). Drainage channels from both agricultural lands and urban settlements can act as conduits for a variety of pollutants, including heavy metals, chemicals, and pathogenic bacteria, to enter the reservoir. The presence of E. coli, as indicated by water quality analyses, suggests fecal contamination, which poses serious health risks if the water is used for drinking or recreational purposes (Marselina et al., 2021 & Wardhani and Sugiarti, 2021).

To address these pressing environmental issues, a comprehensive approach to monitoring and remediation is required. This includes the implementation of sustainable agricultural practices, improvements in domestic waste management, stringent controls on industrial discharge, and rehabilitation of the reservoir's catchment area. Payment for Environmental Services (PES) models, as explored in the Upper Citarum Basin, could incentivize the maintenance of agricultural land as a catchment area, potentially reducing sedimentation and pollution (Juliastuti et al., 2021; Mushfiroh and Marselina, 2021; Subehi et al., 2018).

4. Conclusion

In conclusion, the Saguling Reservoir faces significant environmental challenges due to the confluence of unregulated agricultural activities and densely populated settlements, leading to substantial water pollution. This degradation not only compromises the reservoir's water quality but also threatens the surrounding aquatic ecosystem, the sustainability of local water resources, and the health of the human populations that rely on this crucial water supply. To combat this pressing issue, a multifaceted approach is essential. Educating farmers on sustainable agricultural practices such as the judicious use of fertilizers and effective soil erosion management can mitigate the influx of agricultural runoff. Additionally, the implementation of robust sewage treatment systems in nearby settlements is critical to prevent the direct discharge of untreated domestic waste into the water. Redesigning drainage channels to efficiently filter and reduce pollutants before they enter the reservoir can further alleviate the pollution load. Regular monitoring and surveillance of water quality and potential pollution sources are indispensable for timely intervention and assessment of the effectiveness of implemented measures. Moreover, stringent government regulations and policies must be enforced to ensure compliance and accountability in environmental management and pollution control. Ultimately, the restoration and preservation of the Saguling Reservoir require collaborative efforts from local communities, government bodies, and various stakeholders to ensure the long-term sustainability of this vital water resource. These concerted actions are not just necessary for environmental restoration but are also crucial for the health and well-being of the local community and the ecosystem at large.

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