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Spatial Analysis of Physical Parameters Influencing Water Quality: A Case Study in Seloromo Reservoir, Central Java, Indonesia

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Abstract: Reservoirs are vital water resources that have an essential role from the perspective of living things. Utilization of reservoirs by humans frequently causes problems in the reservoir ecosystem, such as water pollution. Seloromo Reservoir was the second reservoir built to support various activities such as agriculture, fisheries, and tourism. Complex activities can influence the quality of reservoir water because sources of pollution are absorbed and flow into the water body. For this reason, monitoring is essential to determine factors that affect water quality of the reservoir. The aim of this research is to analyze the water quality of Seloromo Reservoir by testing physical parameters such as water temperature, degree of acidity (pH), Electrical Conductivity (EC), Total Dissolved Solid (TDS). In order to show the spatial distribution of each physical characteristic, grab samples were collected and measured in real time using a water checker. The results will be shown on a map. Spatial distribution maps were created by using the Inverse Distance Weighted (IDW) method which provides the simplest formulation and accurate results. Results show that human activities such as agriculture, livestock, and tourism around the reservoir and inputs from the river inlet indicate the condition of water quality in Seloromo Reservoir. Spatial distribution maps of physical parameters show that the northern area is more affected than the southern area of the reservoir. Local communities have an important role in conserving the water resources in this reservoir. Consequently, the research can contribute new knowledge about the condition of the reservoir and provide additional reference in establishing policies.

Keywords: reservoir, water quality, physical parameter, spatial distribution

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1. Introduction

Reservoirs are freshwater resources to supply the water needs of life. According to the Regulation of the Minister of Public Works and Public Housing No. 27 of 2015, reservoirs are artificial water bodies formed as a result of the construction of dams. According to Nurruhwati et al. (2017), reservoirs are built by river damming. Reservoir ecosystems are categorized as inland public waters. Technically, inland public waters are useful for irrigation sources, electricity generation, tourism, industry, water transportation, and aquaculture development. Ecologically, inland public waters are useful for the habitat of aquatic biota and suppliers of nutrients to the surrounding marine waters (Jummiati et al., 2021).

Sources of water pollution originate from natural and human contaminants (Rezagama & Tamlikha, 2016). The World Health Organization (WHO) predicts that approximately 80% of water pollution in developing countries is caused by domestic waste (Bouslah et al., 2017). Anthropogenic activities in the industrial, domestic and

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agricultural fields produce waste containing physical, chemical and microbiological pollutants (Khouni et al., 2021). Reduction in freshwater quality caused by these contaminants is a national problem because it frequently occurs in Indonesian territorial waters (Soeprobowati et al., 2016). Cases of decreased freshwater quality examples such as domestic activities and capture fisheries cages in Lake Rawapening (Piranti et al., 2018), waste disposal in Situ Gunung Putri Bogor (Aristawidya et al., 2020), settlements and farmlands in Jatibarang Reservoir (Putrisia et al., 2022), also industrialization in Ameenpur Lake, India (Srinidhi et al., 2022).

Seloromo Reservoir is multipurpose and open so that its utilization can be carried out by various parties as long as they meet the stipulated conditions. The construction of this reservoir originally came from the Netherlands' desire to make a dam with the main function as irrigation. The Seloromo Reservoir, constructed in 1930 to dam the flow of the Sani River, is currently used for irrigating agricultural land. Since then, the reservoir has been developed as a fish farming and nature tourism destination. Unfortunately, development of population activities around the river can produce waste that has an impact on water quality. This is because the water flow from upstream to downstream passes through densely populated areas with various activities. The degradation of reservoir water quality can come from many human activities, both human activities directly on the reservoir body and river water that carries waste into reservoir waters.

Water quality is influenced by natural processes and human activities (Bouslah et al., 2017). This research refers to analyzing the physical parameters of water quality, such as temperature, pH, TDS, and EC. These parameters present critical environmental information and provide useful data for water quality control and can be used to monitor changes in water quality due to human activities (Marisi et al., 2016; Romdania et al., 2018). This research aims to analyze the factors that affect water quality in Seloromo Reservoir and determine the spatial distribution of water quality based on physical parameters of water quality. Spatial distribution approaches are used in the water quality monitoring process to represent the distribution of sample points (Prasetyo et al., 2022). The research location is a location that has never been used for academic research so the journal is still limited. Results can support water quality management, identify and control pollution sources, and increase knowledge to protect water resources in Seloromo Reservoir.

2. Materials and Method

2.1. Study Area

Seloromo Reservoir, locally known as Gembong Reservoir, is located on the southeastern slopes of Mount Muria. It serves as an important water body within the region. The geographic setting of the study area is shown in Figure 1. Administratively, the reservoir falls within the jurisdiction of Gembong Sub-district, Pati Regency, Central Java Province, Indonesia. The study area exhibits varied topography, ranging from lowlands to elevations of up to +159.5 meters above sea level (BBWS Pemali Juana, 2019). Seloromo Reservoir covers approximately 5 km², with a catchment area of 15 km². Land use is dominated by residential areas, agricultural land, forests, and minor shrubland patches. The reservoir receives inflow from the Sentul, Jering, Lampeyan, Wuni, and Tempur sub-watersheds (BBWS Pemali Juana, 2019). It is utilized for agricultural irrigation, freshwater aquaculture, and recreational activities (Tourism Information Center Kabupaten Pati, 2020).

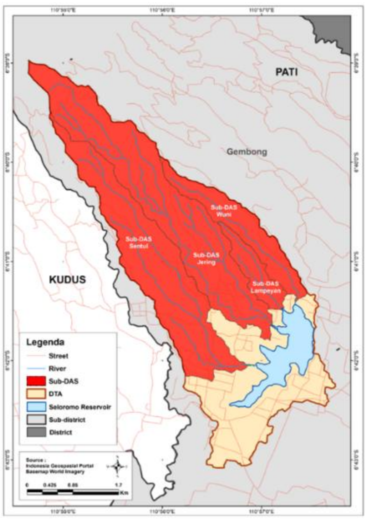

Figure 1. Map of the study area showing Seloromo Reservoir, its catchment boundary, and the major contributing sub-watersheds.

Reservoir water sources come from rainwater catchment and river flow. River flows are Inlet 1 (Wuni River), Inlet 2 (Lampeyan River), Inlet 3 (Jering River), Inlet 4 (Sentul River). Growth in population activities around the watershed can generate waste and reduce reservoir water quality. It happens because the upstream to downstream water flow moves through populated areas with various activities. Water quality degradation of reservoirs can occur due to many human activities, both human activities directly on the water body and river water that carries effluents into reservoir waters.

2.2. Data Collection and Sampling

Survey conducted on 11 February 2023, in the morning (09.00 a.m.) until noon (12.00 p.m). Conditions at that time had begun the dry season based on BMKG predictions indicating that the peak of the rainy season in the Eastern Pati Regency area occurred around December 2022 until January 2023 (BMKG, 2022). Primary data were collected from direct measurements (in situ) at the reservoir. These physical parameters included temperature, acidity (pH), electrical conductivity (EC), and total dissolved solid (TDS) because these parameters can be measured with a water checker directly in the field (Faisyal et al., 2017). Water pH measurements were also taken using litmus paper (Krisno et al., 2021), specifically to measure pH of water in the Ngablak Dengklek DAM to support the analysis (Figure 2).

Figure 2. Measuring water pH at Ngablak Dengklek Dam using litmus paper for pH assessment.

Sampling locations were identified using a systematic random sampling method by creating a grid with a size of 150 m × 150 m using ArcGIS software, then point locations were randomly selected within each grid (Sejati, 2017). It is recommended that one observation point represents a grid of 2.25 ha with a mapping scale of 1:15,000 (Triadi et al., 2016). Total sampling was determined by grid results of 50 samples. Figure 3 shows the sampling locations based on the systematic random sampling method. Water samples are composite, a combination of samples collected at the water surface to a depth of 5 meters. Water samples were collected using a water sampler, then measured with a water checker.

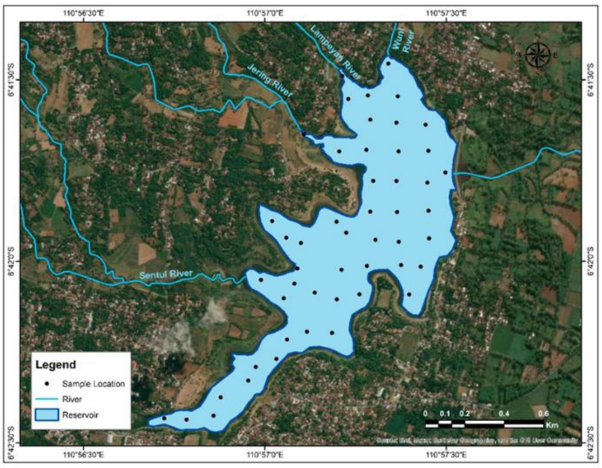

Figure 3. Map of sampling locations showing 50 sample points distributed across Seloromo Reservoir for water quality assessment.

2.3 Analytical Method

Reservoir water quality data were analyzed using descriptive - quantitative methods to explain the results of field measurements in order to identify factors that affect water quality in Seloromo Reservoir. Spatial analysis was also performed to present reservoir water quality data in a map created using the Inverse Distance Weighted (IDW) interpolation technique. This method is commonly used in spatial analysis (Yang et al., 2020). Maps shown are spatial distribution maps of temperature, pH, EC, and TDS parameters for a simplification of water quality analysis.

3. Result and Discussion

Water quality analysis was conducted on 50 samples that were evenly distributed in the water body, including the inlet and outlet points. Results of in situ water quality samples for the physical parameters of temperature, pH, DHL, and TDS at the inlet and outlet locations can be seen in Table 1.

3.1. Temperature

Temperature is influenced by sun light intensity which is related to the level of water depth (Alfionita et al., 2019; Koniyo, 2020). In addition, water temperature is affected by observation time, seasonal conditions, air circulation, weather cloud cover, latitude, and vegetation. Based on the inlet and outlet water temperatures (Table 1), the values were varied. According to Alfionita et al. (2019), high temperature can be due to sampling during the daytime. However, the results of this study actually disagree with this opinion because at inlet 3 with observation time at 10:45 WIB had lower temperature values than other locations with observation time about 30 minutes earlier. These results were due to the location of the temperature measurement at inlet 3 close to the trees. In contrast to inlet 1, 2, 4, and outlet locations which have higher temperature values because sampling is taken during sunny weather and without vegetation cover.

Figure 4 shows the distribution of water temperature conditions in Seloromo Reservoir varying between 27,9°C – 29,3°C and almost dominated by the range of 28,6°C – 29,0°. The water temperature of this reservoir is included in the optimum temperature for the life of aquatic organisms with values that are close to each other. The small difference in temperature values resulted from the weather during sampling, which was rather cloudy so that the intensity of sunlight hitting the water body was lower. Moreover, measurements were taken compositely from the surface to a depth of 5 meters so the depth factor as a reason for differences in water temperature was unable to be proven.

Table 1. Physical water parameters of Seloromo Reservoir, including pH, electrical conductivity (EC), and total dissolved solids (TDS), as measured across various locations

Physical parameter	Location				
	Inlet 1	Inlet 2	Inlet 3	Inlet 4	Outlet
Local time (AM)	10.15	10.14	10.45	09.46	09.24
Temperature (°C)	29.00	29.10	28.10	29.00	28.60
Acidity/pH	8.34	9.06	8.57	8.80	8.89
TDS (mg/L)	100.00	99.80	102.00	97.00	100.00
EC (µs/cm)	139.70	140.20	143.80	137.00	140.90

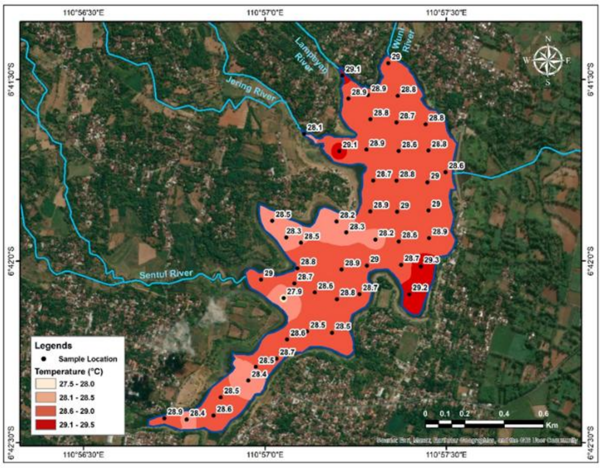

Figure 4. Spatial Distribution Map of Temperature in Seloromo Reservoir

3.2 Degree of Acidity/pH

Various environmental factors contribute to changes in the pH of water, both high and low. Several factors that affect pH changes include the concentration of CO_2 in water, chemicals, temperature, soil and rock composition, and the decomposition process of organic materials (The Healthy Journal, 2023). According to inlet and outlet (Table 1), the pH condition of the water at inlet 1 is the lowest and lower than the outlet because of organic waste such as leaves and tree branches that fall into the water, and the possibility of animal corpses (Figure 5a).

High levels of organic matter can reduce the pH value due to the process of respiration and decomposition process of organic substances in sewage (Supriatna et al., 2020). Highest pH value is in inlet 2 due to the activities of livestock farms by citizens near inlet 2 (Figure 5b). Livestock activities produce liquid waste that causes water pollution to reservoir water quality. This condition agrees with the research of Tatangindatu et al. (2013) and Putri (2019) which proves that the sampling location near the livestock activity causes the pH value of the water to be alkaline.

Figure 5. Inlet 2 conditions showing (a) organic waste accumulation and (b) effects of agricultural activities on the surrounding environment

According to the distribution of water pH conditions in Seloromo Reservoir, the values varied between 8,00 – 9,34 (Figure 7). Water pH values in the north area are more alkaline than the south area. Northern areas of the reservoir receive water supply from three inlets (Wuni, Jering, Lampeyan Rivers) that carries pollutants from the sub-watershed area. Meanwhile, southern areas of the reservoir receive water supply from one inlet, the Sentul River. Related to this, water supply from the Wuni River inlet is the largest supply that drains water from the Ngablak Dengklek dam (north of the reservoir). The simplification observation at Ngablak Dengklek Dam shows that the pH of the water is alkaline with a value of 8 (Figure 2). Land use surrounding this dam is dominated by agricultural activities. Agricultural land use in the sub-watershed area can have an impact on changes in pH of reservoir water (Saputra et al., 2020; Soeprobowati et al., 2019). Fertilizers and pesticides carried by runoff water and river flow will enter the reservoir waters. Besides, agricultural activities in the Jolong area probably supply the Wuni River.

In addition to agricultural activities, many commercial activities are also carried out in the northern area of the reservoir, specifically the periphery of the reservoir. This activity can increase the pH to alkaline through soap waste that is washed by rainwater and then enters the water body. This condition is consistent with the research of Wijayanti (2019) which states that domestic waste in the form of detergents and soaps is alkaline, it causes water to have an alkaline pH. Evidently, there are several small drains near food stalls as water drainage to the water body (Figure 6a). In addition, human waste from commercial and tourism activities is abundant around the periphery of the reservoir (Figure 6b). Housing waste is suspected to increase the pH to alkaline (Dewi et al., 2022).

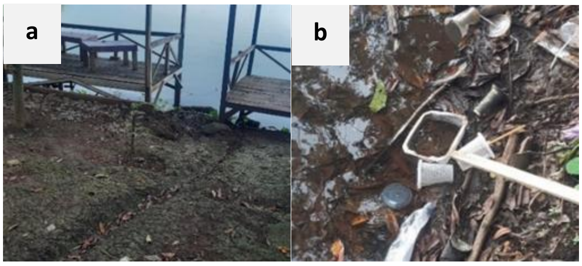

Figure 6. Conditions affecting the reservoir: (a) Drainage runoff entering the reservoir and (b) Contribution of housing waste to water pollution

Finally, third factor that can affect pH water is human activity around the reservoir area. Land use as a housing area around the reservoir sub-watershed is relatively large with a total area of 131,74 hectares. Based on the housing area in the Wuni, Jering and Lampeyan sub-watersheds have a total area of 67,95 hectares, which is relatively larger than the Sentul sub-watershed of 64,90 hectares. This indicates that human activities in the northern area of the reservoir are higher, so that the impact of water discharges from land use is more significant than in the southern area of the reservoir. For example, household waste such as soapy water from car/motorcycle washing and laundry businesses. Reservoir water flow conditions also support this analysis because the dominant direction flows from west to east and a small portion to the northeast. Elevations in the western side of the reservoir that are higher than the eastern side cause water to flow to lower areas. Therefore, the distribution of pH from the inlet location to the center, the pH value is increasing caused by the direction of water flow towards the outlet. It shows that sediment or waste material is spread in accordance with the distribution of water flows (Indrayana et al., 2014).

3.3 Total Dissolved Solid (TDS)

The TDS limit according to WHO is <1000 mg/L (Fatima et al., 2022). TDS originates from natural sources (soil erosion, leaves and silt), feces, surface rainwater, fertilizers and pesticides, as well as domestic and industrial waste (Ustaoglu & Tepe, 2019). According to Table 1, the highest TDS value was 102,0 mg/l at inlet 3 (flow from Jering River). The presence of agricultural activities beside the river that leads to inlet 3 caused the fertilizer/pesticide solution material to be carried into the reservoir. Agricultural land in the Jering sub-watershed is also the largest at 308,65 hectares. In addition, animal feces are suspected to have entered the reservoir because of livestock activities near inlet 3. Animal feces waste carried in irrigation waterways causes an increase in nutrient content (Saputra et al., 2020).

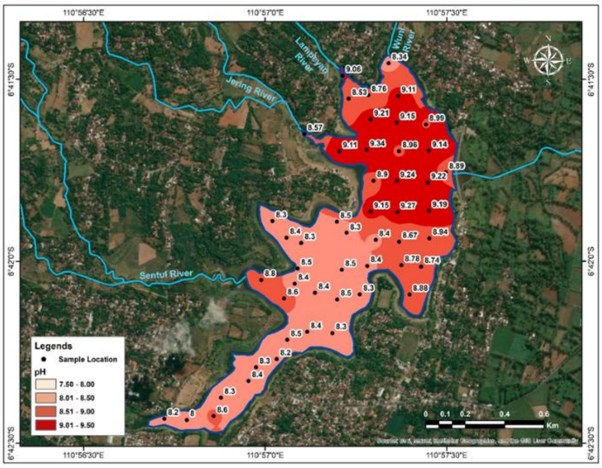

Figure 7. Spatial Distribution Map of pH in Seloromo Reservoir

TDS spatial distribution maps show higher values in the north between 98,6 – 100,0 mg/l than the south between 97,0 – 98,5 mg/l (Figure 8). The northern side has more inputs from three inlets, while the southern side has only one inlet. Northern areas get the largest supply from the Wuni River, where the surrounding land use is dominated by agricultural and forest activities. In addition, total area of agricultural and forest land use from all three sub-watersheds (Jering, Wuni, Lampeyan) is approximately 623,15 hectares, while the Sentul sub-watershed is approximately only 331 hectares. Water flow from irrigated land in the sub-watershed area can increase the concentration of dissolved substances in the river flow, so that the condition of river water quality is getting worse (Helmi et al., 2017).

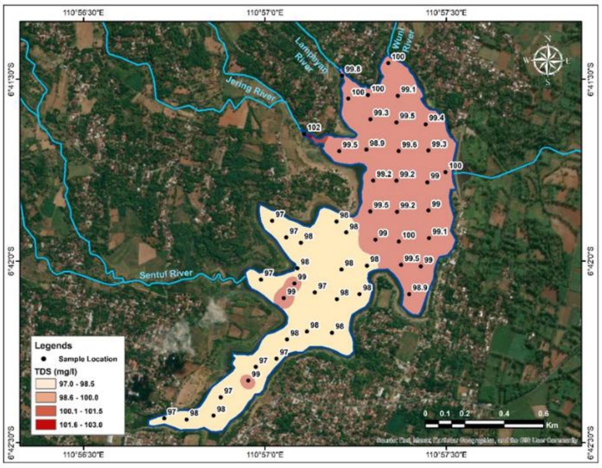

Figure 8. Spatial Distribution Map of TDS in Seloromo Reservoir

3.4 Electrical Conductivity (EC)

EC describe as an ability of water to conduct electrical energy, higher value means more salt content in the water. Table 1 show that the lowest EC value was found at inlet 4 (input from Wuni River). This is caused by fertilizers from agricultural activities near the inlet not being absorbed by the plants and then carried by the flow of water towards the outlet (Saputra et al., 2020). Inlet 3 (input from Jering River) are higher than outlet because of agricultural activities with fertilizers or pesticides carried in the water. Agricultural land in the Jering sub-watershed is the largest at 308,65 hectares. In addition, the housing area in the Jering sub-watershed is also relatively large at 39,08 hectares which assumes activities such as washing and bathing. Higher EC in the inlet can be caused by human activities that use soap and detergents (Saputra et al., 2020). EC ranged from 136,0 – 143,8 µs/cm and was categorized as fresh water because it was below 1,500 µs/cm. EC distribution pattern is similar to the TDS distribution pattern, which is higher in the northern side than the southern side of the reservoir (Figure 9). This means that the salt ion content is more in the northern side of the reservoir. TDS conditions in the northern side are higher because of the influence of agricultural activities, so it is assumed that these activities increase EC values.

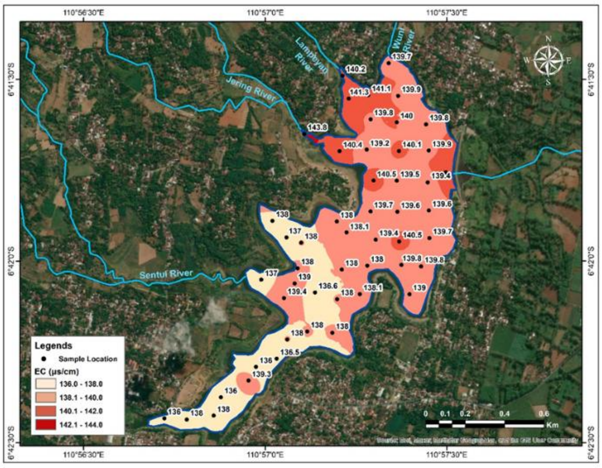

Figure 9. Spatial Distribution Map of EC in Seloromo Reservoir

Water quality conditions in Seloromo Reservoir based on physical parameters can be indicated by human activities around the reservoir area. For example, TDS conditions in the southern part of Seloromo Reservoir are lower than the northern part, in accordance with research (Tyas et al., 2021) that areas that are less contaminated by pollutants from natural activities such as erosion and activities of the surrounding community have lower TDS values.

Analysis of factors affected water quality in Seloromo Reservoir only limited to human activity factors, and not natural factors. Additionally, the parameters used are also physical parameters that can be tested directly in the field. This study neither used bathymetry maps to show the water depth and bottom conditions of the reservoir waters, nor measurements of reservoir water discharge at the inlet and outlet locations. Consequently, the analysis of water quality conditions was only based on the conditions during sampling and also observations of activities in the catchment area.

4. Conclusion

This study assessed the impact of human activities around the Seloromo Reservoir catchment on water quality, focusing on physical parameters such as pH, electrical conductivity (EC), and total dissolved solids (TDS). The findings reveal that agricultural practices, human settlements, tourism, and livestock contribute to water quality variations, particularly in the northern part of the reservoir, which is more vulnerable due to the higher concentration of these activities. This research underscores the importance of understanding the relationship between land use and water quality in freshwater ecosystems.

While the study provides valuable insights, the reliance on physical parameters limits a comprehensive analysis of water quality. Future research should expand to include more complex indicators, such as nutrient levels and microbial contamination, to better understand the ecological health of the reservoir. The findings highlight the need for effective catchment management strategies to address the impacts of human activities, ensuring the sustainability of Seloromo Reservoir for its various uses, including irrigation, aquaculture, and recreation.

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Data availability statement

All data used in the research is public knowledge and there is not any confidential information

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Author Contributions

The author was responsible for the conceptualization, design, and execution of the study, including data collection, analysis, and interpretation. The author also drafted and revised the manuscript for publication

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