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Physicochemical Assessment and Water Quality Classification of the Hiwakloy Sulfur Spring River, Camarines Sur, Philippines

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ABSTRACT

Freshwater ecosystems are essential for sustaining biodiversity, supporting human health, and promoting socioeconomic development. However, increasing anthropogenic activities have contributed to the deterioration of river water quality, highlighting the need for continuous monitoring and assessment. This study evaluated the physicochemical water quality of the Hiwakloy Sulfur Spring River in Goa, Camarines Sur, Philippines, and determined its classification based on the Department of Environment and Natural Resources (DENR) Administrative Order No. 2016-08. A descriptive-quantitative research design was employed using water samples collected from three designated sampling stations representing the head, body, and foot of the river during the wet season in November 2022. Six physicochemical parameters were analyzed, namely turbidity, pH, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), and salinity.

The results revealed distinct descriptive differences among the sampling stations. Turbidity increased downstream, with the highest value recorded at the river foot, indicating greater sediment accumulation from surface runoff and nearby human activities. In contrast, pH remained stable within the slightly basic range, while dissolved oxygen levels consistently exceeded the minimum standard required to support aquatic life. The measured TDS, EC, and salinity values remained within acceptable freshwater limits, with relatively higher concentrations observed at the headwaters due to the river's natural sulfur spring characteristics. Based on DENR standards, the average values for pH, dissolved oxygen, and total dissolved solids met the criteria for Class AA inland waters, indicating excellent water quality suitable as a source of public water supply requiring only disinfection. The remaining parameters could not be classified because corresponding regulatory limits are not specified in the current DENR guidelines.

Overall, the measured physicochemical parameters remained within acceptable ranges during the wet-season sampling period, with pH, dissolved oxygen, and total dissolved solids meeting the Class AA criteria under DENR Administrative Order No. 2016-08. The study provides baseline information for future monitoring and may support future watershed conservation planning, environmental monitoring, and evidence-based water resource management in Camarines Sur.

Keywords: Hiwakloy Sulfur Spring River, physicochemical analysis, water quality, dissolved oxygen, freshwater ecosystem, Camarines Sur

INTRODUCTION

Freshwater ecosystems are indispensable for sustaining biodiversity, safeguarding public health, and supporting socioeconomic development. Rivers provide a wide range of ecosystem services, including water for domestic consumption, agriculture, fisheries, recreation, and industrial activities. Because of these interconnected functions, maintaining good river water quality is essential for preserving ecological integrity and ensuring the sustainable utilization of freshwater resources (United Nations, 2023). However, increasing anthropogenic pressures have accelerated the degradation of freshwater ecosystems worldwide, making water quality monitoring an urgent environmental priority.

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Globally, freshwater resources are increasingly threatened by rapid population growth, urbanization, industrialization, agricultural intensification, and climate change. The United Nations World Water Development Report 2024 identifies water pollution as one of the greatest barriers to achieving sustainable development, leaving millions of people dependent on vulnerable and deteriorating freshwater sources (UNESCO, 2024). Although river water quality is naturally influenced by geological processes, hydrological conditions, and seasonal rainfall, human activities have become the dominant drivers of freshwater degradation (Vörösmarty et al., 2010). Agricultural runoff, untreated domestic wastewater, industrial discharges, and land-use conversion introduce excessive nutrients, sediments, pathogens, and other contaminants into river systems, altering their physical and chemical characteristics and reducing their ecological functions.

These environmental pressures are further intensified by climate change. Extreme rainfall events accelerate the transport of sediments and pollutants into river networks, while increasing air and water temperatures reduce the oxygen-holding capacity of freshwater systems, thereby threatening aquatic biodiversity and ecosystem resilience (IPCC, 2023). In response, the international community has prioritized freshwater conservation under Sustainable Development Goal (SDG) 6, which aims to ensure the availability and sustainable management of clean water and sanitation for all (United Nations, 2023).

The Philippines faces similar challenges in protecting its freshwater resources. Rapid urban expansion, intensive agricultural practices, deforestation, and inadequate wastewater management have contributed to the declining quality of many river systems. Recent investigations of Philippine river systems have consistently demonstrated that upstream reaches generally exhibit better water quality than downstream sections, where anthropogenic activities, land-use change, and urban development contribute to elevated sediment loads, nutrient enrichment, and declining ecological condition. Since downstream sections receive and accumulate pollutants transported from upstream catchments, spatial variations in physicochemical characteristics provide valuable indicators of watershed condition and the cumulative impacts of land-use change, agricultural activities, and urban development (Allan, 2004). Consequently, regular water quality monitoring is essential for establishing baseline environmental conditions, detecting changes associated with anthropogenic pressures, and supporting evidence-based watershed management and conservation strategies (UNEP, 2021).

One important freshwater resource in Camarines Sur is the Hiwakloy Sulfur Spring River, which traverses the municipalities of Goa and Lagonoy. Goa is a first-class municipality with a population of 71,368 distributed across 34 barangays (Philippine Statistics Authority [PSA], 2020). The Hiwakloy Sulfur Spring River provides water for domestic use, agricultural irrigation, livestock production, backyard fisheries, and other community activities. In addition to its socioeconomic importance, the river represents a unique freshwater ecosystem because of its sulfur spring source, which naturally influences its physicochemical characteristics. However, increasing residential expansion, agricultural activities, and improper waste disposal within its watershed expose the river to potential contamination from untreated domestic wastewater, agricultural runoff, and solid waste accumulation. Despite its ecological and socioeconomic importance, no published peer-reviewed study has comprehensively characterized the physicochemical water quality of the Hiwakloy Sulfur Spring River using the current DENR Water Quality Guidelines. Consequently, scientific evidence needed to support watershed management and long-term environmental monitoring remains limited.

Physicochemical assessment is widely recognized as a reliable and efficient approach for evaluating the current condition of freshwater ecosystems because physical and chemical parameters respond rapidly to both natural processes and anthropogenic disturbances (Chapman, 1996). Unlike biological assessments, which generally reflect long-term ecological changes, physicochemical monitoring provides an immediate quantitative assessment of water quality. Parameters such as turbidity, pH, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), and salinity collectively describe sediment transport, acid-base balance, oxygen availability, ionic composition, and mineral content of river water. Turbidity reflects the concentration of suspended particles that reduce light penetration and primary productivity (Davies-Colley & Smith, 2001). The pH determines the chemical balance of aquatic systems and influences nutrient availability and metal toxicity (Wetzel, 2001). Dissolved oxygen is a critical indicator of the capacity of rivers to sustain aquatic organisms and is strongly influenced by organic pollution and water temperature (Chapman, 1996). Meanwhile, TDS, EC, and salinity characterize the concentration of dissolved ions and mineral constituents, providing

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valuable indicators of watershed geology, agricultural runoff, and potential contamination (Hem, 1985). Together, these parameters provide a comprehensive understanding of the ecological condition of river systems and serve as essential indicators for environmental monitoring.

In the Philippines, river water quality is regulated by the Department of Environment and Natural Resources (DENR) through Administrative Order No. 2016-08, together with subsequent amendments, including DAO No. 2021-19. These regulations establish Water Quality Guidelines and classify inland water bodies according to their designated beneficial uses, thereby providing nationally accepted standards for evaluating the suitability of rivers for domestic water supply, recreation, fisheries, agriculture, and other purposes. Comparing measured physicochemical parameters with these regulatory thresholds provides an objective basis for determining the environmental condition and appropriate classification of freshwater systems.

Although numerous studies have documented the physicochemical characteristics of major Philippine rivers, published baseline information for the Hiwakloy Sulfur Spring River remains limited. This lack of scientific data restricts the ability of local government units and environmental managers to formulate effective conservation measures and monitor future changes in water quality. Establishing baseline information is particularly important for rivers experiencing increasing anthropogenic pressures, as it enables the early detection of environmental degradation and supports evidence-based watershed management.

Therefore, this study assessed the physicochemical water quality of the Hiwakloy Sulfur Spring River by analyzing turbidity, pH, dissolved oxygen, total dissolved solids, electrical conductivity, and salinity across three designated sampling stations representing the headwaters, midstream, and downstream sections of the river. Furthermore, the measured values were evaluated using the Water Quality Guidelines prescribed under DENR Administrative Order No. 2016-08 to determine the river's water quality classification. The findings provide baseline scientific information that can support long-term environmental monitoring, watershed conservation, and sustainable water resource management in Goa and neighboring communities in Camarines Sur.

METHODOLOGY

Research Design

This study employed a descriptive-quantitative research design to evaluate the physicochemical water quality of the Hiwakloy Sulfur Spring River. The design enabled the systematic collection and quantitative analysis of field and laboratory data to establish a baseline water quality profile of the river. Six physicochemical parameters—turbidity, pH, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), and salinity—were measured to characterize the spatial variation in water quality across the sampling stations. Field sampling was conducted during the wet season (November 2022), providing a representative assessment of the river's physicochemical condition under high-flow conditions.

Study Area and Sampling Stations

The study was conducted along the Hiwakloy Sulfur Spring River, which traverses the municipalities of Goa and Lagonoy in Camarines Sur, Philippines. Water sampling was carried out on November 3, 2022, during the wet season to assess the river's physicochemical characteristics under high-flow conditions. Three sampling stations were strategically established to represent the upstream (headwaters), midstream, and downstream sections of the river, thereby capturing the spatial variability in water quality along its course. The geographic coordinates of each sampling station were recorded using a Global Positioning System (GPS) device, and the locations are illustrated in Figure 1.

The designated sampling stations were as follows: Station 1 (Headwaters), located across the Goa–Tinambac Road near the sulfur spring source; Station 2 (Midstream), situated at the spillway in Barangay Salog, Goa; and Station 3 (Downstream), located in Barangay Loho, Lagonoy, Camarines Sur. These stations were selected to represent areas with varying hydrological and land-use characteristics, enabling the assessment of potential changes in water quality along the river continuum.

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Comparative analysis of the three sampling stations allowed for the evaluation of spatial variations in key physicochemical parameters and the identification of possible influences of natural processes and anthropogenic activities on river water quality. The resulting baseline information provides a scientific basis for future monitoring efforts, watershed conservation, and sustainable management of the Hiwakloy Sulfur Spring River.

Figure 1. Location of Hiwakloy Sulfur Spring River Sampling Stations

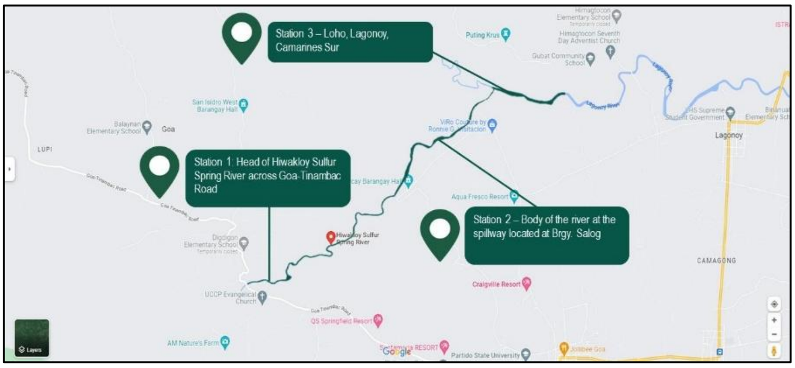

Table 1. Geographical coordinates, sampling time, weather conditions, and description of Hiwakloy Sulfur Spring River, Goa, Camarines Sur during water sampling on November 3, 2022.

Stations	Geographical Coordinates	Time of Sampling	Weather Condition	In-situ observations	Pictures using GPS camera
Station 1 (Headwaters) Hiwakloy Sulfur Spring across Goa–Tinambac Road	Lat 13.6674, Long 123.4047	12:36 PM	Mild Sunny	Riverbanks were shaded by mature trees. Floating dried leaves and twigs were observed, with rocky to boulder substrates dominating the channel.	
Station 2 (Midstream) Spillway, Brgy. Salog, Goa	Lat 13.7363, Long 123.4733	11:54 AM	Mild Sunny	Small pieces of debris and twigs were observed. The site serves as a local swimming area and is adjacent to residential properties with backyard vegetation. Livestock grazing was observed on the opposite riverbank.	
Station 3 (Downstream) Brgy. Loho, Lagonoy	Lat 13.7359, Long 123. 5461	11:21 AM	Mild Sunny	Residential settlements were present near the river. Solid waste was observed along portions of the riverbank, with grasses and cogon vegetation dominating both sides.	

Note: All photographs were taken by the authors during field sampling on 3 November 2022 using a GPS-enabled digital camera. Photographs are presented for site documentation only and are not intended for quantitative analysis. GPS coordinates were recorded in the field. The photograph for Station 2 does not

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contain an embedded GPS stamp because of limited satellite signal reception during data collection; however, the location was verified using handheld GPS coordinates and field notes.

Data Collection, Parameters, Specifications, and Equipment

Water sampling was conducted on November 3, 2022, during the wet season to characterize the physicochemical condition of the Hiwakloy Sulfur Spring River. Samples were collected from the three designated sampling stations representing the upstream, midstream, and downstream sections of the river. At each station, three replicate water samples were collected from locations extending from near the riverbank toward the midstream using sterile 1.5-L polyethylene sampling bottles. The collected samples were immediately placed in an insulated cooler and transported to the Partido State University Water Quality Laboratory for analysis within one hour to preserve sample integrity.

The study evaluated six physicochemical parameters: turbidity, pH, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), and salinity. These parameters were selected because they are widely recognized indicators of freshwater quality and provide information on the physical and chemical condition of river ecosystems. Analytical procedures followed standard laboratory methods using calibrated instruments available at the Partido State University Water Quality Laboratory.

For each sampling station, measurements from the three replicate samples were averaged to obtain the representative value of each parameter. Field sampling was conducted under generally mild and sunny weather conditions. The geographic coordinates of the sampling stations were recorded using a Global Positioning System (GPS)-enabled camera. Where GPS data could not be obtained because of limited internet connectivity, coordinates were estimated based on field observations and mapping references.

Table 2 summarizes the physicochemical parameters analyzed, their units of measurement, and the analytical methods employed in this study.

Table 2. Physicochemical Parameters, Units, and Analytical Methods

Parameter	Unit	Method
Turbidity	NTU	Nephelometric method
pH	_	Electrochemical method
Dissolved Oxygen	mg/L	Electrochemical method
Total Dissolved Solids	Ppm	Electrochemical method
Electric Conductivity	µs	Electrochemical method
Salinity	mg/L	Electrochemical method

Quality Assurance and Quality Control

To ensure the reliability and accuracy of the analytical results, all field and laboratory procedures followed standard water quality assessment protocols. Portable instruments used for measuring pH, dissolved oxygen, total dissolved solids, electrical conductivity, and salinity were calibrated according to the manufacturers' specifications before field sampling. Three replicate water samples were collected from each sampling station, and the mean values were used for analysis to minimize measurement variability. Water samples were transported in insulated containers and analyzed at the Partido State University Water Quality Laboratory within one hour of collection to preserve sample integrity and reduce potential changes in physicochemical characteristics during transport.

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Data Analysis

Descriptive statistics were used to summarize the physicochemical characteristics of the river. For each parameter, the mean value of the three replicate measurements was computed for every sampling station. The resulting averages were compared with the Water Quality Guidelines specified under DENR Administrative Order No. 2016-08 to determine the corresponding water quality classification.

RESULTS AND DISCUSSION

Physicochemical Characteristics of the Hiwakloy Sulfur Spring River

The mean physicochemical characteristics of water samples collected from the three monitoring stations along the Hiwakloy Sulfur Spring River are presented in Table 3. Water samples were collected during the wet season (November 2022) at an average water temperature of 25.1°C. The measured parameters included turbidity, pH, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), and salinity.

Overall, the river exhibited generally stable physicochemical conditions across the three sampling stations. Most parameters showed only slight spatial variation, indicating relatively uniform water quality throughout the river. Turbidity was the only parameter that increased substantially toward the downstream station, suggesting greater sediment transport and accumulation in the lower reaches. In contrast, dissolved oxygen, total dissolved solids, electrical conductivity, and salinity showed a gradual decrease downstream, while pH remained consistently within the slightly alkaline range. These trends suggest that the river's physicochemical characteristics are largely influenced by its natural sulfur spring origin, with localized downstream effects associated with surface runoff and surrounding human activities.

Table 3. Mean (±SD) physicochemical characteristics of water samples collected from the Hiwakloy Sulfur Spring River.

Parameter	Unit	Station 1 (Headwaters)	Station 2 (Midstream)	Station 3 (Downstream)
Turbidity	NTU	3.67 ± 1.15	3.67 ± 1.15	10.00 ± 1.73
pH	—	7.31 ± 0.10	7.78 ± 0.04	7.43 ± 0.20
Dissolved Oxygen	mg/L	12.43 ± 0.32	11.33 ± 0.15	11.30 ± 0.52
Total Dissolved Solids	ppm	118.57 ± 4.21	82.27 ± 1.32	86.67 ± 1.97
Electrical Conductivity	µS/cm	182.70 ± 2.31	124.43 ± 0.51	124.90 ± 4.06
Salinity	mg/L	118.03 ± 1.08	94.37 ± 1.20	87.27 ± 6.09

Note: Values are presented as mean ± standard deviation (n = 3).

Turbidity

Turbidity exhibited the greatest spatial variation among the measured physicochemical parameters, increasing from 3.67 NTU at both the headwaters and midstream to 10.00 NTU at the downstream station. Although the downstream site showed visibly higher suspended sediments, the measured turbidity remained relatively low compared with values reported for disturbed tropical rivers. The increase in turbidity is likely associated with sediment transport from surface runoff, riverbank erosion, and nearby residential and agricultural activities observed during field sampling. Similar downstream increases in turbidity have been reported in Philippine river systems, where rainfall and watershed runoff contribute to greater sediment loads during the wet season (Laud et al., 2016). Despite this increase, the relatively low turbidity values observed in the Hiwakloy Sulfur Spring River suggest that sediment disturbance remains localized and that the river generally maintains good physical water quality.

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pH

The river maintained a stable and slightly alkaline pH, ranging from 7.31 to 7.78, with an overall mean of 7.51. All measurements fell within the DENR Class AA guideline of 6.5–8.5, indicating favorable conditions for freshwater organisms and aquatic biochemical processes. The relatively narrow variation in pH suggests that the river possesses good buffering capacity, likely influenced by dissolved minerals originating from the sulfur spring source. Comparable pH values have been reported in Philippine spring-fed freshwater sources, where groundwater flowing through mineral-rich geological formations contributes to stable water chemistry (Besagas et al., 2015). These findings indicate that the sulfur spring exerts a stabilizing influence on the river's acid-base balance while maintaining conditions suitable for aquatic life.

Dissolved Oxygen

Dissolved oxygen concentrations remained consistently high throughout the river, ranging from 11.30 to 12.43 mg/L, with all stations substantially exceeding the DENR minimum criterion of 5.0 mg/L for Class AA inland waters. The slightly higher dissolved oxygen concentration observed at the headwaters may be attributed to groundwater discharge from the sulfur spring, increased turbulence, and continuous natural aeration. The slight downstream decline likely reflects increasing biological respiration and reduced water mixing as the river flows through areas with greater human activity. The observed trend is consistent with findings reported by Martin et al. (2018), who likewise observed elevated dissolved oxygen concentrations in protected freshwater systems. In contrast, rivers subjected to intensive urbanization often exhibit lower dissolved oxygen concentrations because of increased organic loading and wastewater discharge (Magbanua et al., 2025). The elevated dissolved oxygen observed in the present study therefore reflects the relatively undisturbed condition of the Hiwakloy Sulfur Spring River.

Total Dissolved Solids

Total dissolved solids ranged from 82.27 to 118.57 ppm, remaining well below the DENR guideline value of 500 ppm. The highest concentration occurred at the headwaters, reflecting the natural dissolution of minerals associated with the sulfur spring source. Lower concentrations downstream may have resulted from dilution by tributary inflows and increased river discharge. Similar trends have been reported in Philippine spring-water systems, where groundwater emerging from mineral-bearing formations exhibits relatively higher dissolved mineral concentrations near the source before becoming diluted downstream (Besagas et al., 2015). The relatively low TDS values indicate that, despite the river's sulfur spring origin, dissolved mineral concentrations remain within acceptable freshwater limits.

Electrical Conductivity

Electrical conductivity varied from 124.43 to 182.70 µS/cm, exhibiting a spatial pattern similar to that of total dissolved solids. The highest conductivity at the headwaters reflects the elevated ionic composition associated with sulfur spring water, while the downstream decrease suggests dilution by freshwater inputs. The close relationship between conductivity and total dissolved solids indicates that dissolved mineral ions are the principal contributors to water chemistry. Similar conductivity patterns have been reported in Philippine spring-water sources, where groundwater-derived minerals increase ionic concentrations at the source (Besagas et al., 2015). Compared with rivers influenced by urban and industrial activities, where conductivity values are often substantially elevated because of anthropogenic inputs, the relatively low conductivity observed in the Hiwakloy Sulfur Spring River indicates that its ionic characteristics are predominantly controlled by natural geological processes rather than pollution (Magbanua et al., 2025).

Salinity

Salinity remained consistently low across all sampling stations, ranging from 87.27 to 118.03 mg/L. The gradual downstream decrease reflects dilution of naturally mineralized spring water as additional freshwater enters the river system. Because the Hiwakloy River originates from a sulfur spring, the relatively higher salinity at the headwaters is attributed to naturally occurring dissolved mineral salts rather than anthropogenic contamination

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or seawater intrusion. Similar observations have been reported for Philippine spring-water sources, where groundwater contributes naturally elevated dissolved salts while maintaining freshwater conditions (Besagas et al., 2015). The salinity values recorded in this study therefore confirm that the sulfur spring enhances the river's natural mineral composition without altering its freshwater characteristics.

Overall Interpretation

The physicochemical assessment indicates that the Hiwakloy Sulfur Spring River maintained generally favorable physicochemical conditions during the wet-season sampling period. Although descriptive differences were observed among the sampling stations, the measured parameters remained within acceptable ranges and reflected the combined influence of the river's sulfur spring origin and localized environmental conditions. Based on the evaluated physicochemical parameters, the river met the applicable Class AA guideline values under DENR Administrative Order No. 2016-08. These findings provide important baseline information for future seasonal monitoring, watershed conservation, and evidence-based water resource management while highlighting the need to incorporate microbiological, biological, and additional chemical indicators in subsequent assessments to achieve a more comprehensive evaluation of water quality.

Water Quality Classification Based on DENR Administrative Order No. 2016-08

The mean physicochemical values obtained from the three sampling stations were evaluated against the Water Quality Guidelines prescribed under DENR Administrative Order No. 2016-08 to determine the water quality classification of the Hiwakloy Sulfur Spring River (Table 4). Among the six physicochemical parameters analyzed, pH, dissolved oxygen (DO), and total dissolved solids (TDS) complied with the regulatory criteria for Class AA inland waters, indicating favorable water quality conditions during the wet-season sampling period. Under the DENR classification system, Class AA waters are designated as sources of public water supply requiring only disinfection prior to distribution, emphasizing the river's potential as a valuable freshwater resource.

In contrast, turbidity, electrical conductivity (EC), and salinity could not be used for official water body classification because the current DENR Water Quality Guidelines do not provide classification thresholds for these parameters. Nevertheless, the measured values remained within ranges generally considered acceptable for freshwater ecosystems and did not indicate evidence of significant physicochemical degradation during the sampling period.

Table 4. Water Quality Classification of the Hiwakloy Sulfur Spring River Based on Mean Physicochemical Parameters and DENR Administrative Order No. 2016-08

Parameter	Mean Value	DENR Water Quality Guideline (DAO 2016-08)	Meets DENR Guideline	Water Quality Classification
pH	7.51	6.5–8.5	Yes	Class AA
Dissolved Oxygen (mg/L)	11.68	≥ 5.0	Yes	Class AA
Total Dissolved Solids (ppm)	95.84	≤ 500	Yes	Class AA
Turbidity (NTU)	5.78	No classification criterion	N/A	Not classified
Electrical Conductivity (μS/cm)	144.01	No classification criterion	N/A	Not classified
Salinity (mg/L)	99.89	No classification criterion	N/A	Not classified

Note: Water quality classification was determined only for parameters with established guideline values under DENR Administrative Order No. 2016-08. Turbidity, electrical conductivity, and salinity were measured to characterize the river's physicochemical condition but are not assigned classification thresholds under the current DENR guidelines for inland waters.

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The Class AA classification demonstrates that the Hiwakloy Sulfur Spring River maintained excellent physicochemical quality during the wet-season sampling period despite minor spatial variations among the sampling stations. The elevated turbidity observed at the downstream station reflects localized sediment inputs associated with surface runoff, riverbank erosion, and nearby residential activities. Conversely, the relatively higher concentrations of TDS, EC, and salinity at the headwaters are attributable to the natural mineral composition of the sulfur spring source rather than anthropogenic contamination. These spatial patterns indicate that the river's water quality is predominantly controlled by natural geological processes while showing only limited influence from surrounding land-use activities.

The favorable physicochemical characteristics and Class AA classification have important implications for local water resource management. As a potential source of public water supply requiring only disinfection, the river should be protected through continued watershed conservation, effective solid waste management, regulation of domestic wastewater discharge, and erosion control measures, particularly in downstream areas where sediment accumulation was observed. The baseline information generated by this study provides a scientific foundation for long-term environmental monitoring and evidence-based management of the Hiwakloy Sulfur Spring River. Future monitoring across both wet and dry seasons, together with the inclusion of microbiological, biological, nutrient, and heavy metal analyses, is recommended to provide a more comprehensive assessment of the river's ecological condition and support sustainable watershed management.

CONCLUSION

This study evaluated the physicochemical water quality of the Hiwakloy Sulfur Spring River through the analysis of turbidity, pH, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), and salinity across three sampling stations representing the upstream, midstream, and downstream sections of the river. The results demonstrated spatial variations in water quality, with turbidity increasing toward the downstream section, indicating greater sediment inputs associated with surface runoff and nearby human activities. In contrast, pH remained relatively stable within the slightly alkaline range, while dissolved oxygen concentrations consistently exceeded the minimum standard required to sustain aquatic life. The observed TDS, EC, and salinity values reflected the river's natural sulfur spring characteristics and remained within acceptable freshwater conditions.

Comparison of the measured physicochemical parameters with the Water Quality Guidelines under DENR Administrative Order No. 2016-08 showed that pH, dissolved oxygen, and total dissolved solids satisfied the criteria for Class AA inland waters, indicating its potential as a source of public water supply requiring only disinfection prior to distribution. Although turbidity, electrical conductivity, and salinity are not assigned water quality classification thresholds under the current DENR guidelines, their measured values did not indicate significant physicochemical impairment of the river.

Overall, the findings establish baseline scientific information on the physicochemical condition of the Hiwakloy Sulfur Spring River that can serve as a reference for future environmental monitoring, watershed conservation, and sustainable water resource management. Continued monitoring and the inclusion of additional biological, microbiological, and chemical indicators are recommended to provide a more comprehensive assessment of the river's ecological health.

Limitations of the Study

This study was limited to a single sampling event conducted during the wet season (November 2022) and focused exclusively on selected physicochemical parameters. Consequently, temporal and seasonal variations in water quality could not be evaluated, and the findings should be interpreted as representative only of wet-season conditions. Future investigations incorporating both wet- and dry-season sampling are necessary to better characterize seasonal fluctuations in water quality and improve the generalizability of the results.

In addition, the study did not include microbiological indicators (e.g., total and fecal coliform), biological indicators (e.g., benthic macroinvertebrates and plankton communities), nutrient concentrations (e.g., nitrate and phosphate), or heavy metals, all of which are important components of comprehensive freshwater quality

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assessment. Therefore, the present findings provide baseline physicochemical information rather than a complete evaluation of the river's ecological health.

Recommendations

Continuous monitoring of the Hiwakloy Sulfur Spring River is recommended to evaluate temporal changes in water quality during both the wet and dry seasons. Seasonal monitoring would provide a more comprehensive understanding of natural hydrological variation and improve long-term environmental assessment.

Future studies should expand the scope of water quality assessment by incorporating microbiological indicators (total and fecal coliform), biological indicators such as benthic macroinvertebrates and plankton communities, nutrient concentrations, and heavy metal analyses to provide a more comprehensive evaluation of the ecological condition of the river.

Local government units, the Department of Environment and Natural Resources (DENR), and other relevant agencies should strengthen watershed protection programs through improved solid waste management, regulation of domestic wastewater discharge, erosion control measures, and community-based environmental education to preserve the river's excellent water quality.

The baseline information generated by this study may also serve as a scientific basis for the development of a Water Quality Index (WQI), integrating physicochemical, biological, and microbiological indicators into a simplified measure of ecological condition that can support long-term monitoring and evidence-based water resource management.

Conflict of Interest

The authors declare that there are no financial, professional, or personal conflicts of interest that could have influenced the conduct, analysis, or reporting of this study.

Data Availability

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. The data are not publicly available because they form part of ongoing research activities and institutional records.

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