**Physicochemical analysis of the limnetic and littoral zones of lake pinamaloy, don carlos,**

**Bukidnon, philippines**

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**ABSTRACT**

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| Lake Pinamaloy is an important freshwater resource in Bukidnon, Philippines, providing water for fishing, household use, and recreation. This study assessed its water quality by measuring temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), salinity, and turbidity at five sampling stations in both the limnetic and littoral zones. Water samples were collected and analyzed on-site using a multiparameter digital water quality tester and a turbidity meter. Most of the results—pH at 6.78, EC at 61.13 µS/cm, TDS at 29.6 mg/L, and salinity at 30.33 mg/L—were within acceptable levels. However, turbidity had a high average of 20.08 NTU, which is above the recommended limit of 5 NTU and may affect aquatic life. There were significant differences (P < 0.05) in temperature, turbidity, and salinity between the sampling stations, which may be caused by natural conditions or human activities. These findings provide useful baseline information for future monitoring and lake management. It is recommended that future studies identify pollution sources through land use mapping and watershed analysis and include other parameters such as total coliform count, dissolved oxygen, and biochemical oxygen demand, as well as biological indicators such as plankton or macroinvertebrates to better understand the lake’s ecological condition. |

***Keywords:*** *freshwater ecosystem, in-situ analysis, Lake Pinamaloy, physicochemical parameters, water quality*

**1. INTRODUCTION**

Lakes serve as critical freshwater resources for agriculture, industry, and biodiversity conservation (Cull, 2023). According to the United Nations Environment Programme (UNEP), lakes contain 90% of the planet’s surface freshwater, making them essential in supporting wildlife, sustaining ecosystems, and meeting water demands across sectors (UNEP, 2022). However, growing human activities have contributed to the degradation of many lake systems, particularly in developing regions where pollution and overexploitation of resources are common issues (Brillo, 2015). Monitoring physicochemical parameters such as temperature, pH, turbidity, salinity, total dissolved solids (TDS), and electrical conductivity is important for evaluating water quality and ecological health. Assessing the physicochemical characteristics of lake water is important in evaluating its quality, ecological status, and suitability for different uses (Redoble et al., 2025).

Lake Pinamaloy, located in Don Carlos, Bukidnon, is one of the major freshwater lakes in Mindanao, Philippines. It holds ecological, cultural, and economic significance for the surrounding communities. Despite its importance, there is limited research on its water quality, especially its physicochemical properties. Fluctuations in temperature, pH, turbidity, salinity, total dissolved solids (TDS), and electrical conductivity can show signs of pollution or chemical contamination in freshwater systems. Elevated turbidity and TDS often result from surface runoff and sedimentation, while shifts in pH and conductivity are commonly linked to agricultural or industrial discharges (Palamuleni and Akoth, 2015). In Lake Lanao, nutrient loading and poor waste management have led to significant changes in water quality (Angagao et al., 2017). Understanding parameters such as temperature, pH, turbidity, salinity, total dissolved solids (TDS), and electrical conductivity provides awareness into the lake’s ecological condition and the impact of anthropogenic activities.

Physicochemical parameters are important for maintaining aquatic ecosystems balanced and productive. A case study on Dal Lake in Kashmir, India highlights the importance of regularly monitoring physicochemical properties to solve water quality problems, such as pollution from farming and sewage, which harm the lake’s ecosystem (Azifa Parvaiz et al., 2024). Additionally, a study of lentic ecosystems in Aboh Mbaise, Nigeria shows that monitoring water quality is important worldwide for the sustainable use and protection of freshwater resources (Mbachu et al., 2023). Moreover, temperature and pH affect biological activities, such as metabolism and the availability of nutrients in the water. Turbidity affects light penetration, which impacts photosynthesis and the growth of aquatic vegetation. Salinity, total dissolved solids (TDS), and electrical conductivity show the concentration of dissolved ions and possible pollutants, showing the chemical condition of the water (Leiva-Tafur et al., 2022). Shifts in these factors often show signs of environmental stress due to pollution or human activities, this emphasizes the importance of regular assessments for the protection and sustainable management of freshwater systems (Nirmala et al., 2022).

Studies in similar freshwater bodies such as Kalawaig Creek in Bukidnon, physicochemical analysis of Kalawaig Creek provided essential baseline data, examining parameters such as temperature, total dissolved solids, pH, dissolved oxygen, and total alkalinity to evaluate water conditions and environmental health (Damasco et al., 2024). Additionally, limnological research on LakeWood examined stratification and water quality, emphasizing the role of such studies in understanding seasonal and ecological dynamics (Buarao, 2021). Moreover, investigations into molluscan fauna in lakes such as Lake Lakewood demonstrated how physicochemical conditions influence aquatic biodiversity and the distribution of sensitive species (Mahinay-Cardente et al., 2024). Despite the presence of comparable freshwater ecosystems in the region, Lake Pinamaloy has not been thoroughly studied.

This study aims to assess the physicochemical properties of the limnetic and littoral zones of Lake Pinamaloy by measuring key parameters: temperature, pH, turbidity, salinity, TDS, and electrical conductivity. By analyzing these parameters, the study seeks to establish baseline data that will aid in understanding the current water quality and its trends over time. The research will also identify potential sources of pollution or contamination affecting the lake’s ecosystem.

**2. Methodology**

**2.1 Research design**

This study used a quantitative descriptive research design to assess water quality in Lake Pinamaloy. In situ measurements of temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), salinity, and turbidity were taken from five sampling stations in the limnetic and littoral zones. The independent variables were the physico-chemical parameters, while the dependent variable was the water quality condition across the different stations. The study described the current water conditions and compared results between stations to identify differences.

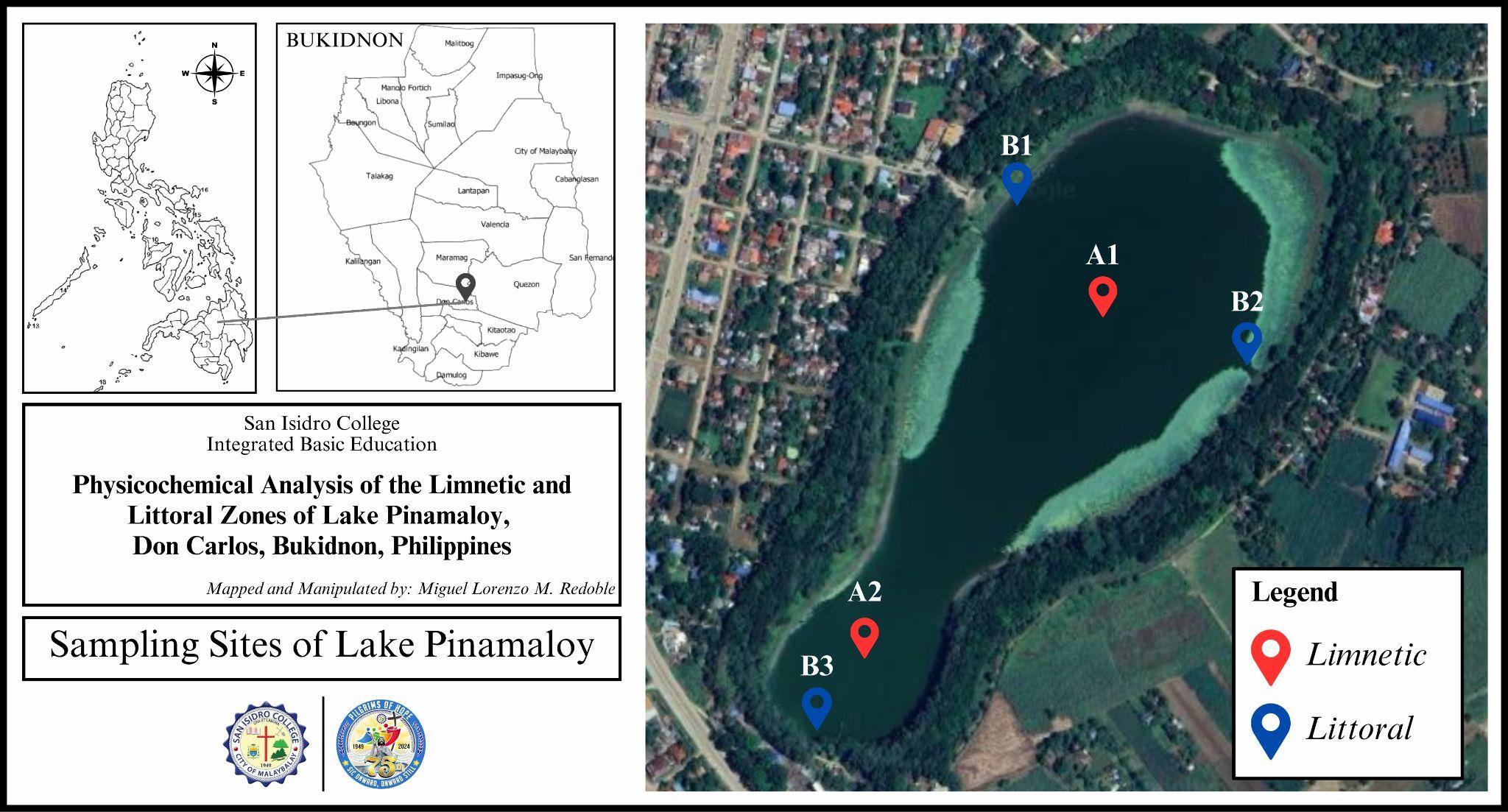
**2.2 Entry Protocol**

Prior to the conduct of the study, all necessary permissions and ethical clearances were obtained. Formal approval was secured from the Lake Pinamaloy Management Office to ensure compliance with local environmental and regulatory guidelines. Institutional consent was also granted by the administration of San Isidro College. Informed consent was obtained from participants or their legal guardians, following a clear explanation of the study’s purpose, scope, and duration. All procedures were conducted in accordance with ethical research standards to ensure transparency, accountability, and respect for all stakeholders involved.

**2.3 Study Site**

Lake Pinamaloy (7°58′45″N, 125°05′49″E) is a 60-hectare tectonic freshwater lake located in Don Carlos, Bukidnon, Philippines, at an elevation of 312 meters above sea level. The lake is primarily sustained by surface runoff and serves as a key resource for potable water, agricultural irrigation, and local tourism due to its natural landscape and ecological significance (Mahinay-Cardente et al., 2024).

**Figure 1**: Location and Sampling Stations in Lake Pinamaloy, Don Carlos, Bukidnon



Data collection was conducted from February to March 2025. During this period, five sampling stations were established across the lake to represent spatial variability. Two stations were situated in the limnetic zone (open water), and three stations were located in the littoral zone (nearshore areas). At each station, triplicate in situ measurements of selected physico-chemical parameters were conducted to ensure reliability and accuracy of data.

**2.4 Identification and Collection of Water Samples Of Physicochemical Parameters**

Adapting the protocols of Igloria et al. (2024), the assessment of physico-chemical parameters was conducted in situ at each designated sampling station in Lake Pinamaloy. Triplicate readings were taken per station to reduce variability and ensure the reliability of the results. The parameters measured included turbidity, water temperature (°C), pH, total dissolved solids (TDS), electrical conductivity (EC), and salinity—providing a broad assessment of the lake’s water quality.

Measurements were conducted using a digital multiparameter water quality tester. To ensure accuracy and consistency, the device was calibrated before and after each use in accordance with the manufacturer’s guidelines. The average of the triplicate readings for each parameter was calculated and used for statistical analysis to assess spatial variations between stations.

**2.5 Statistical Treatment of Data**

Descriptive statistics were used to summarize the measurements of each physico-chemical parameter across sampling stations. To determine whether there were significant differences in water quality among the stations, one-way analysis of variance (ANOVA) was performed, followed by Tukey’s post hoc test for pairwise comparisons of means. A significance level of 0.05 was applied. Prior to conducting ANOVA, the Shapiro-Wilk test was used to assess the normality of data distribution and ensure that statistical assumptions were met.

**2.6 Documentation**

The research process was thoroughly documented through photographs capturing key stages such as site observation, water sampling, and in situ measurement of physico-chemical parameters. All data were recorded systematically in both digital formats and handwritten field logs to ensure accuracy, consistency, and data backup. These records served as references for verification and analysis.

**2.7 Ethical Considerations**

This study followed established ethical guidelines to uphold the credibility, integrity, and transparency of the research. Emphasis was placed on objectivity and accuracy, particularly in the collection, interpretation, and reporting of data. Fieldwork was conducted in accordance with safety protocols to minimize risks to the researchers and the environment. Compliance with the Data Privacy Act was ensured by implementing safeguards to protect any personal or sensitive information. All data was securely stored and accessible only to authorized personnel. Any personal identifiers were removed or anonymized to maintain confidentiality and privacy throughout the research process.

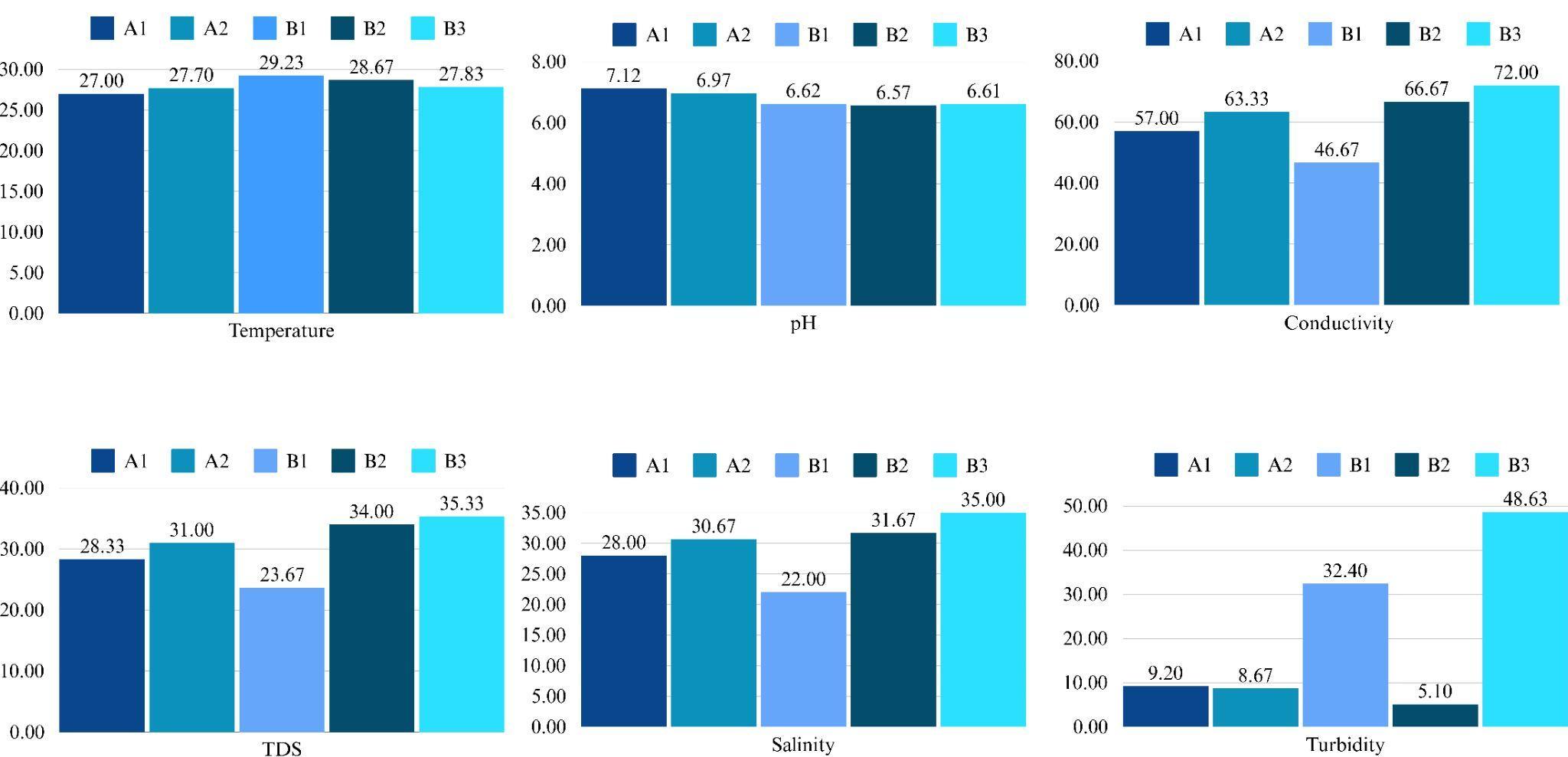
**2.8 Precautionary Measures**

To ensure the safety and well-being of all participants during fieldwork, precautionary measures were strictly implemented. Researchers wore appropriate personal protective equipment (PPE), including gloves, boots, and masks when necessary. Fieldwork was conducted during safe weather conditions to avoid potential hazards, and sampling equipment was sanitized before and after use to prevent contamination.

**3. results and discussion**

**3.1 Physicochemical Properties**

Figure 2. Physicochemical properties of water across the limnetic and littoral zones



**Table 1. Physicochemical Measurements Across Sampling Stations**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **Sampling Sites** | | | | | **Average** | **Standard** | **Remarks** |
| **A1** | **A2** | **B1** | **B2** | **B3** |
| Temperature (℃) | 27.37 | 27.70 | 29.23 | 28.67 | 27.83 | 28.16 | 25℃-31℃ | Passed |
| pH | 7.12 | 6.97 | 6.62 | 6.57 | 6.61 | 6.78 | 6.5-8.5 | Passed |
| Conductivity (μS/cm) | 57.00 | 63.33 | 46.67 | 66.67 | 72.00 | 61.13 | <1,500 μS/cm | Passed |
| TDS (mg/L) | 28.33 | 31.00 | 22.00 | 31.67 | 35.00 | 29.60 | <1000 mg/L | Passed |
| Salinity (mg/L) | 28.00 | 30.67 | 23.67 | 34.00 | 35.33 | 30.33 | <500 mg/L | Passed |
| Turbidity (NTU) | 9.20 | 8.67 | 32.4 | 5.10 | 48.63 | 20.08 | <5 NTU | Did not pass |

Figure 2 shows the physicochemical results from five sampling stations, with A1 and A2 representing the limnetic zone and B1, B2, and B3 representing the littoral zone. Temperature readings are close across all stations, with slightly higher values observed in the littoral zone. pH levels are slightly higher in the limnetic zone, but all stations fall within a slightly acidic to neutral range. Conductivity is higher in the littoral stations, particularly in B3, while B1 has the lowest value. A similar trend is seen in total dissolved solids and salinity, where B2 and B3 record the highest levels and B1 the lowest. The most noticeable difference is in turbidity, with B3 and B1 showing much higher levels, indicating more particles in the water, while the limnetic stations have significantly lower turbidity, indicating clearer water. Overall, the results show that the littoral zone generally has higher concentrations of dissolved substances and suspended particles compared to the limnetic zone. Supporting this, Table 1 presents a summary of these physicochemical measurements, including temperature, pH, conductivity, total dissolved solids, salinity, and turbidity, and compares the values from each station against standard values to evaluate water quality. It also provides the average for each parameter and indicates whether the readings pass or fail based on compliance with established water quality limits.

The temperature across the sampling stations ranges from 27.37°C to 29.23°C, with an average of 28.16°C, all within the acceptable range of 25°C to 31°C, indicating stable thermal conditions favorable for aquatic life. pH levels range from 6.57 to 7.12, averaging 6.78, within the permissible range of 6.5 to 8.5, suggesting slightly acidic to neutral water quality suitable for freshwater ecosystems. Conductivity values range from 46.67 to 72 μS/cm, with an average of 61.13 μS/cm, well below the 1,500 μS/cm limit, reflecting low ion concentrations, while TDS levels range from 22.00 to 35.00 mg/L, with an average of 29.60 mg/L, below the 1,000 mg/L limit, indicating minimal dissolved solids. Salinity levels are also low, between 23.67 and 35.33 mg/L, well below the 500 mg/L threshold, consistent with freshwater characteristics. However, turbidity values vary widely, ranging from 5.10 NTU to 48.63 NTU, with an average of 20.08 NTU, exceeding the acceptable limit of 5 NTU at stations B1 and B3. High turbidity suggests elevated sediment or pollutant levels, potentially linked to local environmental factors affecting water clarity.

Excess nutrients from agricultural runoff, urban wastewater, and industrial discharges drive eutrophication, leading to algal blooms that increase turbidity by reducing light penetration (Hietala et al., 2004; Wiik et al., 2015). Surface runoff from rainfall or flooding transports sediments into littoral zones, as seen in hurricanes that raise turbidity by introducing tannin-stained water and sediments (Timbs & Kolterman, 2023). Urban and industrial wastewater also contributes suspended solids, disrupting aquatic ecosystems, as observed in Lake Ladoga (Romanov & Arshanitsa, 2023). Additionally, construction projects like dams alter hydrodynamics, redistributing sediments and increasing turbidity (Makaoui et al., 2018). Wind-carried pollutants can also settle into water bodies, as seen in Lake Baikal (Ia & Ib, 2020). Submerged aquatic vegetation (SAV), crucial for stabilizing sediments, is often lost due to herbivory or low light, worsening turbidity (Timbs & Kolterman, 2023).

High turbidity reduces light availability for photosynthesis, disrupts food webs, and impairs fish reproduction, as noted in Lake Ladoga, where pollution-induced turbidity caused fish toxicosis (Romanov & Arshanitsa, 2023). Nutrient enrichment further diminishes buffer capacity against algal blooms in vegetated zones (Heitala, 2004). Stable temperatures are vital for regulating aquatic metabolic rates, enabling species to thrive without stress from extreme fluctuations (Guzzo et al., 2017). Similarly, pH stability indicates environmental health, with sudden changes signaling pollution or ecological disturbances (Santhanam & Dhyani, 2022).

**Table 2. Mean, variance, standard deviation, and standard error of Water Quality Parameters**

The data presented in the table provides an overview of the mean values for the water quality parameters measured across the five sampling stations, along with their corresponding variance, standard deviation, and standard error. The statistical results highlight variations in water quality, with some parameters exhibiting greater fluctuations across locations.

| **Parameter** | **Mean** | **Variance** | **Std. Dev.** | **Std. Err.** |
| --- | --- | --- | --- | --- |
| Temperature | 28.16 | 0.55 | 0.74 | 0.191 |
| pH | 6.78 | 0.36 | 0.60 | 0.156 |
| EC | 61.13 | 154.12 | 12.41 | 3.210 |
| TDS | 29.60 | 34.84 | 5.90 | 1.524 |
| Salinity | 30.33 | 29.70 | 5.45 | 1.407 |
| Turbidity | 20.08 | 342.29 | 18.50 | 4.780 |

Table 2 presents the descriptive statistical values for the water quality parameters measured across the five sampling stations. The mean values summarize the central tendency of the data, while variance, standard deviation, and standard error provide insights into the level of variability for each parameter. Temperature shows low variance (0.55) and standard deviation (0.734), indicating minimal fluctuations across stations. Similarly, pH values remain stable, with a mean of 6.78 and a standard deviation of 0.60, suggesting a consistent acidity level throughout the lake.

To better understand these variations, the sampling stations are categorized into two zones: limnetic (A1, A2) and littoral (B1, B2, B3). The limnetic zone, characterized by deeper open water, generally exhibits more stable temperature and water chemistry due to its depth and reduced exposure to external influences (Shariff, 2014). In contrast, the littoral zone, being shallow and nearshore, is subject to greater environmental fluctuations, sediment disturbances, and human activity (Hoverman, 2012). Studies on freshwater lakes have shown that nearshore areas often experience more variation in turbidity and electrical conductivity due to their interaction with surrounding land (Obegi et al., 2021; Leidonald et al., 2024).

Electrical conductivity (EC) exhibits the highest variance (154.12), indicating notable differences in ion concentration across stations, while turbidity has a variance of 342.29 and a standard deviation of 18.50, reflecting significant fluctuations in water clarity. Turbidity values are notably higher in the littoral zone (B1 and B3) compared to the limnetic zone (A1 and A2), showing that nearshore areas experience greater sediment resuspension due to wave action and watershed inputs. Organic matter accumulation, such as decaying vegetation in the littoral zone, may also contribute to increased turbidity levels (Austin et al., 2017). The standard error values further emphasize the reliability of these means, with lower values suggesting higher precision in measurement. Greater fluctuations in EC and salinity in the littoral zone indicate stronger external influences such as runoff and groundwater seepage, while studies in tropical lakes confirm that fluctuations in ion concentrations often correlate with seasonal changes and human activity (Obegi et al., 2021; Leidonald et al., 2024). This pattern aligns with the research conducted at Dal Lake, where pollution from agricultural runoff and sewage has been found to negatively impact water quality (Azifa Parvaiz et al., 2024).

The stability of temperature and pH suggests that Lake Pinamaloy provides a consistent habitat for aquatic life. According to Easwaramoorthy et al. (2024), minimal temperature variation in lakes helps maintain fish metabolism and reproductive cycles. However, the high EC and salinity variability may indicate localized influences such as agricultural runoff or varying sediment composition (Guan et al., 2022; Chianca et al., 2023; Olaojo & Oladunjoye, 2023; Pratiwi et al., 2024). Greater fluctuations in turbidity confirm localized disturbances that may impact light penetration and photosynthesis. Research by Erhenhi et al. (2024) and Motunrayo (2024) suggests that high turbidity reduces dissolved oxygen levels, affecting aquatic biodiversity.

**Table 3. One-Way ANOVA Results for Water Quality Parameters**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **F-value** | **p-value** | **Statistically Significant?** |
| Temperature | 91.57 | <0.0001 | Yes |
| pH | 0.35 | 0.8372 | No |
| EC | 2.26 | 0.1517 | No |
| TDS | 2.37 | 0.1390 | No |
| Salinity | 4.46 | 0.0346 | Yes |
| Turbidity | 19.81 | 0.0003 | Yes |

Table 3 presents the one-way ANOVA results, analyzing whether significant differences exist in water quality parameters across the five sampling stations. The F-values reflect the degree of variation among stations, with higher F-values indicating greater differences between stations relative to variations within each station. The corresponding p-values determine whether these differences are statistically significant.

The ANOVA results indicate statistically significant differences among stations. Temperature had the highest F-value of 91.57 with a p-value < 0.0001, indicating a highly significant variation among the stations. Turbidity also varied significantly (F = 19.81, p = 0.0003), with littoral stations (B1, B2, B3) recording notably higher turbidity levels compared to limnetic stations (A1, A2). Salinity differences were significant as well (F = 4.46, p = 0.0346), particularly in station B2, where salinity peaked due to possible runoff influence (Payler et al., 2019; Mackenzie et al., 2024). In contrast, the littoral zone (B1, B2, B3), located near the shoreline, exhibits greater variability in turbidity and salinity. These results (p < 0.05) show that shoreline conditions cause changes in water quality, highlighting the need to regularly monitor different parts of the lake. This variability results from exposure to physical forces such as waves and tides, biological processes like algal blooms, and human influences, including runoff, all of which contribute to fluctuating water conditions in shoreline areas compared to more stable deep-water regions (Cho, 2007; Austin et al., 2017).

These variations underscore the littoral zone’s vulnerability to environmental changes and their ecological consequences. Increased turbidity can reduce light penetration, affecting photosynthesis and dissolved oxygen levels, which are crucial for aquatic life (Lunt & Smee, 2019; Nunes et al., 2022; Garcia et al., 2024). Meanwhile, the relative stability of pH, EC, and TDS across zones suggests that the lake’s natural buffering and mixing processes help maintain a chemical balance, preventing extreme fluctuations in water composition (Sobczyński & Joniak, 2013; Sojka et al., 2020; DeSellas et al., 2023).

These findings align with previous studies showing that temperature remains more stable in deeper limnetic zones due to reduced exposure to surface influences (Heling et al., 2018; Miller, 2020; Sulawesty & Yustiawati, 2021). Research also confirms that littoral zones typically experience greater turbidity fluctuations due to wave-induced sediment resuspension and watershed runoff (Biswas et al., 2021; Abhishek et al., 2024). Additionally, studies on tropical lakes emphasize that salinity differences often reflect localized groundwater seepage and human activity near shorelines (Dalkıran & Zünbülgil-Ünsal, 2023; Malashenkov et al., 2024). These findings reinforce the role of internal mixing mechanisms in maintaining chemical stability in freshwater lakes, consistent with previous research (Lazarus et al., 2023; Wand’arhasima et al., 2025).

**4. Conclusions and Recommendations**

The results of the study show that the physicochemical parameters of Lake Pinamaloy, specifically temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), salinity, and turbidity are mostly within acceptable standards for freshwater ecosystems. However, turbidity exceeded the recommended limit of <5 NTU. The elevated turbidity suggests a high level of suspended particles, which may affect aquatic organisms and overall water clarity. In conclusion, Lake Pinamaloy maintains generally good water quality, but the high turbidity indicates potential environmental stress and pollution sources that need to be addressed. It is recommended that regular water quality monitoring be conducted to detect changes over time, and that efforts be made to control runoff, erosion, and human activities around the lake. Future research should explore the seasonal variations in the physicochemical parameters of Lake Pinamaloy to assess how water quality changes throughout the year. It is also recommended to expand the scope by including biological indicators, such as plankton or macroinvertebrates, and other parameters like total coliform count, dissolved oxygen, and biochemical oxygen demand, to gain a more comprehensive understanding of the lake's ecological health. Further studies could investigate the potential sources of turbidity and other pollutants through land use mapping and watershed analysis. Lastly, incorporating community perceptions and stakeholder involvement in future studies can help link scientific findings with local conservation efforts and policy development

**Ethical Approval and Consent:**

Formal approval was secured from the Lake Pinamaloy Management Office to ensure compliance with local environmental and regulatory guidelines. Institutional consent was also granted by the administration of San Isidro College. Informed consent was obtained from participants or their legal guardians, following a clear explanation of the study’s purpose, scope, and duration.

**Disclaimer (Artificial intelligence)**

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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