PHYSICOCHEMICAL PARAMETERS AND GROUNDWATER QUALITY IN A MINING AREA OF THE ANDES. PARÁMETROS FISICOQUÍMICOS Y CALIDAD DEL AGUA SUBTERRÁNEA EN UNA ZONA MINERA DE LOS ANDES

Marcos Luis Quispe Pérez[1*], Gustavo Franco Choque Ticona[2], Mary Nicol Rios Challco[3], Ademir Amilcar Apaza Ramos[4], Oxanoiska Astrid Molina Arias[5], Mayeli Nicole Chipana Zeballos[6],

ABSTRACT

"Importance of Water Quality in Mining Areas and its Relation to Mining Activity According to Supreme Decree No. 004-2017-MINAM". Introduction: Mining is vital for the global economy, but it can negatively impact water quality. Managing water quality in mining areas is crucial due to its environmental and human health impacts. Supreme Decree N° 004-2017-MINAM regulates physicochemical parameters of water used in mining. Hydrogeochemical studies are essential to evaluate and control water contamination. Objective: Examine water quality in mining areas, its link to mining, and compliance with regulations for environmental and human health. Methods: In situ measurements were conducted to determine electrical conductivity, pH, total dissolved solids (TDS), salinity, and temperature. Additionally, the Gibbs Diagram was utilized to analyze dissolved solids concentration and associated processes. Results: The results show that the values of electrical conductivity, pH, total dissolved solids, salinity, and temperature remain within established standards. The Gibbs Diagram reveals processes of solid concentration due to evaporation. Conclusion: Analyzing groundwater in mining areas is vital for water quality management. Results meet standards, ensuring safe water and environmental protection.

Keywords: Electric Conductivity, Gibbs Diagram, Precipitation, Water Quality.

[1*]Universidad Nacional de Moquegua, facultad de Ingenieria de Minas. mquispep@unam.edu.pe, ORCID: https://orcid.org/0000-0002-8661-3806
[2]Universidad Nacional de Moquegua, facultad de Ingenieria de Minas. 2019103110@unam.edu.pe, ORCID: https://orcid.org/0000-0001-6705-4263
[3]Universidad Nacional de Moquegua, facultad de Ingenieria de Minas. 2019103131@unam.edu.pe, ORCID: https://orcid.org/0009-0003-5907-256X
[4]Universidad Nacional de Moquegua, facultad de Ingenieria de Minas. 2018103072@unam.edu.pe, ORCID: https://orcid.org/0009-0008-9217-1881
[5]Universidad Nacional de Moquegua, facultad de Ingenieria de Minas. 2019103122@unam.edu.pe, ORCID: https://orcid.org/0009-0006-7275-5834
[6]Universidad Nacional de Moquegua, facultad de Ingenieria de Minas. 2020103041@unam.edu.pe, ORCID: https://orcid.org/0009-0008-9068-4034

***Corresponding Author:** Marcos Luis Quispe Pérez
*Universidad Nacional de Moquegua, facultad de Ingenieria de Minas. mquispep@unam.edu.pe, ORCID: https://orcid.org/0000-0002-8661-3806

DOI: 10.53555/ecb/2024.13.06.01

RESUMEN
"Importancia de la Calidad del Agua en Zonas Mineras y su Relación con la Actividad Minera Según Decreto Supremo N° 004-2017-MINAM". Introducción: La minería es vital para la economía global, pero puede impactar negativamente la calidad del agua. Gestionar la calidad del agua en áreas mineras es crucial debido a sus impactos ambientales y en la salud humana. El Decreto Supremo N° 004-2017-MINAM regula los parámetros fisicoquímicos del agua utilizada en la minería. Los estudios hidrogeoquímicos son esenciales para evaluar y controlar la contaminación del agua. Objetivo: Examinar la calidad del agua en áreas mineras, su relación con la minería y el cumplimiento de las regulaciones para la salud humana y ambiental. Métodos: Se realizaron mediciones in situ para determinar la conductividad eléctrica, pH, sólidos disueltos totales (TDS), salinidad y temperatura. Además, se utilizó el Diagrama de Gibbs para analizar la concentración de sólidos disueltos y los procesos asociados. Resultados: Los resultados muestran que los valores de conductividad eléctrica, pH, sólidos disueltos totales, salinidad y temperatura se mantienen dentro de los estándares establecidos. El Diagrama de Gibbs revela procesos de concentración de sólidos debido a la evaporación. Conclusión: Analizar las aguas subterráneas en áreas mineras es vital para la gestión de la calidad del agua. Los resultados cumplen con los estándares, garantizando agua segura y protección ambiental.

Palabras claves: Conductividad Eléctrica, Diagrama de Gibbs, Precipitación, Calidad del Agua

INTRODUCTION

Mining is crucial for the global economy, providing vital resources for various industries, yet it can harm water quality (Pons et al., 2021; Mardonova and Han, 2023).

The industry faces challenges in integrating sustainability, particularly concerning water quality (Carmona García, Cardona Trujillo and Restrepo Tarquino, 2017; Villa, Ávalos and Mamani, 2022).

Mineral extraction and processing can pollute water bodies, necessitating water quality management (Ortiz Gómez, Nuñez Espinoza and Mejía Castillo, 2019; Pabón et al., 2020).

The interdisciplinary field of mining and water quality evaluates surface and groundwater pollution, leading to regulatory measures (Meza Duman et al., 2022; Loza del Carpio et al., 2020; Moschini-Carlos et al., 2011).

Supreme Decree No. 004-2017-MINAM sets standards for water quality in mining, highlighting its importance for the environment and human health (MINAM, 2017).

Hydrogeochemical studies, such as the hydrochemical characterization of groundwater, identify contamination sources (Amiri et al., 2021; Zhang et al., 2022; Rocha Echalar et al., 2023).

Geological factors, human activities, and contaminants affect groundwater pH, impacting ecosystems and human health (Calcina-Benique et al., 2022; Huallpara et al., 2021).

Assessing water quality in mining areas, adhering to regulations, and using tools like the Gibbs Diagram are essential to safeguard the environment and human well-being.

MATERIALS AND METHODS

The mining operations area is situated on the western flank of the Western Cordillera of the Andes, with altitudes ranging from 4250 to 5000 meters above sea level.

The polymetallic mine area is characterized by a thick sequence of clastic rocks, with an erosional unconformity over the limestone of the Jumasha formation, covered at the top by pyroclastic volcanic series, conglomerate, and limestone packages intercalated with sandstone and shale layers, with thicknesses ranging from 80 to 200 meters.

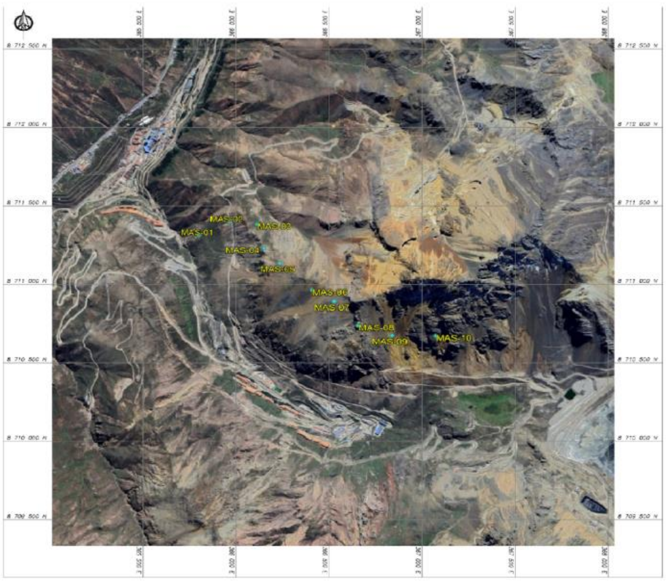
The mineralogy of the ore includes sphalerite, galena, tetrahedrite, tenantite, and some chalcopyrite, while gangue minerals consist of pyrite, quartz, calcite, rhodochrosite, and manganiferous calcite.

Underground mining primarily employs long-hole drilling methods in bodies and veins, as well as uphole cut and fill techniques.

Groundwater sampling was conducted at 10 control points represented by stations (MAS-01 to MAS-10), with locations recorded using a handheld GARMIN VISTA GPS device.

Field instruments, including a pH meter, conductivity meter, and thermometer from the brand EXTECH, were utilized for measuring pH, electrical conductivity, and temperature, respectively.

Samples for salinity, total dissolved solids, and other chemical elements were sent to an accredited laboratory in Peru for analysis.



COORDINATES		
Samples	East	North
MAS-01	365728	8711268
MAS-02	365932	8711341
MAS-03	366118	8711320
MAS-04	366175	8711175
MAS-05	366281	8711085
MAS-06	366467	8710930
MAS-07	366584	8710867
MAS-08	366702	8710730
MAS-09	366858	8710673
MAS-10	367077	8710673

Figure 1. Location and Study Samples.

The comparative analysis of groundwater data will be conducted according to the standards set by Supreme Decree 004-2017-MINAM of Peru, specifically in Category 3: Vegetable Irrigation and Animal Drinking, which defines the physical-chemical parameters.

Graphs, tables, and the Gibbs diagram will be utilized to comprehend groundwater parameters, including values such as standard deviation and coefficient of variation, along with the relationship between anions (Cl-) and cations (Na+), and total dissolved solids.

RESULTS

Electrical Conductivity

The metallic minerals are known for their high electrical conductivity due to their crystalline structure and the presence of free electrons in their lattice. These minerals are widely used in the mining industry because of their ability to efficiently conduct electricity (Parodi et al., 2022). It is important to note that electrical conductivity in mining can be affected by factors such as the presence of impurities, temperature, and humidity. Electrical conductivity can also vary depending on the type of mineral and its purity level (Guerrero Useda and Pineda Acevedo, 2016).

That being said, in-situ measurements of electrical conductivity were taken at temperatures below 11.07°C, from which a maximum value of 1917 µs/cm corresponding to MAS-10 station was obtained, and a minimum value of 1496 µs/cm corresponding to MAS-04 station, see Figure 2. When comparing with the ECA of Cat 3-D1 and Cat 3-D2, none of the stations exceed the standard.

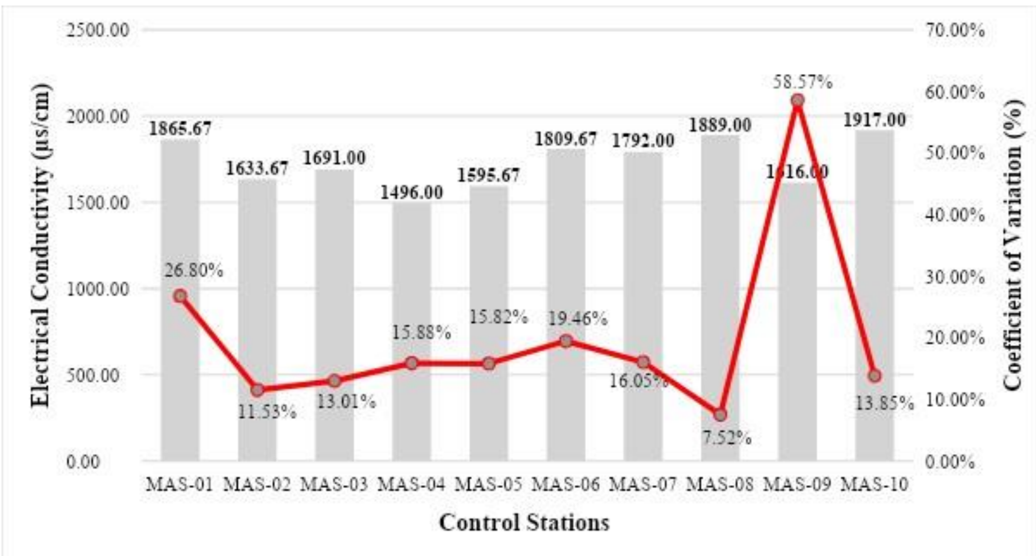


Figure 2. Electric Conductivity Results.

Potential of Hydrogen (pH)

The results obtained from the field analysis indicate pH values, with a minimum pH value of 7.65 (neutral), corresponding to station MAS-05, and a maximum value of 8.13 (slightly alkaline), corresponding to station MAS-06, see Figure 3. According to Supreme Decree 004-2017-MINAM of Peru, specifically in Category 3: Vegetable irrigation and animal drinking, the pH limits are between 6.5 - 8.5. When comparing with the ECA of Categories 3-D1 and 3-D2, it can be observed that the pH obtained from stations MAS-05 and MAS-06 are within the limits established by Peruvian regulations.

Additionally, we can infer that it is important to take into account that the pH of water can vary depending on the source and other factors (Abdel-Shafy and El-Khateeb, 2019). So it is necessary to perform periodic analysis to ensure that the water used meets the established standards for each type of crop and use. It is also important to note that the tendency towards alkalinity in water bodies is due to hydrogeochemistry or the presence of domestic wastewater (Khan et al., 2018).

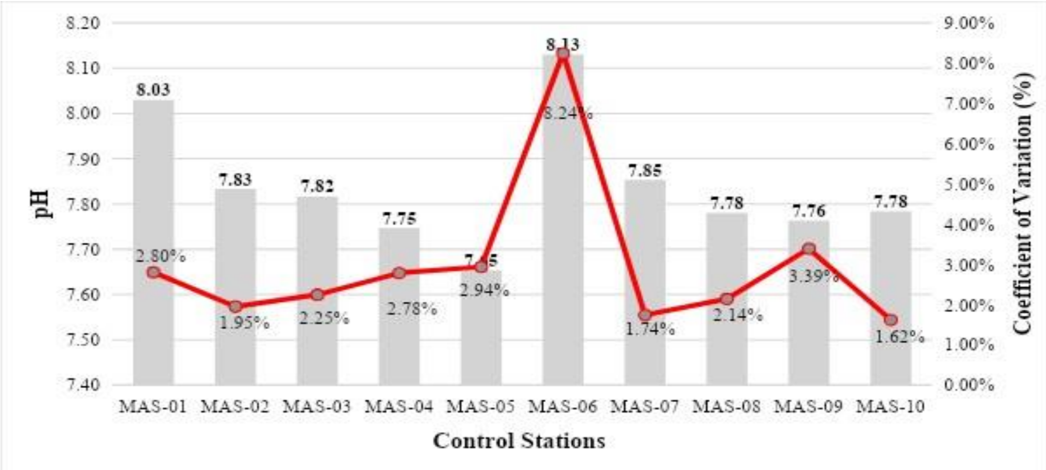


Figure 3. pH Results

Total Dissolved Solids (TDS)

Total dissolved solids are a measure of the amount of solid matter dissolved in an aqueous solution. In the context of mining, this is an important parameter for evaluating the quality of water used in mining processes and its impact on the environment (Ccanccapa-Cartagena et al., 2021). They can come from various sources, such as mineral leaching, infiltration of groundwater, or the release of solid particles during mineral extraction and processing. These solids can include metals, minerals, salts, and other compounds dissolved in water (López Velandia, 2018).

From the field data obtained for this parameter, a minimum value of 1045.33 ppm has been obtained, corresponding to station MAS-04, and a maximum value of 1334.33 ppm, corresponding to station MAS-08, see Figure 4. The presence of this parameter in water in mining can have several negative effects, it affects the quality of drinking water, damages aquatic ecosystems, and hinders water treatment and purification processes (Gaete et al., 2007).

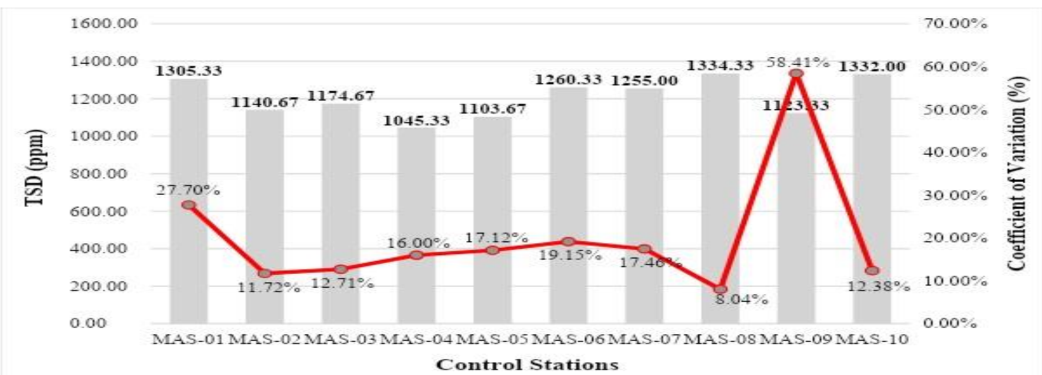


Figure 4. Results of Total Dissolved Solids (TDS)

Salinity

From the data obtained in the field for salinity, a minimum value of 744.33 ppm has been obtained, corresponding to station MAS-04, and a maximum value of 939.00 ppm, corresponding to station MAS-08, see Figure 5. It is important to note that salinity can affect the quality of water and its suitability for various uses, such as agricultural irrigation, human consumption, or supporting aquatic life. In areas where mining can influence water quality (González Abraham et al., 2012). It is important to assess and control salinity to ensure that water meets environmental and health standards (Gómez-Gutiérrez et al., 2016).

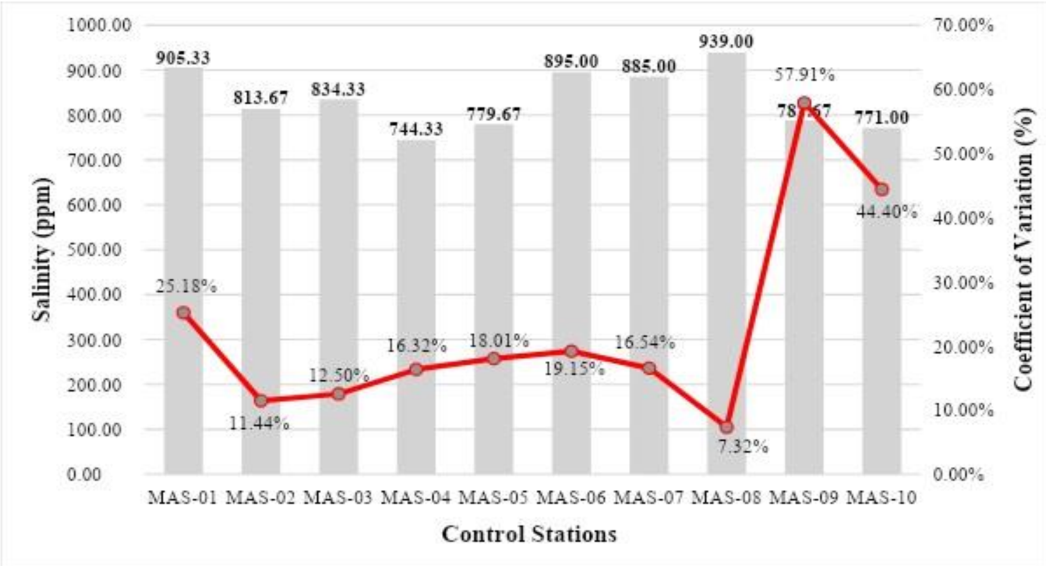


Figure 5. Results of Salinity

Temperature

The results obtained from the temperature measurements in the field range from a minimum temperature of 10.03°C, corresponding to station MAS-05, to a maximum temperature of 11.07°C, corresponding to station MAS-08, see Figure 6. The temperature value obtained is optimal and guarantees the survival of the species present in the area. This value falls within the appropriate ranges for the development and adaptation of the organisms that inhabit the ecosystem. It is also important to note that each species has different temperature tolerances, so the values considered acceptable may vary depending on the species.

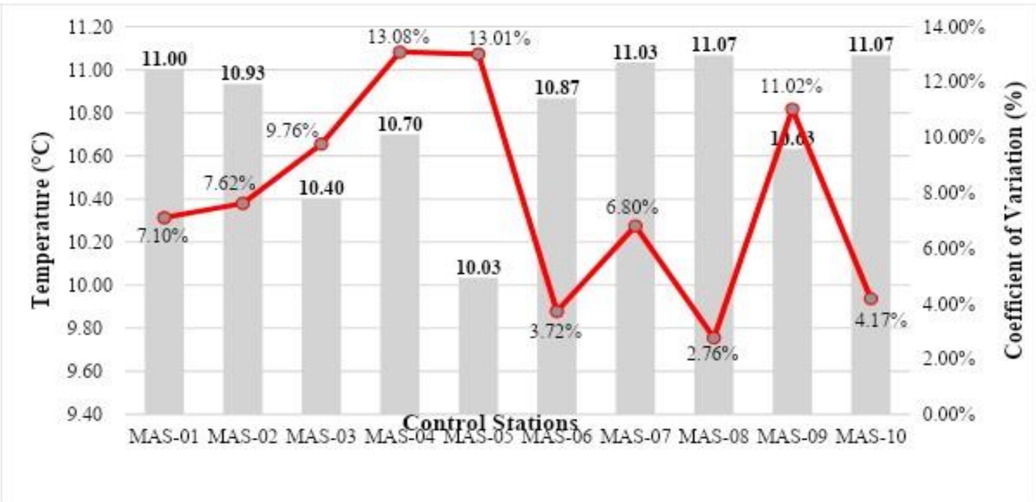


Figure 6. Temperature Results.

Gibbs Diagram

The Gibbs Diagram is a tool developed by Gibbs in 1970, which is used to analyze the chemical composition of water, both surface and groundwater (Malagón et al., 2021). This diagram graphically represents the concentration of dissolved solids and the ratio of $Na^+/(Na^+ + Ca^{2+})$ for cations, and the ratio of $Cl^-/(Cl^- + HCO_3^-)$ for anions (Cardona-Castaño, Rivera-Giraldo and Chávez-Vallejo, 2023).

The main objective of the Gibbs Diagram is to identify and understand the processes that occur in groundwater through its chemistry (Nagaraju, Thejaswi and Sreedhar, 2016). Three main processes can be distinguished: the precipitation dominance process, the rock dominance process, and the evaporation precipitation process (Burillo et al., 2017). The Gibbs diagram is a tool used to analyze the hydrochemistry of groundwater in a study area. The mechanism that controls the geochemistry of groundwater, through the reaction between groundwater and aquifer minerals, plays an important role in water quality and helps to understand the genesis of water.

In this paper, the values of the Gibbs diagram for cations, see Figure 7, range from 0.60 to 0.80, with a maximum TDS value of 1334.33 ppm, corresponding to station MAS-08, which is located in the precipitation by evaporation zone. The groundwater is experiencing a process of concentration of dissolved solids due to evaporation. This can have important implications for water quality and mineral formation in the mining environment. It is essential to monitor and understand these processes to ensure that water meets quality standards and to properly manage water resources in the study area.

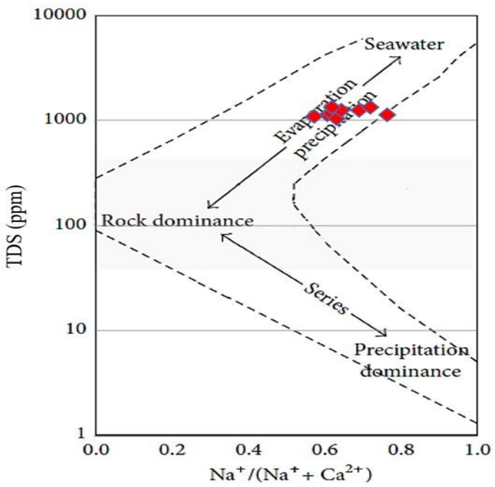


Figure 7. Gibbs Diagram for cations.

In this paper, the values of the Gibbs diagram for anions, see Figure 8, range from 0.40 to 0.80, with a maximum TDS value of 1334.33 ppm, corresponding to station MAS-08, which is located in the precipitation by evaporation zone. This suggests that groundwater is experiencing a process of concentration of dissolved solids due to evaporation. These findings indicate that groundwater in the study area is undergoing evaporation, resulting in the concentration of dissolved solids in the water. It is essential to understand these processes to ensure that water meets quality standards and to properly manage water resources in the mining environment.

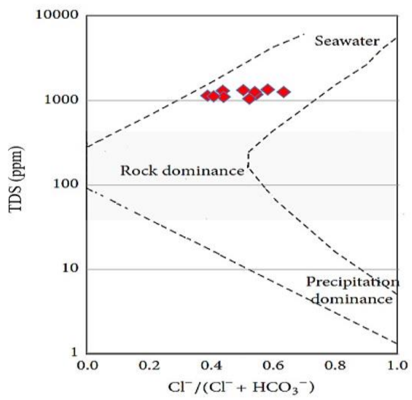


Figure 8. Gibbs Diagram for anions.

DISCUSSION

The in-situ measurements of electrical conductivity indicated values ranging from 1496 µs/cm to 1917 µs/cm across different sampling stations, falling within acceptable limits without exceeding regulatory standards. pH values ranged from 7.65 to 8.13, indicating a slightly alkaline nature of the water samples, within permissible ranges defined by regulatory standards. Total dissolved solids varied between 1045.33 ppm and 1334.33 ppm, highlighting the importance of careful management and treatment measures due to their potential adverse effects on water quality. Salinity levels ranged from 744.33 ppm to 939.00 ppm, emphasizing the need for regular assessment and control to ensure compliance with environmental and health standards. Temperature measurements fell within the optimal range for supporting aquatic species survival, although species-specific tolerances warrant consideration in ecosystem management. The Gibbs diagram analysis revealed a concentration of dissolved solids due to evaporation, signaling potential implications for water quality and mineral formation in the mining environment. Understanding these processes is crucial for effective water resource management and quality assurance, ensuring sustainable utilization while mitigating potential environmental impacts.

ACKNOWLEDGMENTS

''Physicochemical Parameters and Groundwater Quality in a Mining Area of the Andes'', It is a research project of the National University of Moquegua. We are grateful to the mining concession holder for facilitating our research by allowing us to use their facilities for our comparative analysis of groundwater physicochemical parameters.

We also thank the Ministry of Energy and Mines of Peru for their collaboration and provision of essential information, as well as the National University of Moquegua for their role in enhancing the theoretical foundations of our analysis. Our appreciation extends to all organizations whose contributions have enriched our research journey and led to the successful completion of this paper: National University of Moquegua, Ministry of Energy and Mines of Peru and Mining Concession.

ETHICS, CONFLICT OF INTEREST, AND FUNDING STATEMENT

The authors claim to have followed the ethical and legal requirements throughout the study process and writing the manuscript. Likewise, they ensure that there is no conflict of interest and that all funding sources are duly specified in the acknowledgments section. Furthermore, they are satisfied with the final edited version of the document, the signed copy of which is archived in the journal.

The contribution of the authors is as detailed below: G.F.C.T., M.N.R.C. & M.L.Q.P.: researcher, data analysis and writing of the article. M.N.C.Z., A.A.A.R. & O.A.M.A.: researcher and writing of the article.

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