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Determination of the Water Quality Index (ICA-PE) of Lake Chinchaycocha, Junín, Peru

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ABSTRACT

The objective of the research was to determine the water quality index of Lake Chinchaycocha, which has faced pollution problems for several years. To do this, we worked with data from ten water quality monitoring points collected by the National Water Authority (ANA) during the period 2019-2023, after which the water quality index (ICA-PE) was calculated by analyzing a total of 12 parameters, using the Water Quality Standard (ECA) for water category 4 E1 (lagoons and lakes). The results of the physicochemical parameters indicated that the values of total nitrogen exceed the limits established in the ECA in 82% of the data obtained, pH in 13%, and phosphorus in 1%. In the evaluation of inorganic parameters, data from the LChin1S monitoring point showed that lead and zinc levels exceeded the values established in the ECA by 8% and 3%, respectively. Regarding the ICA-PE of the dry and wet seasons, it was determined that both present a good quality according to their averages and with the results obtained from the ICA-PE in a general way, it is concluded that Lake Chinchaycocha has a good water quality having total nitrogen as the main pollutant.

INTRODUCTION

Water resources are essential for human survival and development. However, the quality of surface and groundwater bodies has deteriorated over time due to various human and natural activities (Aldrees et al. 2024). Primarily, industrialization, agricultural activities, and the discharge of untreated wastewater have contributed significantly to this deterioration and pollution (Lin et al. 2022), altering the chemical and biological characteristics, as well as the physical appearance of surface waters. These alterations affect the health of living beings and ecosystems, as contaminated water can cause viral and parasitic diseases in humans, in addition to modifying the composition of soil and groundwater (Kılıç 2021).

Lakes make up less than 3% of the planet's freshwater and are essential for the development and survival of humanity, as they are used for fishing, drinking water consumption, and as places of recreation, in addition to being areas that are home to a wide diversity of species. However, population growth has increased the demand for drinking water over the years (Chèvre 2018). At the same time, the advance of excessive urbanization has led human beings to pollute this primordial resource for all forms of life, and consequently, these water sources are becoming increasingly scarce. Therefore, the preservation of lakes is an issue of utmost importance for the entire population (Mohammed & Niger 2022).

Water quality refers to the conditions in which a body of water is found in relation to its physicochemical and biological characteristics, considering the alterations derived from anthropogenic activities or its natural state; therefore, to evaluate the quality of the water, the parameters of an analyzed sample are compared with the established quality standards (Baeza 2016). Water quality management requires the collection and analysis of a varied set of data, which can be complex to analyze and synthesize. In this context, the Water Quality Index (ICA) is used as a tool that facilitates the evaluation of a large amount of complex data, allowing the analysis of temporal and spatial variations in water quality and generating a unique easy-to-interpret value that indicates the quality of the water body (Galal et al. 2021).

Lake Chinchaycocha belongs to the Junín National Reserve and is considered the second-largest lake in Peru. Having a basin area of 529.9 km², located at an altitude of 4080 m.a.s.l., between the regions of Pasco and Junín, it is fed by 20 streams and 12 rivers, mainly by the San Juan River. In addition, Lake Junín gives birth to the Mantaro River, the main contributor to the Amazon River. It has been recognized by the Ramsar Convention since 1997 as a wetland of international importance due to being a very productive ecosystem with a wide biological diversity housing a variety of aquatic and bird species, finding the Junín grebe and the Junín giant frog of great relevance. Species considered endangered also provide us with services, such as thermoregulation, carbon capture, and soil erosion control. It also plays a very important role in the development of electricity generation in Peru at the national level by generating around 33% of the energy consumed by the country, in addition to the fact that its waters are used for aquaculture and agricultural irrigation in different areas of the center of the country. Country, important areas to produce agricultural products (SERNANP 2020). In relation to its water quality, it is worth mentioning that it has been damaged over the years by different environmental threats when receiving effluents from different economic activities that take place in its surroundings, these being the discharge of domestic wastewater from 10 polluting sources in the towns of Villa Pasco, Vicco, Shelby, Ondores and two sectors of Carhuamayo who discharge their wastewater directly to the receiving body, while the locality of Ninacaca, a sector of Carhuamayo and two sectors of Junín discharge their wastewater into different rivers which later flow into Lake Chinchaycocha, also according to the reports presented by the National Water Authority of the monitoring carried out during the years 2013 to 2016 it was identified that the parameters of pH, dissolved oxygen and total nitrogen exceeds the ECA-Water, in the same way, it was reported that the lake had been affected by the presence of heavy metals such as lead, copper and zinc (MINAM 2017a). Likewise, different studies were carried out, such as (Flusche et al. 2005) with the measurement of dissolved strontium, which exists in smaller proportions from the amount of marine limestones and silicate rocks found in the basin to which Lake Chinchaycocha belongs. It also mentions through a hydrogeochemical study that the measurements captured from the water discharges, in combination with the strontium isotopic data, indicate that the main sources are three rivers that contribute more than 90% of the surface water of the lake: the Chacachimpa River, the San Juan River, and the Palcamayo River. Another study such as that of (Bernal 2008), identified several potential sources of mining contamination that occurred in past years, where hydrological and hydrochemical characterizations were shown that indicated that in the northern part of Lake Chinchaycocha, one of its main sources of water entry, the San Juan River and the Upamayo Delta contained mining discharges, likewise, another research where the Water Quality Index of Lake Chinchaycocha was analyzed by different methods carried out by (Custodio et al. 2020) found that the lake has a good quality using the ICA CCME method except for point LCh1, while the Shannon-Wiener method qualified it with a moderate and extremely polluted water quality index.

To date, these problems have not been solved, as problems of contamination from mining activities, wastewater, and solid waste persist. Consequently, it is essential to evaluate the quality of the water in the water body since if the quality conditions are not met, both the environment and the health of the population will be affected. Therefore, the objective of this research is to present the evaluation of the water quality index of Lake Chinchaycocha using the methodology for the determination of the ICA-PE applied to surface continental water bodies, proposed by the National Water Authority (ANA 2018).

MATERIALS AND METHODS

Study Area

Lake Chinchaycocha belongs to the Junín National Reserve, located between the departments of Junín and Pasco, exactly between the districts of Carhuamayo, Ondores, Junín, Ninacaca and Vicco; the lake is located in the extreme northeast of the Pampa de Junín, with geographical coordinates of 10°50’50” S - 75°59’25” W. and 11°09’55” S - 76°15’40” W (Shoobridge 2006) (Fig. 1). It has an area of approximately 470 km^2 of water mirror and has an average depth that ranges between 8 to 12 m in the central areas of the lake, and it is fed by springs and infiltrations that come from the eastern and western mountain range of the San Juan River and other minor rivers (Cusiche & Miranda 2019). As for its climate, it belongs to the lower floor of the Puna region, where its temperature varies between 3° and 7°C. The coldest season occurs between May and September and has an average annual rainfall of 940 mm, having the rainiest season between the months of December and April (SERNANP 2019).

Data Collection and Pre-Processing

The data was collected from water quality monitors carried out by the National Water Authority (ANA) between 2019 and 2023, analyzing 10 monitoring points and 24 parameters, which include physical-chemical, inorganic, and microbiological aspects. These data are available at the following link: https://snirh.ana.gob.pe/VisorPorCuenca/. It should be noted that for the determination of the Water Quality Index of Peru (ICA-PE), only 12 parameters were considered since the methodology applied considers only 17 parameters, according to the assigned category of the body of water (ANA 2018), of which two were not found in the monitoring carried out, and three presented incomplete data. The data that exceeded the Environmental Quality Standard (ECA) were compared with the values of E1: Lakes and Lagoons of Category 4: Conservation of the Aquatic Environment, as established by the Ministry of the Environment (MINAM 2017b).

Determination of the ICA-PE

To calculate the water quality index, the Canadian formula must be applied, which encompasses three factors (frequency, scope, and amplitude) that must be found with the following formulas.

Frequency: Indicates the total number of parameters that did not comply with the ECA-Water in relation to the total of the parameters evaluated.

Table 1: ICA-PE Rating Range.

ICA-PE	Qualification
90-100	Excellent
75-89	Good
45-74	Regular
30-44	Bad
0-29	Appalling

$$F_1 = \frac{\text{Number of parameters that do not comply with the ECA}}{\text{Total number of parameters to evaluate}} \times 100$$

Scope: Indicates the number of data that does not comply with the ECA-Water in relation to the total of the data evaluated.

$$F_2 = \frac{\text{Number of data that does not comply with the ECA}}{\text{Total number of data to evaluate}} \times 100$$

Amplitude: Indicates the measure of deviation of the data in relation to the parameters of the ECA-Water.

$$F_3 = \frac{\text{Normalized sum of surpluses}}{\text{Normalized sum of surpluses+1}} \times 100$$

Canadian formula: Once the three factors have been found, the formula for the ICA-PE calculation is applied, giving us a single value result that is between 0 and 100; this value will indicate the water quality index by placing it on the five-range scale as indicated in (Table 1).

$$\text{ICA-PE} = 100 - \sqrt{\frac{F_1^2 + F_2^2 + F_3^2}{3}}$$

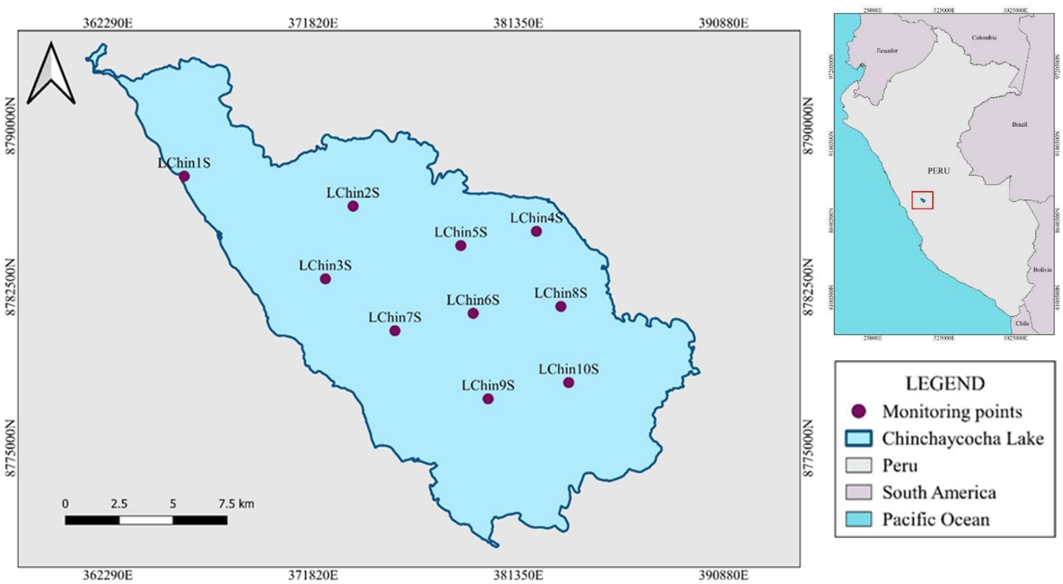

Fig. 1: Map of the study area.

RESULTS AND DISCUSSION

The present study was carried out for 5 years considering an evaluation by seasons (dry and wet) and, in general, considering 12 parameters for the determination of the ICA-PE; it is worth mentioning that not all the parameters collected were used because complete data were not available for all monitoring points.

Physicochemical Parameters

From the physicochemical parameters evaluated (pH, total phosphorus, oils and fats, total nitrogen, biochemical oxygen demand (BOD), and total suspended solids), it was identified that most of the values were below the Environmental Quality Standard for Water (ECA-Water). However, some parameters exceeded the values established in the ECA-Water; in particular, it was observed that the total nitrogen exceeded the values established in the ECA-Water in 82% of the data obtained from the 10 monitoring points, the data varied from the minimum value of 0.05 $mg.L^{-1}$ to a maximum value of 3.48 $mg.L^{-1}$ and an overall average of 0.59 $mg.L^{-1}$, regarding pH, it was identified that 13% of the values exceeded the limits established by the ECA-Water, the data in this parameter presented a minimum value of 5.25 and a maximum of 9.17 with a general average of 8.64. In relation to total phosphorus, it was determined that 1% of the data from the monitoring carried out exceeded the ECA-Water, registering a minimum value of 0.01 $mg.L^{-1}$ and a maximum of 0.08 $mg.L^{-1}$, with a general average of 0.10 $mg.L^{-1}$. Regarding the parameters of oils and fats, BOD, and total suspended solids, none of the values analyzed did not comply with the limits of the ECA-Water, as can be seen in (Table 2).

Inorganic Parameters

Of the inorganic parameters evaluated (arsenic, mercury, lead, and zinc), most of the monitoring data were below the values established in the ECA-Water. However, it was determined that the LchinS1 monitoring point was the only one where the data exceeded the ECA-Water. In relation to lead, 8% of the values exceeded the ECA, registering a minimum value of 0.0002 $mg.L^{-1}$, a maximum value of 0.08 $mg.L^{-1}$, and a general average of 0.002 $mg.L^{-1}$. Regarding zinc, it was identified that 3% of the data exceeded the ECA, with a minimum value of 0.004 $mg.L^{-1}$, a maximum value of 0.25 $mg.L^{-1}$, and a general average of 0.03 $mg.L^{-1}$. The other parameters presented concentrations below the limits established by the ECA-Water, as indicated in (Table 2).

Microbiological Parameters

For this study, only the microbiological parameter of thermotolerant coliforms was evaluated, of which the values collected were below the ECA-Water, registering a minimum value of 1.80 $MPN.100\ mL^{-1}$ and a maximum value of 460 $MPN.100\ mL^{-1}$ with an average of 10.44 $MPN.100\ mL^{-1}$ as shown in (Table 2)

Water Quality Index (ICA-PE)

Dry and Wet Season: Data were processed according to the dry and wet seasons. The dry season runs from May to September, while the wet season runs from October to

Table 2: Summary table of the parameters evaluated for the determination of the ICA-PE.

Parameters	P	F%	Min.	Max.	Prom.	ECA	Unit
Total nitrogen	82/100	82	0.05	3.48	0.59	0.315	mg/L
pH	13/100	13	5.24	9.17	8.64	6.5-9	pH unit
Lead	8/100	8	0.0002	0.08	0.002	0.0025	mg/L
Zinc	3/100	3	0.004	0.25	0.03	0.12	mg/L
Total phosphorus	1/100	1	0.01	0.08	0.015	0.035	mg/L
Oils and fats	0/100	0	0.10	1.00	0.52	5	mg/L
Dissolved oxygen	0/100	0	6.27	10.43	8.01	≥ 5	mg/L
Biochemical oxygen demand (BOD)	0/100	0	2.00	4.00	2.40	5	mg/L
Total suspended solids	0/100	0	2.00	19.00	3.68	≤ 25	mg/L
Arsenic	0/100	0	0.0001	0.013	0.004	0.15	mg/L
Mercury	0/100	0	0.00003	0.00009	0.00007	0.0001	mg/L
Thermotolerant coliforms	0/100	0	1.80	460	10.44	1000	MPN/100 ml

Q: Number of data that did not comply with the ECA-Water over the total amount of data obtained.

F%: Total percentage of data that did not comply with the ECA-Water.

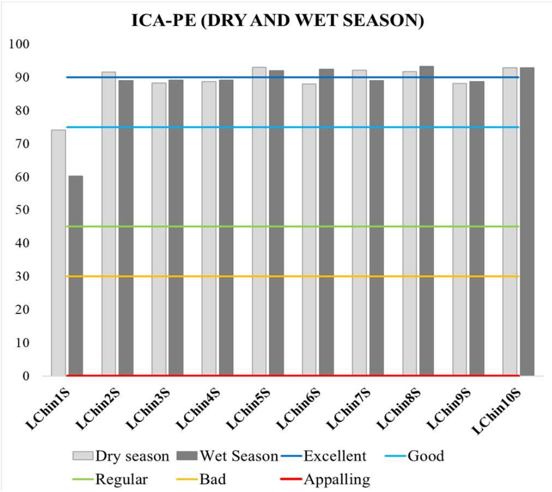

Fig. 2: Graph of ICA-PE results in dry and wet seasons.

April. To determine the Water Quality Index (ICA-PE) by season, the Canadian formula was applied. In the results of the dry season, 50% of the monitoring points qualified with excellent quality, 40% obtained good quality, and 10% presented regular quality. Also, an average of 88.56 was obtained, which qualifies it as a good quality for the dry season. Regarding the wet season, 40% of the points studied rated with an excellent quality, 50% obtained a good quality, and 10% presented a regular quality with an average of 87.03, which indicates a good quality according to (Table 3 and Fig. 2). It is important to note that the LChin1S point showed a significant variation compared to the other monitoring points in both seasons, presenting the lowest value and qualifying with a regular quality in both seasons.

General Water Quality Index

The values of the Water Quality Index (ICA-PE) for the

Table 3: Results of the variables and ICA-PE in dry and wet seasons.

Monitoring Point	Dry Season				Wet Season			
	Variables		ICA-PE		Variables		ICA-PE	
LChin1S	F1	33.33	74.09	REGULAR	F1	41.67	60.23	REGULAR
	F2	13.33			F2	16.67		
	F3	26.92			F3	52.25		
LChin2S	F1	8.33	91.58	EXCELLENT	F1	16.67	88.97	GOOD
	F2	8.33			F2	8.33		
	F3	8.59			F3	4.20		
LChin3S	F1	16.67	88.16	GOOD	F1	16.67	89.07	GOOD
	F2	10.00			F2	6.67		
	F3	6.53			F3	6.00		
LChin4S	F1	16.67	88.69	GOOD	F1	16.67	89.06	GOOD
	F2	8.33			F2	6.67		
	F3	6.07			F3	6.07		
LChin5S	F1	8.33	92.96	EXCELLENT	F1	8.33	91.98	EXCELLENT
	F2	6.94			F2	8.33		
	F3	5.57			F3	7.35		
LChin6S	F1	16.67	87.90	GOOD	F1	8.33	92.32	EXCELLENT
	F2	10.00			F2	8.33		
	F3	7.84			F3	6.18		
LChin7S	F1	8.33	92.09	EXCELLENT	F1	16.67	88.91	GOOD
	F2	8.33			F2	8.33		
	F3	6.99			F3	4.68		
LChin8S	F1	8.33	91.72	EXCELLENT	F1	8.33	93.21	EXCELLENT
	F2	8.33			F2	6.67		
	F3	8.17			F3	4.94		
LChin9S	F1	16.67	88.13	GOOD	F1	16.67	88.59	GOOD
	F2	8.33			F2	8.33		
	F3	8.70			F3	6.56		
LChin10S	F1	8.33	92.74	EXCELLENT	F1	8.33	92.87	EXCELLENT
	F2	6.67			F2	3.33		
	F3	6.65			F3	8.49		
AVERAGE	88.56			GOOD	87.03			GOOD

10 monitoring points of Lake Chinchaycocha ranged from a minimum value of 63.85 at the LChin1S point to a maximum value of 92.58 at the LChin5S point. Of the monitoring points evaluated, 20% rated with excellent quality, 70% with good quality, and 10% with fair quality, according to (Fig. 3 & 4 and Table 4). It is important to note that the LChin1S point presented the highest concentrations of parameters that exceeded the values established in the ECA, unlike the other monitoring points. An average value of the ICA-PE of 86.55 was obtained, which qualifies Lake Chinchaycocha, in general, with a good water quality index, according to the ranges established in (Table 1). This indicates that the lake's water quality tends to move slightly away from the desired or natural quality due to current conditions showing damage of little magnitude.

Analysis of Identified Contaminants

The results of the study carried out indicate that the parameters of total nitrogen, the potential of hydrogen, phosphorus, lead, and zinc exceed the values established in the ECA for the water of Category 4-E1 (Lagoons and Lakes) at the collection points of certain seasons.

a) Total Nitrogen

According to the results obtained, the total nitrogen parameter exceeds the limit of 0.315 $mg.L^{-1}$ established in the Environmental Quality Standard (ECA) in the ten monitoring points evaluated. This is the main contaminant identified. Specifically, the LChin1s point shows a high concentration of total nitrogen, registering a value of 3,479 mg/L, indicative of a greater accumulation of this parameter in the northwest region of the lake. These findings suggest that the rivers that flow into Lake Chinchaycocha are impacted by pollution, with the reservoir of the San Juan, Colorado, and Chacachimpa rivers being the main contributors to the increase in the total nitrogen load in this area. The high presence of total nitrogen probably originates from untreated domestic wastewater and the use of fertilizers applied in the production of crops such as maca and potato by local people (Porras 2023).

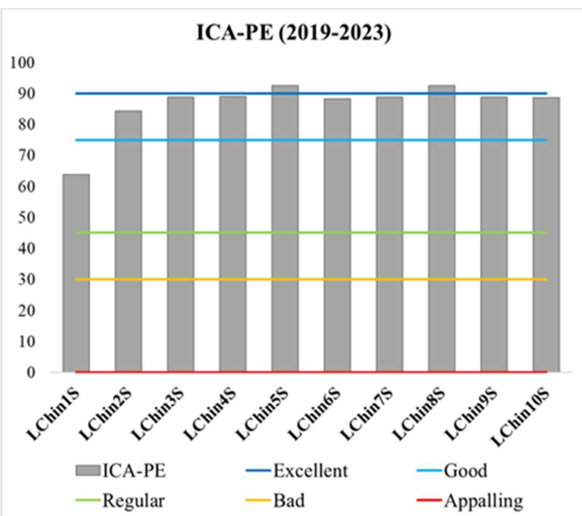

Fig. 3: General results of the ICA-PE.

Table 4: Results of the general ICA-PE.

Monitoring Point	Variables		ICA-PE	
LChin1S	F1	41.67	63.85	REGULAR
	F2	20.00		
	F3	42.24		
LChin2S	F1	25.00	84.24	GOOD
	F2	9.17		
	F3	6.00		
LChin3S	F1	16.67	88.85	GOOD
	F2	7.50		
	F3	6.27		
LChin4S	F1	16.67	89.02	GOOD
	F2	7.50		
	F3	5.26		
LChin5S	F1	8.33	92.58	EXCELLENT
	F2	7.50		
	F3	6.29		
LChin6S	F1	16.67	88.29	GOOD
	F2	9.17		
	F3	7.02		
LChin7S	F1	16.67	88.72	GOOD
	F2	8.33		
	F3	5.85		
LChin8S	F1	8.33	92.49	EXCELLENT
	F2	7.50		
	F3	6.58		
LChin9S	F1	16.67	88.74	GOOD
	F2	8.33		
	F3	5.73		
LChin10S	F1	16.67	88.70	GOOD
	F2	6.67		
	F3	7.79		
AVERAGE			86.55	GOOD

The excessive accumulation of total nitrogen is one of the main causes of pollution in water bodies since its increase favors the accelerated growth of algae, exceeding the natural capacity of ecosystems to manage this process (Liu et al. 2020). This leads to the eutrophication of water-receiving bodies, significantly degrading their quality (Quispe 2021).

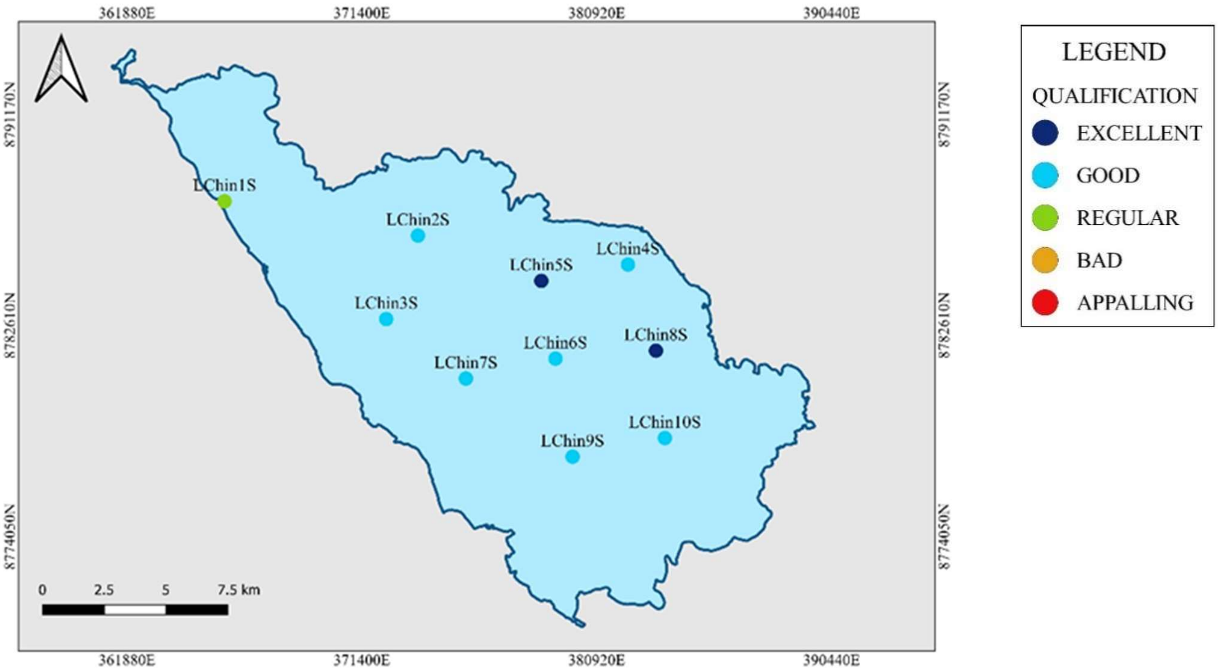

Fig. 4: Map of ICA-PE results.

b) Hydrogen Potential

In relation to the results obtained, it is observed that the pH values exceed the limit of 9 established in the Environmental Quality Standard (ECA) at six monitoring points, which indicates that Lake Chinchaycocha experiences periods with a slightly alkaline pH. This temporary alkalinity is attributed to the presence of carbonates and bicarbonates in the water. pH is a crucial parameter in the evaluation of water quality due to its influence on the chemical and biological processes that take place in aquatic bodies (Dewangan et al. 2007). In addition, it allows the chemical evolution of several metals to be determined, as well as their solubility and bioavailability in water (ANA 2018).

c) Total Phosphorus

The results indicated that Lake Chinchaycocha does not present significant contamination by total phosphorus since a value of 0.08 $mg.L^{-1}$ was found, which exceeds the limit of 0.035 $mg.L^{-1}$ established by the Environmental Quality Standard (ECA). However, it is important to mention that phosphorus is an essential component for the development of plants and animals. However, high concentrations of phosphorus can lead to an increase in algae growth in water, leading to eutrophication (Islam et al. 2016). Therefore, a eutrophic lake, characterized by high levels of phosphorus, is rich in nutrients and presents a prolific growth of algae, plants, and fish; however, this indicates poor water quality (Peña et al. 2018). In addition, eutrophication can lead to the death of fish and other aquatic species. This accumulation of phosphorus is mainly due to anthropogenic sources, such as wastewater discharge.

d) Lead

According to the results obtained, at the LChin1S sampling point, the value of 0.0025 $mg.L^{-1}$ established by the Environmental Quality Standard (ECA) was exceeded, registering a maximum value of 0.0762 mg/L. The increase in lead concentration at this point is likely attributed to the fact that the water from the San Juan River and Colorado River reservoirs, which enters Lake Chinchaycocha from the northwest side, contains heavy metal contaminants, the result of mining activity (Porras 2023). Lead is a highly toxic element for flora and fauna, considered a significant potential pollutant. It is estimated that lead exposure causes approximately 143,000 human deaths each year (Bernabe 2019) because it affects the function and structure of various organs, producing adverse effects in both humans and wildlife (Clausen et al. 2011).

e) Zinc

According to the results obtained, the concentration of zinc at the LChins1S point has exceeded the limit of 0.12 mg/L established by the Environmental Quality Standard (ECA), registering a value of 0.246 mg/L. This increase in zinc concentration is due to the influence of the reservoir of the San Juan and Colorado rivers, which flow into Lake

Chinchaycocha and contain heavy metals because of mining activity (Porras 2023). Zinc is an abundant metal on Earth, covering two-thirds of its surface (Sankhla et al. 2019). In addition, this metal is toxic to the ecosystem, posing significant health risks by directly and indirectly affecting many living organisms in Lake Chinchaycocha (Marcelo 2018). It should be noted that the lake does not have widespread zinc contamination, as only three values have been recorded that exceed the limits established by the ECA.

Sources of Pollution

The main possible sources of contamination are domestic wastewater discharges, which reach Lake Chinchaycocha through the drainage and sewerage systems of nearby towns, such as Ondores, Junín, and Carhuamayo. This wastewater does not always receive adequate treatment before being discharged into nearby water bodies. During rainy seasons, wastewater mixes with surface runoff and is transported directly to the lake, increasing the pollutant load. In the dry season, when flows are lower, pollutant concentrations become more critical due to lower dilution (Cusiche & Miranda 2019).

Mining activity in the Junín region is also one of the main sources of pollution in Lake Chinchaycocha. Nearby mines, particularly those dedicated to the extraction of heavy metals such as lead, zinc, and copper, have contributed to the dumping of toxic waste and acidic waters into the bodies of water that flow into the lake. A relevant case is that of the Ragra River, a tributary of the San Juan River, which is seriously affected by leachate and effluents of mining waste from the Cerro SAC company. Studies carried out at the source of the Ragra River ravine, which receives the effluents from the company (Volcán Compañía Minera SAA), have shown levels of metals that considerably exceed the national limits established for the protection of the aquatic ecosystem. This has intensified pollution in the Ragra River basin, then spreading to the San Juan River basin, which in turn flows into Lake Chinchaycocha. Despite being a habitat for endemic species and being recognized as a reserve nationally and internationally as an important wetland, the lagoon continues to receive waste derived from mining exploitation, which has a negative impact on its natural ecosystem (Source 2022).

The presence of nitrogen and phosphorus induces an increase in the growth of aquatic flora and other organisms, which, together with the presence of heavy metals, generates an ecological imbalance that adversely affects the biodiversity of the lake. This phenomenon endangers threatened species, such as the giant frog of Lake Junín, the grebe of Junín, and the black redfish of Junín, whose risk of extinction is mainly due to the degradation of their habitat caused by the destruction of riparian vegetation, mining activity and the discharge of wastewater, which significantly impact the quality of the water in the lake and its surroundings (SERNANP 2020). In addition, the degradation of these ecosystems increases the vulnerability of the local communities that inhabit the basin, reducing their capacity to adapt to climate change and affecting their productive activities, which has led to an increase in fish mortality (Wetlands 2024).

To effectively address the sources of pollution in Lake Chinchaycocha, it is crucial to implement measures such as the rehabilitation of degraded areas through reforestation and wetland restoration. These actions not only improve water quality by acting as natural filters but also restore the habitat of native and endangered species, such as the giant frog, the Junín grebe, and the Junín black hen. Carrying out projects for the development of wastewater treatment plants, likewise, the implementation of efficient solid waste and wastewater management systems in the communities surrounding the lake is essential to prevent urban waste from reaching the body of water. In addition, it is necessary to review and strengthen current environmental policies, which implies the creation of stricter regulatory frameworks and the application of effective sanctions to activities that contribute to the pollution of the lake.

CONCLUSIONS

Based on the results analyzed from the 10 monitoring points, taking into account the 12 parameters shown in (Table 2) for the determination of the ICA-PE of Lake Chinchaycocha during the period 2019 - 2023, taking as a reference the values established in the ECA-Water in Category 4: E1 (conservation of the aquatic environment), it was determined that the physicochemical parameters that exceeded the ECA-Water are total nitrogen with 82% of data being The main pollutant compared to pH with 13% of data, as for the inorganic parameters, values were identified that exceed the ECA - Water mainly at the monitoring point Lchin1S, these being Lead with 8% and Zinc with 3% of the data in total and of the microbiological parameters having as the only parameter the thermotolerant coliforms it was determined that the data collected are below the ECA - Water.

Regarding the ICA-PE water quality index in both the dry and wet seasons, it was determined that the dry season has a higher percentage with respect to excellent quality, 50%, followed by 40% corresponding to good quality, and finally, 10% of regular quality. About the wet season, 50% was obtained in good quality, followed by 40%, which qualifies with excellent quality, and finally, 10% which represents the regular quality. Also, according to the averages obtained in both seasons, it is concluded that they present a good water quality.

In relation to the General Water Quality Index of Lake Chinchaycocha, it can be concluded that 20% of the monitoring points have excellent water quality, 70% good quality, and 10% regular quality, considering the general average of 86.55 of the results obtained from the ICA-PE, it is also concluded that Lake Chinchaycocha has a good water quality. We delimit this result considering that, after applying the Methodology for the Determination of the ICA-PE Water Quality Index Applied to Surface Inland Water Bodies already established and completing all the necessary procedures, the result of the general average is within the range of good quality. It should be clarified that to classify water as suitable for animal or drinking consumption, it is essential to carry out a more exhaustive study. This additional analysis is crucial due to the risks associated with water consumption, which requires special care to guarantee its safety and quality since Lake Chinchaycocha presents pollutants mainly due to total nitrogen due primarily to the discharges of wastewater from nearby populations into the rivers, which subsequently flow into the lake presenting a risk to aquatic life. Likewise, the discharges of mining effluents cause a concentration of heavy metals in the lake, so the mitigation of these polluting sources is an urgent issue to address.

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