Essay

Wastewater pollution and quality indicators in the 'Junín Lake' National Reserve, Peru

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Abstract

In Peru, water pollution is one of the biggest environmental problems (Custodio and Chávez, 2017), considering that the fragility of aquatic ecosystems destructively impacts biodiversity, whose local biota concentrates unique ecological communities. This problem was studied in Junín Lake, where anthropogenic pressure ignores the conservation and sustainability of the environment and biodiversity. Premium the satisfaction of productive needs (livestock, agriculture and extractive) and the pressure of companies and institutions (mining, hospitals, markets) who pour their wastewater into the lake affecting habitats. The objective of this research was to scrutinize the impact of wastewater on these ecosystems and their area of influence, indicating the level of water quality. The type of research that covered from 2015 to 2017 is descriptive, of longitudinal contemporary evolutionary design. Two sampling periods (rain and drainage) were established for the physicochemical and bacteriological analysis of water. The results show that the biochemical oxygen demand (DBO_5) exceeds the maximum permissible limits and during the dry season they are poor quality waters. The wastewater discharges is a polluting factor with danger of toxicity to the aquatic life of the lake, affecting species of endemic flora and fauna and in general the entire ecosystem.

Keywords: chemical pollutants, Junín Lake, lake threat, Peru.

Reception date: July 2019
Acceptance date: August 2019

72% of the world's lakes and wetlands are contaminated by urban and industrial discharges, causing more than half of the known infectious diseases (Trabajos de Ciencias Naturales, 2013). In some countries, lakes and rivers have become receptacles for an immense variety of waste, domestic sewage, toxic industrial tributaries and chemical substances from agricultural and leaching activities to surface and groundwater waters (Agudelo, 2005). The construction of dams that cause alterations in the aquatic environment, and the mining operations that discharge polluting compounds, especially metals, are deteriorating the lacustrine aquatic biodiversity.

This is the case of Junín Lake or Chinchaicocha, context where the investigation was incurred (period 2015 to 2017), which integrates an average extension of 470 km^2 of water mirror, located at 4 080 meters above sea level within the Junín National Reserve (Figure 1). Its average depth varies between 8 to 12 m in the central areas of the lake, receiving contributions from springs and infiltrations that descend from the eastern and western ridge of the San Juan River and other minor rivers.

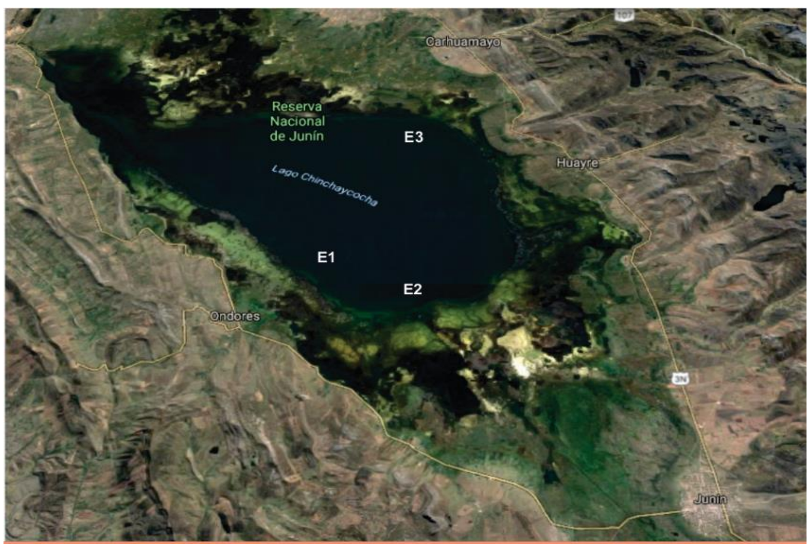

Figure 1. Map of 'Junín Lake' sampling stations. Source: National Center for Space Studies (CNES, 2019).

The landscape offers abundant hydrobiological organisms formed by flora and fauna, which are part of the trophic chains of endemic life. Biological biodiversity corresponds to the location in flood areas and associations of hydrophilic plants (Plan Maestro RNJ, 2012). Among the species that stand out are the Junín diver (*podiceps taczanowskii*), the Andean condor (*vultur gryphus*), the black hen (*laterallus tuerosii*), the peregrine falcon (*falco peregrinus*) and the giant gallareta (*fulica gigantea*).

In mammals the Andean fox (*psedalupex culpaeus*), the zorrino (*conepatus chinga*), the weasel (*mustela frenata*), the wildcat (*oncifelis colocolo*), the puma (*puma concolor*), the vicuña (*vicugna vicugna*), the vizcacha (*lagidium peruanum*) and the guinea pig (*cavia tschudii*). In amphibians and reptiles are the toad (*bufo spinulosus*) amphibian species nocturnal anuro, toad (*gastrotheca*), toad (*pleuroderma marmorata*)). Of all of them, the 'Junín frog' (*batrachophrynus macrostomus*) stands out as a symbol of the lake, which is half a meter long.

Among the most frequent types of vegetation cover are the grasslands, puna grass, bofedales, oconales and totorales. According to the Plan Maestro RNJ (2012) 'the surface area of the shore is green algae (*chlorophyta*) with 20 species representing 37% of individuals, deatomeas have 47% of individuals and blue-green algae contribute 15%, the benthos the presence of Ostracoda micro invertebrates of the order Podocopa, embody 90% with 6% of invertebrate organisms not determined'. The landscape presents a scenario of living environmental offer, in which for hundreds of generations it is the livelihood of surrounding peasant communities.

However, this wide and complex environmental offer, two decades ago is in danger of extinction, due to the pollution of the lake and its sphere of influence. The responsibility for such an impact is attributed to the wastewater that arrives from the towns of Ondores (256 L h^{-1} from 40% of the population), Junín (580 L h^{-1} represents 85% of the population), Carhuamayo (184 L h^{-1} from 45% of the population), Ninacaca and Vicco. The water and food of the area, when consumed by animals and plants, show a decrease in its population.

The Plan Maestro de la Reserva Nacional de Junín (2012) states that 'in the RNJ, there were 368 species of plants and 98 species of birds and in 1998, according to Chauca there were only 26 species of plants and 36 of birds'. Likewise, the fragility of the fauna can be related to the partial destruction of the habitats. The Plan Maestro de la Reserva Nacional de Junín (2012) 'proved by histological studies that the frog is affected by copper poisoning and the diver has problems due to the disappearance of his main food orestias (chalhua) also poisoned by copper and zinc'.

Discharges into the lake of contaminated water summarize residues of copper sulfate, zinc, sulfuric, nitric and lime acids, among other components, being the mining companies 'Activos Mineros', 'Aurifera Aurex', 'Volcan' and 'El Brocal' '(…) who have participation in the effects of mining pollution and environmental liabilities' (Chamoro and Medrano, 2010. '(…) the effluent of the Cia. *Aurex*, presents a high risk in the quality of water, finding copper, lead and zinc above the maximum permissible limits regulated by the Ministry of Energy and Mines' (Carrera, 2011).

Large numbers of mining tailings for decades have come to the lake; through the runoff from the rainwater of the San Juan river with a highly toxic impact. The parameters analyzed for lead metals (0.8 mg L^{-1}) and zinc (9.04 mg L^{-1}) exceed the maximum permissible limits established by the Ministry of Energy and Mines and also the environmental quality standards of the Ministry of Environment-MINAM (Carrera, 2011).

The polluting landscape, other actors and externalities worsens. According to the Plan Maestro RNJ (2012), the wetland, 'is in the process of eutrophication, due to the contamination of hospitals, hotels, dairy companies, micro-baking companies, traces and the small maca industry (*Lepidium meyenii* Walpers)'. Likewise, the overgrazing of cattle and sheep, the exploitation of pastures, illegal hunting and fishing (Chamorro and Medrano, 2010) and now the presence of an incipient tourism (Ondores, Uco and Pari).

Thus, the deterioration of biodiversity reflected in water pollution and habitat damage is caused especially by anthropogenic sources. According to INRENA (2000) the amount of dissolved oxygen decreases, increasing the concentration of phosphorus causing its eutrophication. Flusche *et al*. (2005) states that the concentration of chemical compounds increases and the risk to the subsistence of aquatic biodiversity. According to Manahan (2007) 'wastewater from domestic, commercial, food processing and industrial sources, contains a wide variety of contaminants, including organic pollutants' (fat, blood, whey and detergents).

Chemically and biologically it contains a large amount of organic matter and microorganisms respectively, which is a breeding ground for diseases in both humans and animals. Naquira (2010) argues that fasciolosis is a parasitic zoonosis caused by the adult state of the trematode Platominto Fasciola hepatic. Marcelo (2018) shows that in the area there is presence of digestive problems such as diarrhea, intestinal parasitosis and dermatological diseases.

The high oxygen demand of wastewater, when discharged into the aquatic environment depletes dissolved oxygen (Doménech, 2014). In this sense, 'some pollutants, particularly substances that demand oxygen' (Manahan, 2007) to degrade organic materials, oil, grease and solids, interfere with the entry of O_2 into the water and the exit of CO_2 and very toxic inorganic contaminants in concentrations that exceed the quality standards for surface waters intended for recreation. There are phosphorus, arsenic and cadmium that are difficult to remove even in specialized treatment plants. Complete the landscape, soil degradation, the decrease in the surface of natural pastures and the contamination of most peripheral areas.

There are specific sanitary norms and alternatives to guarantee water quality standards for lakes and lagoons. According to Español (2016), 'water quality is understood as its potential environmental function, with specific laws that determine the critical, average and minimum thresholds of admissible concentrations by type of contaminant in the water'. The mining companies surrounding the lake report compliance with the Environmental Adaptation and Management Program (PAMA, by its acronym in Spanish) for the reduction of impacts but does not reduce pollution.

According to the Ministry of Environment (MINAM, 2015, by its acronym in Spanish), the treatment plants (oxidation pools) of domestic wastewater (WWTP) of the municipalities in the area of the lake, are collapsed, without technical maintenance and have a gray color with various floating materials. There is the Chinchaycocha 2017-2021 Sustainable Management Management Plan, still without results. For its part, the 'Mantaro Water Administrative Authority' (2017) has identified points of direct wastewater discharges to the lake without prior treatment.

Once the complex problem was raised, the objective that guided the investigation was to scrutinize the impact of wastewater on these ecosystems and their area of influence, indicating the level of water quality. As a hypothesis, it is affirmed that the impact of wastewater on the mentioned ecosystems of the lake and its area of influence, has been affecting habitats with a high level of phosphorus and chlorine contamination with problems of extinction of animals, especially the giant frog of Junín. It was analyzed from a holistic approach and the previous revision with projection towards the immediate future.

The purpose of the investigation is to determine the levels of contamination of the lake by physicochemical analysis (phosphates, nitrates, chlorides, calcium hardness, dissolved solids, turbidity, hydrogen potential and electrical conductivity), the determination of indicators of biochemical and chemical contamination (oxygen dissolved, chemical demand and biochemical demand), bacteriological analysis (total coliforms and *Echerichia coli*) finally, determine the lake's water quality.

To obtain integrated information on water quality, the water quality index (ICA) is used, a tool that synthesizes the information provided by the number of parameters in a simple expression, to generate a numerical value that allows the evaluation of water quality of a system (Alarcón and Ñique, 2016). For Carrillo and Villalobos (2011) 'the ICA the value of the analysis can be representative and indicative of the level of contamination'. Through the ICA, a general analysis of water quality at different levels can be carried out and the body's vulnerability to potential threats can be determined (Soni and Thomas, 2014).

If pollution is not reversed, the biodiversity of the lake and the surrounding community will face a high-risk situation in the next two or three decades.

The materials used for the on-site water analysis were provided by the MINSA/Junín support hospital environment area: pH meter, conductimeter, turbometer, Hanna brand, environmental thermometer, water temperature measurement meter and GPS. For the physicochemical and microbiological analysis of the water samples, he supported the equipment of materials and chemical analysis of the Faculty of Chemical Engineering and the water analysis laboratory of the National University of Central Peru.

The type of research is descriptive with a holistic approach. In the study, the variables were observed naturally, consequently, the research is within the design of the non-experimental field because it does not manipulate variables. According to the temporal perspective, it is considered longitudinal contemporary evolutionary because information was obtained from a current event and data (water samples) were collected on the variables at two times to assess their relationship and the change they produce.

The samples were collected both during the rainy season and in the areas of influence. For the significant samples to obtain information on physical, chemical and microbiological contaminants, sampling stations were located about 500 m from the sewage outlet.

The study area

Below, the description of the sampling stations in Junín Lake (Table 1 and Figure 1).

Data collection

Two sampling stages were established, rainy and dry season, the first from October to December 2015 and the second from May to July 2016 respectively with two sampling repetitions; also, three sampling stations in the areas of wastewater discharges to the lake (nearby cities). At each sampling station, water samples were collected for physical-chemical and microbiological analyzes in sterilized containers and other procedures established in the protocol of the Ministry of Energy and Mines (MINEM, 2007). In all sampling stations a GPS was used. Next, the detail of the investigation.

Table 1. Lake water sampling station.

Station	Position geographic	Description
E1	UTM: 8773293 Latitude: 18L0377014 Altitude: 4089	Waters inside the lake next to the totorales in front of the city of Ondores.
E2	UTM: 8775021 Latitude: 18L0380360 Altitude: 4093	Inland waters and desert area at the bottom of the lake facing the Chacachimpa river and Junín city.
E3	UTM: 8786883 Latitude: 18L0382935 Altitude: 4097	Inland near the totorales in front of the city of Carhuamayo.

Collection of samples from the lake's water mirror in areas of wastewater discharges to determine the current state of physicochemical and bacteriological contamination levels of the waters with two repetitions per sampling station.

On-site realization of the measurements of the electrical conductivity, pH, turbidity and the temperature of the water and the environment. For bacteriological analysis, all the stations were collected in 300 mL glass bottles previously sterilized and transferred in refrigeration at 4 °C to the laboratory for analysis before 24 h of collection. Likewise, physicochemical analyzes of lake water samples were performed.

Physicochemical and bacteriological analyzes of the water samples of the discharge channels of the cities and of the lake's water mirror were performed.

For the bacteriological analysis, the 'Colilert/IDEXXQuanti-Tray/2000 test method, most probable number (MPN) for coliforms and *E. coli*', reference 9308-2:1990 of the International Organization for Standardization (ISO) was used. For the biochemical indicators, the biochemical oxygen demand (DBO_5) was determined for 5210-B ROB_5 days, dissolved oxygen (O_2) by the membrane electrode method and the chemical oxygen demand (COD) by photometric closed reflux.

To determine the level of water quality, it was carried out using the Index of the National Sanitation Foundation (INSF) of the United States of America, in the three stations E1, E2 and E3 sampling of the body of water, in the areas of discharge of the residual waters of the lake. According to Ott (1978), the INSF uses a weighted linear sum. The result of its application must be a number between 0 and 100 that represents excellent water quality. This fits with the general public concept of valuations.

For the analysis of the data obtained with the techniques described above, the Excel 97-2003 book and the SPSS 24 program were used. To obtain the descriptive statistics of the physicochemical and bacteriological analysis, the Excel 97-2003 book was used then, the one-way parametric Anova or factor with the SPSS 24 program was applied to the physicochemical and bacteriological data obtained, prior evaluation of the homogeneity of variance with a Levene statistic. For the determination of significant differences, it was used ($p< 0.05$) for the rainy and dry season in the three sampling areas. When finding significant differences ($p< 0.05$) and determining multiple comparisons at each time and sampling sector, Tukey's post hoc test was used.

Results

According to the descriptive statistics of the physicochemical and bacteriological analyzes of the lake waters in the areas of wastewater discharge, coming from the cities under study and considering the season and time of sampling, the following results are obtained. The water temperature of the lake in the rainy season showed an average of 12.2 °C in the sampling stations 1 and 2, corresponding to the cities of Ondores and Junín. In station 3 of Carhuamayo it presented 12.5 °C, while during the dry season they presented an average of 10 °C in the three sampling stations in the lake waters corresponding to the areas under study.

The average of the conductivity of the water of the lake in the rainy season in station 1 is 455 µS/cm and in an estuary 480 µS cm^{-1} in the area of Ondores, the average in the rainy season in season 2 is 451 µS cm^{-1} and in the dry season 475 µS cm^{-1} Junín area and in season 6 in the rainy season it is 514 µS cm^{-1} and 534 µS cm^{-1} runoff. The means of conductivities in the rainy season are lower compared to the dry season. In the three sampling stations of the water body of Lake E1, E2 and E3 the total hardness averages are 144, 146 and 134 mg L^{-1} respectively in the rainy season, while in the dry season the averages are slightly higher (156, 169 and 179 mg L^{-1}) in the three seasons due to carbonate concentration. It presented a range of averages of pH 7.7 to 8.37 in the two sampling periods.

According to Bussing (2002), in general, the pH of the rivers varies between 6.5 and 7.4 and the total hardness is 25 to 70 mg L^{-1}. The lakes are usually more alkaline, with a pH between 7 and 8 and a total hardness between 20 and 150 mg L^{-1}. The waters of Junín Lake contain averages during the rainy season, pH 7.7 at the sampling station E.1, pH 8.3 at station E.2 and 8.37 at station E.3. During the dry season, the pH means are 8.2; 8.21 and 8.3 for E1, E2 and E3 respectively. In general, a homogeneous and almost constant pH but slightly higher than the Bussing range can be considered. As regards the alkalinity in stations E1, E2 and E3, they presented slight variations in periodicity in both rain and dry season.

These variations are due to $CaCO_3$ fluctuations of 124 to 134 mg L^{-1} in the rainy season and 146 to 169 mg L^{-1} in the dry season. In addition, it is observed in the results that the means of the total solids reported are higher than the alkalinity in the three seasons of the lake’s water body, this superiority can be attributed to calcium and magnesium could be associated with nitrates, chlorides and sulfates. Regarding the acidity, pH and salinity of the waters of the lake, they contain means in the rainy season, pH 7.7 at the sampling station E1, pH 8.3 at station E2 and 8.37 at station E3. During the dry season it is slightly higher than the pH described; in general, a homogeneous and almost constant pH can be considered.

Cl-Chlorides determined in the water samples, during the rainy season, show a higher concentration in E1 with an average of 13.01 mg L^{-1}; nevertheless, that they show equality in the means of concentration in the stations of E2 and E3 of 10.01 mg L^{-1}, during the dry season the concentrations of chlorine in stations E1 to 14.05 are increased, in E2 at 15.07 and in E3 to 12.41 mg L^{-1}. The concentration of sulfates (SO_4^{-2}) in the body of lake water during the rainy season, has an average of 38 mg L^{-1} in E1. This concentration is lower than the average 99 mg L^{-1} in E2 and 41mg L^{-1} in E3. Likewise, the average concentration of sulfates during the dry season is increased to 43 mg L^{-1} in E1, 129 mg L^{-1} in E2 and 64 mg L^{-1} in E3.

The means of dissolved oxygen (OD) concentrations in E2 and E3 during the dry season; Likewise, the average E1 in times of rain and dry season is below 5 mg L^{-1} of the permissible limits for lakes and lagoons. The descriptive statistical results of the bacteriological analysis of water, in which the coliforms expressed in NMP/100 mL are found in the rainy season, show that the means of stations E1, E2 and E3 are lower with respect to the means of the period of the same stations corresponding to the body of water of the lake of the areas corresponding to Ondores, Junín and Carhuamayo.

Water quality

The results of the lake's water quality, determined from the physicochemical and bacteriological analyzes, carried out using the index of the National Sanitation Foundation (INSF) of the United States of America, qualified the water body of the sampling stations from Ondores, Junín and Carhuamayo as follows. The NSF index of the waters in the wastewater discharge areas of the city of Ondores in the rainy season is 57.7 according to the water quality classification scale, it is medium quality water; while, during the dry season, the INSF is about 50. It was located within the range of 26-50, therefore, the water is of poor quality.

The INSF of the waters of the lake in wastewater discharge areas of the city of Junín in the rainy season is 60.32 according to the water quality classification scale, it is medium quality water. However, during the dry season the INSF is 47.62, it is within the range of 26-50, the water is of poor quality. The NSF index of lake waters in wastewater discharge areas of the city of Carhuamayo in the rainy season is 60.06 mg L according to the classification scale, it is medium quality water; however, during the dry season the NSF index is 48.6 mg L^{-1} is in the range of 26-50, the water is of poor quality.

Table 2, tests the Anova results of physicochemical and bacteriological analysis of lake water sampled in the three cities, taking into account the time and sampling station. According to the sampling time 83% of indicators show significant differences ($p< 0.05$). However, according to the rainy season, the indicators showing significant differences are phosphates, biochemical oxygen demand and total coliforms. Whereas, in the stations sampled during the dry season, the indicators that show significant differences are the biochemical oxygen demand and total coliforms.

Table 2. Anova of the physicochemical and bacteriological analysis of water from Junín Lake.

Analysis ($p< 0.05$)	Sampling time			Station A, Rain			Station B, Drought		
	F	*p*	Sig	F	*p*	Sig	F	*p*	Sig
Chlorides	10 668	0.017	*	1 754	0.313	ns	3.319	0.174	ns
Phosphates	3 998	0.093	ns	24 185	0.014	*	0.141	0.874	ns
Total solids	8 344	0.028	*	0 186	0.839	ns	0.671	0.74	ns
Dissolved oxygen	18 618	0.005	*	2 468	0.232	ns	0.044	0.958	ns
DBO_5	22 803	0.003	*	110 311	0.002	*	43.756	0.006	*
Total coliforms	417 872	0	*	22 102	0.016	*	24.026	0.014	*

A= sampling stations Ondores, Junín and Carhuamayo sectors in the rainy season; B= sampling stations Ondores, Junín and Carhuamayo sectors during the dry season; *p* -value (sig); F= statistical value of contrast.

According to the statistical test in Table 3, the statistically significant difference ($p< 0.05$) between sampling time; turbidity and dissolved oxygen show a significant difference in the rainy season compared to the dry season. On the other hand, chlorides, total solids, biochemical oxygen demand and total coliforms show a significant difference in the dry season with respect to the rainy season.

Table 3. Tukey HSD multiple comparisons of lake water.

($p< 0.05$)	Sampling time		Station A. Rain			Station B, Drought		
	Rain	Drought	(I)	(J)	Sig	(I)	(J)	Sig
Chlorides	11.01 ±2.1 b	13.84 ±1.5 a						
Phosphates			Ond	Jun	0.013			
			Ond	Car	0.042			
Total solids	665.55 ±138b	879.62 ±64a						
Dissolved oxygen	5.81 ±1.2 a	3.49 ±0.7 b						
DBO_5	22.67 ±19 a	33.37 ±20 a	Ond	Jun	0.002	Ond	Jun	0.016
			Ond	Car	0.002	Ond	Car	0.006
Total coliforms	3.73 ±2.4 b	46.63 ±16 a	Jun	Car	0.014	Ond	Jun	0.013
						Ond	Car	0.048

(I)= sampling station; (J)= sampling station; A= sampling stations in Ondores, Junín and Carhuamayo in the rainy season; B= sampling stations in Ondores, Junín and Carhuamayo during the dry season.

According to the sampling station in the sectors of the 3 cities, in the rainy season for even phosphates with greater variation, they present the Ondores-Junín sector and the Ondores-Carhuamayo sector; for BOD5, the pairs that show the greatest variation were the Ondores-Junín sector and the Ondores-Carhuamayo sector, and for the total coliforms, the pair of greatest variation shows the Junín-Carhuamayo sector.

Discussion

Next, the determination of the current state of the levels of physical, chemical and bacteriological contamination of the waters of Junín Lake.

Physicochemical analysis of lake water

The total hardness of lake waters is the sum of calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per liter. Water of hardness less than 60 mg L of $CaCO_3$ is considered soft, if the hardness is greater than 270 mg L^{-1} of $CaCO_3$, water is considered hard. According to the results, the hardness of the body of water of Junín Lake is superior to the determination of Bussing (2002) in different lakes, in addition the result of the study is less than 270 mg L^{-1} of $CaCO_3$.

The chlorine, present in the wastewater reacts with various organic compounds to form chlorinated products whose chlorinated compounds are not properly separated in the wastewater treatments (in the case of the oxidation pools of the 3 cities), they become residual chlorines that they are poured into the body of water of Junín Lake. This causes toxicity on the aquatic organisms of the lake including benthic, fish ‘challhua’ (*Orestias* spp.) and algae. For Nemerow (1998), almost all salts, some even in low concentrations, are toxic to certain forms of aquatic life. Thus, chlorides are known to be toxic to freshwater fish in concentrations of 4 000 ppm.

Sulfate ion (SO_4^{-2}) is very soluble in water. According to APHA-AWWA- AWWA CF (1992). The dissolved sulfate can be reduced to sulphite and volatilized into the atmosphere as H_2S, precipitated as insoluble salts or incorporated into living organisms. In contrast, barium, strontium and lead sulfates are insoluble in water and if they are discharged into the body of water, it can accumulate over time causing pollution. However, sulfates serve as a source of oxygen to bacteria, under anaerobic conditions, becoming hydrogen sulfide.

In this study, an average sulfate concentration of 129 mg L was reported in the Junín sector during the dry season. There is a concentration of PO_4^{-3} phosphates (mg L^{-1}) in the sampling stations of the Junín Lake body of water (Table 2). In the rainy season, as in the dry season, they exceed the concentration of 0.4 mg L^{-1} PO_4^{-3} of the permissible limits for lakes and lagoons. Indeed, toxicity to the aquatic life of the lake is a danger. In this study, an average of 21.07 mg L^{-1} was reported in the Ondores sector during the rainy season.

Biochemical analysis of lake water

The biochemical oxygen demand in five days (DBO_5), which represents the amount of oxygen needed to biologically stabilize the organic matter contained in a water sample. According to Barba (2002) ‘the DBO, is an estimate of the amount of oxygen required to stabilize biodegradable organic materials by a heterogeneous population of microorganisms’. In this sense, the concentrations of DBO_5 in all the sampling stations of Junín Lake, both during the rainy season and in the dry season, are not within the permissible limits for lakes and lagoons.

Bacteriological analysis of lake water

As for the total coliforms present in the body of lake water, it is in accordance with Romero’s theory (2008) ‘the group of total coliforms, *coli-aerogenes* group, includes the *escherichia* and *aerobacter* genera. In general, the genus *Eschirichia*, species *E. coli*, is considered to be the most representative population of coliform bacteria of fecal contamination’. In this sense, the results of the bacteriological analysis of the body of water in the lake, during the rainy season, are less than the time of the three cities.

Fact that should make the actors and externalities reflect to reverse this difficulty of water pollution. It is urgent to apply more friendly strategies with the lake’s environment, in order to preserve the habitat of endemic flora and fauna.

Determination of the water quality level of the lake

Aguirre *et al*. (2016) in their work on the application of the water quality index (ICA), mention the case of Lake Izabal where studies show that water quality in both dry and rainy seasons is categorized as good. While the water quality of Junín Lake, determined from the physicochemical and bacteriological analyzes, carried out using the index of the National

Sanitation Foundation (INSF) of the United States of America, qualified the water body of the sampling stations from Ondores, Junín and Carhuamayo as medium quality water with ICA-NSF averages of 57.7, 60.32 and 60.06 respectively for the rainy season.

The averages of indices for the body of water of the three stations were 50.24, 47.62 and 48.6 for the period of drainage qualified as bad quality water. Indices that differ from the water quality of the Cunas River reported by Custodio (2013) in which '(…) the INSF rated the water bodies of the San Blas sector as good quality water with ICA-NSF 76.91 for the rainy season and 72.40 for sewage'. While for the 'Huarisca' and 'La Perla' sectors, this index rated the water bodies as medium quality water. The difference in water quality is due to anthropogenic pressure factors to which each aquatic system is exposed, both in sectors of water mass and at the time of sampling.

It is perceived that the lake is increasingly contaminated with the waste of the liabilities of the mining companies of the San Juan river that transfers inorganic materials (zinc, lead, copper, among others) to 50% of the areas of the water mirror and then to rush towards the bottom of the lake obstructing the movement of organisms and the light rays of water necessary for the subsistence of every living being (zooplacton and phytoplankton). Done, that leads the lake to the colmatación. Likewise, as organic and acidic materials are deposited through the wastewater of the surrounding cities, their capacity for self-regulation and sustenance for aquatic life is decreasing.

They cause the formation of immiscible phases due to the presence of organic solvents, fats and oils. Chlorine from wastewater reacting with various organic compounds forms chlorinated products that are discharged into the body of lake water, causing toxicity to especially fish aquatic organisms. Important factor to the poisonings produced by the copper and zinc that cause the decrease of the 'challhua' (*Orestias* spp.), the main food of the endemic bird of Junín (*Podiceps taczanowskii*). Detergents are responsible for the presence of phosphates in wastewater.

When discharged to the body of water, they generate the rapid growth of algae. They use a large amount of oxygen in their growth and development, causing oxygen deficiency for aquatic biota, consequently the death of animals. According to Domenech (2014), in the water 'the pollutant can move to deeper layers with the help of advective movements of the water bodies and before being eliminated by biodegradation, it can be incorporated into living organisms by bioaccumulation or return to the atmosphere by volatilization'. In this scenario, animals are perceived to be the most affected because they manifest discomfort, symptoms or atypical behaviors.

The community members perceive it as a consequence of the contamination of their lake. It is observed that the greatest change perceived in the present century is the threat of extinction of the black chicken (*Laterallus tuerosii*), the giant frog (*Batrachophrynus macrostomus*) and the Junín diver (*podiceps taczanowskii*). Prior to predation, the peasants realize that before the construction of the Upamayo dam (1927), the installation of mining companies (1960) and population growth in the present century, the lake had an average depth of 15 m.

It was navigable using totora horse as a means of river transport. In addition, it was the main source of food for the population in an organized way, since there were associations of fishermen and hunters of frog and wild guinea pig (*Cavia tschudii*). Likewise, a source of plant resources such as totora and in the buffer zones there were natural or grass-free pastures free of contamination that became the main food for cattle and sheep. The 'champas' (coarse fiber grasses) were used as an energy source for cooking food by ancestral custom.

Del Sante (2011) concludes that 54% of respondents believe that Junín Lake no longer presents the same quality and quantity of water, of this group, 76% noticed or heard of changes in Junín Lake in the last 30 years. Of this last group, 39% consider that the disappearance of the frog Junín is the biggest change of the last three decades, while 28% consider that there is more pollution. Another polluting factor of the aquatic ecosystem of Junín Lake in the bacteriological aspect is the presence of total coliforms, specifically the genus *Eschirichia*, species *E. coli*, considered as the population of coliform bacteria more representative of fecal contamination.

In this regard Hidalgo and Mejía (2010) mention that 'the main problem identified is the contamination by domestic wastewater (total coliforms)'. To remedy the problem, bacteriological controls can be carried out by the Directorate General of Health (DIGESA) and the Commission of the 'Chinchaycocha Plan'. However, mitigating actions of bacteriological contamination are not programmed. The NSF index of lake waters in the wastewater discharge areas of the city of Ondores in the rainy season is 57.7 according to the water quality classification scale, being medium quality water. However, during the dry season the INSF is about 50, it is within the range of 26-50, therefore, the water is of poor quality.

The INSF of the waters of the lake in wastewater discharge areas of the city of Junín in the rainy season is 60.32 according to the scale of water quality classification, it is considered medium quality water. However, during the dry season the INSF is 47.62, it is within the range of 26-50, it is inferred that the water is of poor quality.

The NSF index of lake waters in wastewater discharge areas of the city of Carhuamayo in the rainy season is 60.06 m L^{-1} according to the classification scale, it is medium quality water. However, during the dry season the NSF index is 48.6 mg L^{-1} is in the range of 26-50, so the water is of poor quality.

Despite the threat of extinction, some specimens of tadpole age were located miles away from the lake on the tributary of the Chacachimpa River in the 'Sanctuary of Chacamarca' sector. According to the expedition formed by the Continental University of Huancayo, the North American Peace Corps, the National Service of Protected Areas (Sernap) and the San Francisco de Chichausiri community, they report that Junín's giant frog is not extinct: they found tadpoles; however, everything indicates that it is still at risk of extinction (Diario 'La República', 2016).

Conclusions

Indeed, Junín Lake presents evidence of pollution. The components indicate levels of physicochemical contamination of the waters in the areas of wastewater discharges, according to the seasons and time of sampling. They exceed the environmental quality standards for lake water and lagoons. a. The concentrations of PO4-3 phosphates (mg L^{-1}) in the body of lake water, during periods of rain and dryness exceed the permissible limits for lakes and lagoons, being a danger of toxicity to aquatic life; and b. The lowest dissolved oxygen concentration (OD) during the dry season presented the Junín stations with an average of 3.42 mg L^{-1} and the Ondores station with an average of 3.41 mg L^{-1}.

According to the bacteriological results, the concentration of thermotolerant coliforms in the rainy season is lower compared to the period of the lake's water body drainage. This behavior makes it possible to affirm that there is no wastewater treatment of the surrounding cities; therefore, there is a danger of modification of the lake ecosystem with unpredictable impacts on aquatic biodiversity.

Lake waters in the wastewater discharge areas of the city of Ondores with value of ICA-NSF 50, city of Junín with ICA-NSF 47.62 and city of Carhuamayo with ICA-NSF of 48.6, at the time of sewage are waters that are considered at the level of poor quality.

Ecological decompensation translates into damage to the biodiversity of the lake, which shows animals in danger of extinction, such as the giant frog, the Junín diver and the black coot.

Wastewater discharges is a polluting factor with danger of toxicity to the aquatic life of the lake. The urgent need to mitigate the problem is alerted, suggesting generating environmental policies that identify, plan, implement and evaluate the processes and impacts of the peripheral institutions to Junín Lake.

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