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Physicochemical characterization of water quality in the Perlamayo and Tacamache rivers, using benthic macroinvertebrates as biological indicators in the district of Chugur- Cajamarca

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Abstract- The general objective of this research was to determine water quality through physicochemical and sediment analysis. Also, to evaluate the benthic macroinvertebrate community through biotic indices (EPT, BMWP/Bol, BMWP/Col, ABI and CERA) in the Perlamayo and Tacamache rivers. Seven monitoring points were established according to the degree of intervention by anthropogenic activity. During the months of February (rainy season) and July (dry season), the results of the physicochemical variables were compared to Peruvian Environmental Quality Standards. According to Supreme Decree No. 004-20017-MIMAN, and Sediments compared to the Canadian ECA TEL (Threshold Effect Level). To study the relationship between macroinvertebrate communities and environmental variables. An statistical analysis was carried out to determine which pressures most affect the benthic community, using a simple regression model. The results obtained show that the distribution and composition of the benthic community is determined by the physicochemical parameters of temperature, pH, conductivity, dissolved oxygen and the concentrations of heavy metals. Six orders and 16 families of benthic macroinvertebrates were identified. Including, Leptophlebiidae, Gripopterygidae, Leptoceridae, Hydrobiosidae, Hyalellidae and Chironomidae; the ETP index gave a poor water quality; the BMWP/Bol and BMWP/Col indices gave a critical quality; the ABI and CERA indices showed a moderate quality. In conclusion, the levels of alteration evaluated in this research are a useful tool for determining the ecological quality of the Perlamayo and Tacamache river systems. Proving to be an appropriate method for the evaluation and monitoring of other watersheds in the Cajamarca region, Peru.

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keywords: Water quality, benthic macroinvertebrates, biotic indices.

I. Introduction

One of the main causes of environmental conflicts in Perú are related to mining activities. The general objective of this study was to determine the water quality through physicochemical variables, and the community of benthic macroinvertebrates, through biotic indices (EPT, BMWP/Bol, BMWP/Col, ABI and CERA) in the Perlamayo and Tacamache rivers. And mainly, to determine the physical and chemical composition through sampling and laboratory analysis of heavy metals. Comparing their values with the Environmental Quality Standards (Supreme Decree No. 004-2017-MINAM) in surface waters, and in sediments with the Canadian Environmental Quality Standard (TEL). The results presented in the following article were taken from the master's thesis entitled, "Caracterización Fisicoquímica Y De Macro Invertebrados Bentónicos De Los Ríos Perlamayo Y Tacamache, Distrito De Chugur Cajamarca"[1].

5. Materials and Methods

5.1 Location:

The study was conducted in the Perlamayo and Tacamache rivers, which belong to the Chugur district, one of the three districts of the Hualgayoc province. Located on the western fringe of the Andes Mountains by the north of Peru, in the Cajamarca region. The Chugur district is in the lower part of the watershed, between the Perlamayo and Tacamache rivers, at 2753 masl [2]. And at UTM coordinates in WGS 84 East: 750036. 25 and North 9262040.22; it has a land area of 99.6 km 2; with altitudes ranging from 2100 to 4100 meters, which makes its location the support of some life zones with environmental and biodiversity importance [1]. Figure 1.

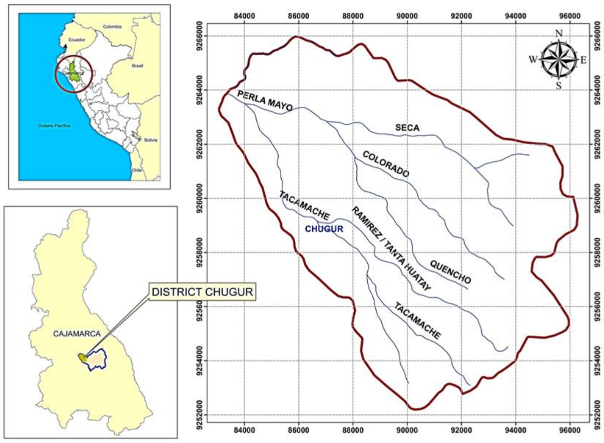


Figure : 1 Location of the study area_ District of Chugur-Province of Hualgayoc.
Source [14].

II. METHODOLOGY.

2.1 Physical Chemical Parameters

It was carried out in accordance with the National Protocol for Monitoring the Quality of Surface Water Resources of the National Water Authority (2016). The monitoring points were identified, and the information was recorded on identification cards for each monitoring point. The geographical location was georeferenced through the use of a portable Extrex Garmin GPS, the physical chemical parameters (T°, pH, Conductivity, dissolved Oxygen) and heavy metals (Al,As,Cd,Cr,Cu,Fe,Mg,Pb , Zn). Hanna Model HI 9829 equipment was used for field data, water samples were taken according to the sampling protocol. And analyzed at the Regional Water Laboratory, as maintained by the Environmental Quality Standards (Decree Supreme No. 004-2017-MINAM Environmental Ministries of Peru). [1]

The collection methodology was defined based on the objectives of the study and on the substrates available in the different aquatic ecosystems. The method used was the Red Surber method, which consists of a metal frame of 30 x 30 cm, to which is attached a net of about 80 cm in length and with a mesh opening of approximately 500 μ. The frame is placed on the bottom and against the current and the bottom material is removed with the hands, trapping the organisms in the net. This operation is repeated at least three times at each sampling station, and the number of organisms per m2 can be calculated. The collected material is then emptied into a container with 90% alcohol to be separated in the laboratory. The Surber net can also be used for qualitative collection by placing it indiscriminately over several places in the stream, but it is important to know that it has been designed for quantitative use.

2.2 Sediments

The sediments were collected on the banks or in accumulation areas, for each sampling point, they were coded and labeled. Then they were transfered to the Regional Water Laboratory for their respective analysis. For their evaluation, they have been compared with the Canadian ECA TEL (Threshold Effect Level), these results were contrastes with the heavy metals of As, Cd, Cr, Cu, Pb, Zn in concentration of ug/kg in bottom sediments. This method was used in this study, because Peru does not have a proper comparison regulation and concentrations for sediments [3].

2.3 Biotic indices.

Collection methodology.

Aquatic macroinvertebrates are defined as those organisms with sizes greater than 0.5 mm in length, meaning, all those organisms that can be seen with the naked eye. Therefore, the word "macro" indicates that these organisms are between 200–500 mm.

For each of the biotic indices EPT, BMWP/Col, BMWP/Bol, CERA and ABI, the description of the characteristics of the river was made. Hence, identifying the types of habitats and main characteristics for each monitoring point Flores [4].

2.4 Collection techniques.

The sampling technique was based on the objective of collecting the greatest possible diversity of macroinvertebrates. To do this, each sampling site was carefully explored, including bottom substrate (rock, sand, mud, vegetation debris), aquatic macrophytes (floating, emergent and submerged), submerged tree roots and artificial substrates (debris that may be present, dikes, etc.). To obtain comparable results, the sampling effort should cover an area between 100 m and be done for 20 to 30 minutes.

In the Perlamayo and Tacamache rivers, they were sampled on both banks. Because the fauna is different due to the shade, meanders, composition of the bottom, contamination may occurs. Thats why sampling at the immediate confluence of two rivers was avoided. Instead, sampling were taken bellow the mixing zone. As well as, in shallow or stagnant waters. The used of handnet were use for sampling the deep waters. In addition, modified suber network was used too. To do this, it is placed the net on the bottom and against the current with the hands. The material then is removed from the bottom, and trapping the organisms in the net. The collected material was emptied into a container (ziploc bag) preserved with 90% alcohol to be separated in the laboratory [5].

2.5 In the laboratory.

They were washed and sifted to separate the fine sediment and proceeded to observe in an Olimpus model SZ microscope/stereoscope, for their identification and then the collected organisms were photographed. The identification of the samples was used in the book on South American benthic macroinvertebrates, systematics and biology. The samples were preserved in alcohol for the collection of the environmental ecology laboratory 2A-104, of the National University of Cajamarca.

2.6 Field data processing

An IBM Spss matrix was developed for data collection, classifying and at the same time processing information with the results of the investigation, the Arc Map 10.3 computer program, was used for the preparation of geographic information, location maps, delimitation and maps of biotic indices.

2.7 Statistical design.

To perform the statistical analysis, since the data had a qualitative characteristic, with a quality level, it was necessary to give them a numerical value for the calculation, assuming values from 1 to 5 as indicated in Table 1, for each biological index. Obtaining an average of the indices for each monitoring point.

Table I
Quantitative values for biological indices

Monitoring Point	River oy Greel	EPT	BMWP-COL.	BMWP-BOL.	ABI	CERA	Average for river quality
P1	Creek Sinchao.	1.0	1.0	1.0	1.0	1.0	1.0
P2	Creek Colorada.	1.0	2.0	2.0	2.0	1.0	1.6
P3	Creek Quencho.	1.0	5.0	4.0	5.0	5.0	4.0
P4	River San Juanpampa.	1.0	3.0	3.0	4.0	4.0	3.0
P5	River Tacamache.	1.0	2.0	2.0	3.0	3.0	2.2
P6	Creek Seca.	1.0	2.0	2.0	2.0	1.0	1.6
P7	Creek Ramirez.	1.0	2.0	2.0	4.0	4.0	2.6
Average for quality according to index		**1.0**	**2.4**	**2.3**	**3.0**	**2.7**	**2.3**

Source: [1].

From the previous table, the numerical values and the averages of the indices were defined to proceed with the evaluation using the IBM-SPSS ver. 24 statistical package. Through a simple regression analysis, which involves the study and the relationship between two or more quantitative variables.

III RESULTS

3.1 The results of the physicochemical characterization showed that the parameters evaluated mostly comply with Peruvian regulations. The most significant variation with acidic characteristics was obtained at station P1, registering a pH of 2.97, and at station P2, a pH of 3.75, during the sampling in the rainy season. Both monitoring points correspond to the Perlamayo River micro-basin and, P5 (Tacamache River) with an average value of 9.1 (July) and P6 (Creek Seca) with an average value of 9 (February), with basic or alkaline pickpockets, due to the geological characteristics of the area (Poma and Alcántara, 2004). Finally, in Dissolved Oxygen in P6 (dry stream) in the month of July, the lowest value was 2.32 mg/l, which does not comply with the ECA, probably due to water eutrophication processes. As shown in the figures below: [1]

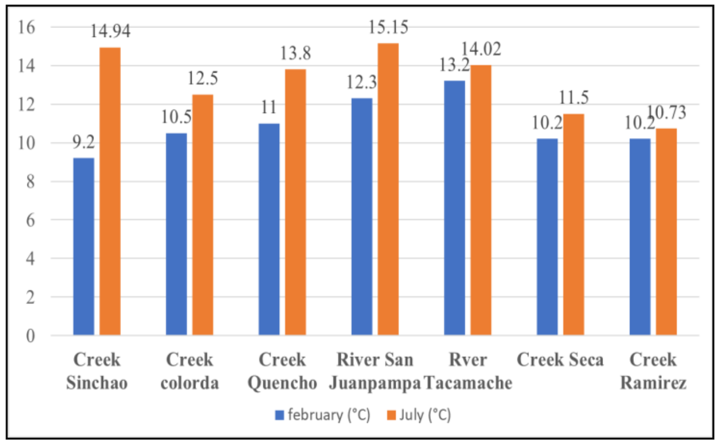


Figure 1 Temperature results Figure 3 .
Source [1].

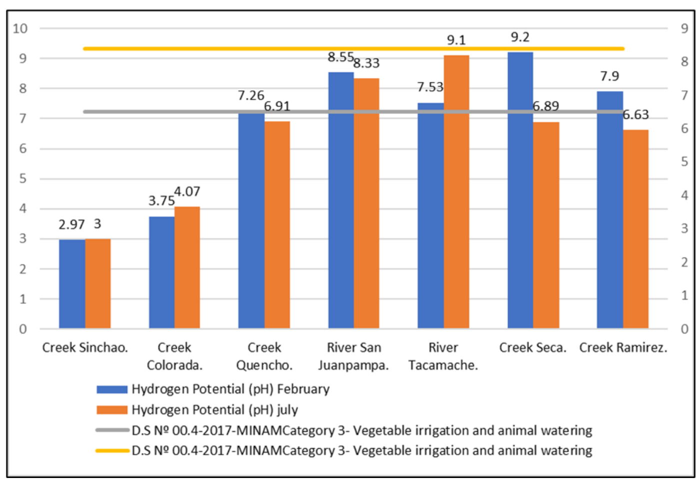


Figure 2 pH results
Source [1].

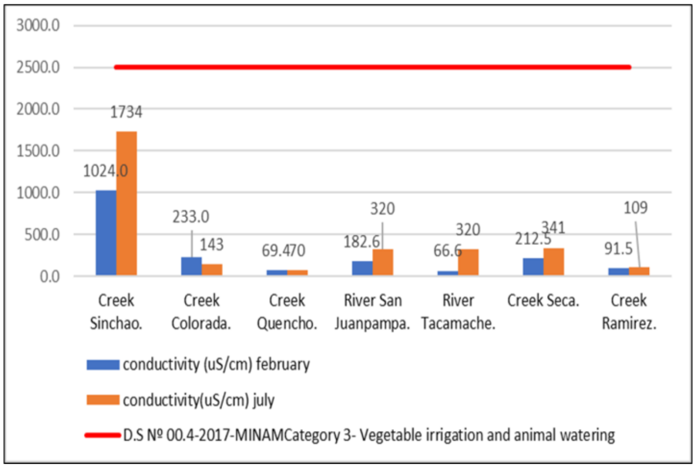


Figure 3 Conductivity Results Figure Source [1].

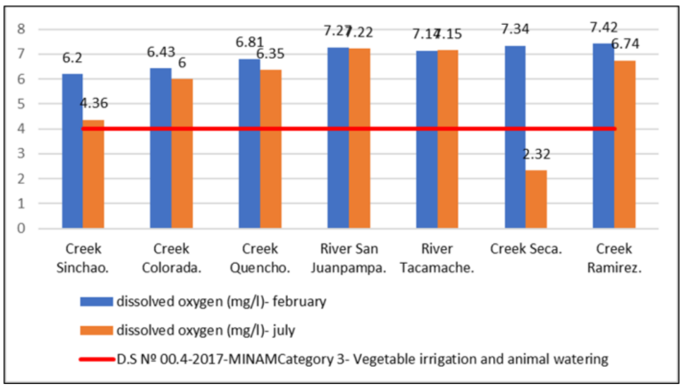


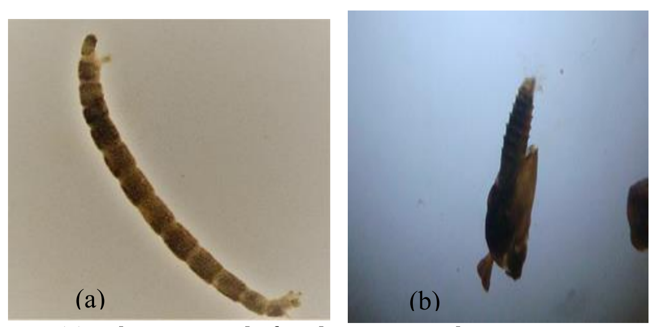
Figure 4 Dissolved Oxygen Results [1].
Source [14].

3.2 Results with sediments.

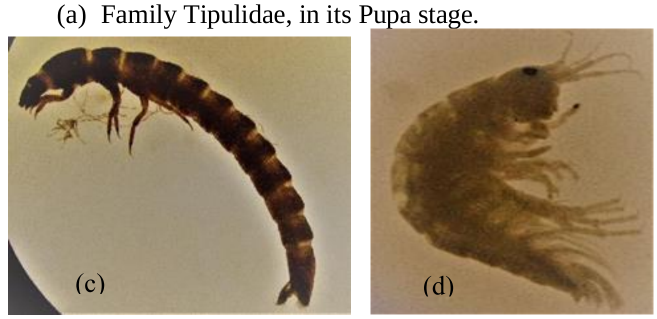
The study of heavy metals only in the wet season through the use of the Canadian standar TEL (Threshold Effect Level) [2], the following results were obtained: in Arsenic (As) in P1 (Sinchao creek) a value of 4250mg/kg; P2 (Creek Colorada) a value of 429.90 mg/kg., P3 with 11.70 mg/kg; P7, 19.60mg/kg. and in P8, a value of 683.80 mg/kg, with the Canadian standar for Arsenic (As) being 5.90 mg/kg. In Cadmium (Cd), the highest values were obtained in P1 (Sinchao stream) with a value of 55.80 mg/kg, in P2 (Creek Colorada) a value of 9.2 mg/kg, both belong to the Perlamayo river. In P3 (Creek Quencho) a value of 6.05 mg/kg and in P4 (San Juanpampa river) a value of 21.20 mg/kg; and finally in P8 (Las Gradas creek) with a value of 21.20mg/kg, being the limit of 0.6 mg/kg, this is worrying due to the toxicity of all these elements that are harmful to human health. [1]

3.3 According to the evaluation of the EPT biotic index, in both sampling periods its ecological quality is POOR, due to the fact that this type of species is highly sensitive in highly polluted waters, verified with the results obtained. For the determination of the ecological quality for the BMWP Col index, an average score of 41 was obtained for the 7 sampling points in the sub-basin of the Perlamayo and Tacamache rivers, which corresponds to a class III, being a doubtful quality, meaning Aguas moderately contaminated. In the evaluation of the ecological quality for the BMWP/Bol index, an average score of 40 was obtained, in the 7 sampling points, for the rainy season and the dry season, which corresponds to a Class 4, a Doubtful quality, meaning contaminated water. For the analysis with the CERA index, the quality of the Perlamayo and Tacamache rivers was analyzed using 3 indices according to Acosta [6] and Alvarez [7] being the IHF index, which evaluates the heterogeneity of the fluvial habitat of the riverbed, the Indices of Riparian Forest (QBR-And) integrated of the structure of the riparian or of the hydromorphological characteristics applied to the micro-basins of the Perlamayo and Tacamache rivers. and the ABI Andean Biotic Index, this index performs a qualitative evaluation of macro invertebrates [8],[9]. The ecological quality according to the CERA index obtained a value of 3, which indicates that the waters of the Perlamayo and Tacamache rivers are of "Regular" quality. According to the ABI values obtained in the rainy season, the sampling points presented a water quality ranging from very poor to very good. The station that presented the highest value was P-3, with very good quality followed by P-4, and P-7 qualified as stations with good water quality, station P-5 with moderate quality, stations P-2 and P-6 with poor quality and the one with the lowest value was station P-1, considered a station with very critical water quality. In the dry season, the sampling stations presented water quality from very good to very poor. The station that presented the highest value was P-3, followed by stations P-4 and P-7 with good quality, stations P5 and P6 were qualified as sampling points of moderate quality, station P-2 With poor quality and the one with the lowest value was P-1, considered as a station with poor water quality [10], [11], [1]

Identification of families of macroinvertebrat



(a) Chrironomiade family in Larva phase.
(a) Family Tipulidae, in its Pupa stage.



(c) Family Elmidae, is Larva stage
(d) Family Hyalellidae, in Adult phase. .
Source [14].

3.4 Results of statistical analysis.

3.4.1 Statistical analysis was performed for both sampling times, with the results obtained, in table I and II the comparison variables were those obtained for category 3 water quality, according to DS. N ° 004-2017- MINAM. The results presented are a simple, residual regression analysis according to Durbin and Waton. Likewise, regression analysis was also carried out for comparison with the results for sediments, and they were compared with the Canadian environmental quality standards (TEL) and the parameters established with respect to the concentration of heavy metals. From the data in table 1, for the regression model tested for 6 metals (As,Cd,Cr,Cu,Pb,Zn), it is explained that 75% of the averages of the biological indices are related to the presence of heavy metals with respect to the water quality of the micro-basins of the Perlamayo and Tacamache rivers in the rainy season And the results of the analysis of variance (ANOVA) of the regression model indicate that this significantly improves the prediction of the independent variable when the value of F= 1,285. [1]

Table I
Statistical analysis (simple regression) for the rainy season (February) [14].

Model	R	R squared	R square adjusted	Standard error of estimate	Durbin-Watson
1	0.750[a]	0.562	0.125	0.9129403	1.906

Source: [1]
(a) Dependent variable: PROMINDBIOL
(b) Predictor: (Constant), zinc, arsenic, lead

Table II
ANOVA statistical analysis for the rainy season (February).

Model		Sum of squares	gl	Mean square	F	Sig
1	Regression	3.214	3	1.071	1.285	0.421[b]
	Residuo	2.5	3	0.833		
	Total	5.714	6			

Source: [1]
(a) Dependent variable: PROMINDBIOL
(b) Predictor: (Constant), zinc, arsenic, lead

3.4.2 From the data in table III for the regression model tested for 6 metals, (As,Cd,Cr,Cu,Pb,Zn), it is explained that 75% that the averages of the biological indices are related to the presence of heavy metals with respect to the water quality of the micro-basins of the Perlamayo and Tacamache rivers in the dry season In table 4, simple regression model, the Durbin-Watson value is 1.90 Therefore , given the values of that delimit our rejection zone, we accept the alternative hypothesis of no autocorrelation. And the results of the analysis of variance (ANOVA) in table IV, of the regression model indicate that this significantly improves the prediction of the independent variable when the value of F= 1.285.

Table III
Statistical analysis (simple regression) for the dry season (July).

Model	R	R squared	R square adjusted	Standard error of estimate	Durbin-Watson
1	0.750[a]	0.562	0.125	0.9129403	1.906

Source: [1]
(a) Dependent variable: PROMINDBIOL
(b) Predictor: (Constant), zinc, arsenic, lead

Table IV
ANVA statistical analysis for the dry season (July).

Model		Sum of squares	gl	Mean square	F	Sig
1	Regression	3.214	3	1.071	1.285	0.421[b]
	Residuo	2.5	3	0.833		
	Total	5.714	6			

Source: [1]
(a) Dependent variable: PROMINDBIOL
(b) Predictor: (Constant), zinc, arsenic, lead

3.4.3 For the regression model tested for 6 metals according to the objectives set, which are (As,Cd,Cr,Cu,Pb,Zn), it is explained that 95.5% that the averages of the indices Biological factors are related to the presence of heavy metals in the sediments according to the Canadian ECA (TEL), with respect to the quality of the waters of the micro-basins of the Perlamayo and Tacamache rivers in rainy season.

3.4.4 As we can see in Table V, the Durbin-Watson value is 3.011. Therefore, given the values of delimiting our rejection zone, we accept the alternative hypothesis. Likewise, the results of the analysis of variance (ANOVA),Table VI, of the regression model also indicate that it significantly improves the prediction of the independent variable when the value of F= 2.092. García [5], defined, through a multivariate analysis, determined that if there are significant differences ($p<0.05$) in the benthic macroinvertebrate community between the altitude ranges in which the sampling stations are located (spatial difference) and between the two study periods (temporary difference).

Table V Statistical analysis (simple regression in sediments (February).

Model	R	R squared	R square adjusted	Standard error of	Durbin-Watson

				estimate	
1	0.955	0.913[a]	0.477	0.706	3.011

Source: [1]
(a) Dependent variable: PROMINDBIOL
(b) Predictor: (Constant), zinc, arsenic, lead, cadmiun

Table VI ANOVA statistical analysis in sediments (July).

Model		Sum of squares	gl	Mean square	F	Sig
1	Regression	5.216	5	1.043	2.092	0.480[b]
	Residuo	0.499	1	0.499		
	Total	5.715	6			

Source: [1]
(a) Dependent variable: PROMINDBIOL
(b) Predictor: (Constant), zinc, arsenic, lead

IV Conclusions

The results of the physicochemical parameters show variations in each of the seven sampled points. Where points P3, P4 and P7 comply with DS No. 004-2017MINAM, with the exception of sampling stations P1 and P2, during the two seasons. Rainy and dry, presented acidic water conditions. At P5 during the dry season and P6 during the rainy season, they presented alkaline water characteristics. Likewise, at station P6 with respect to Dissolved Oxygen, during the dry season it was below below the limit. Hence, the sampling stations P1, P2, P5 and P6 did not comply with Category 3: Irrigation of Vegetables and Animal Drinking, according to Supreme Decree No. 004.2017-MINAM, conditions that seriously limit the development of macroinvertebrates.

The results obtained for heavy metals in sediments, in the eight sampling stations, were compared with the Canadian ECA TEL (Threshold Effect Level). This method considers seven comparison parameters, being the metals As, Cd, Cr, Hg, Cu , Pb and Zn. Due to the fact that, in Peru, there are no regulations for their comparison. It is concluded that the concentrations of heavy metals and their comparison do not comply with the Canadian RCT, (table 13). Also, verified with the statistical analysis where it explains that 95.5% (table 18) of the averages of the biotic indices are related to the presence of heavy metals. Finally, the concentration of heavy metals in sediments, with respect to the water quality of the Perlamayo and Tacamache rivers, is a great concern, being a limitation for the development of macroinvertebrates [12].

The ecological quality using EPT, BMWP/Bol, BMWP/Col, ABI and CERA indices in the seven sampling stations established in the study in the Perlamayo and Tacamache rivers in the district of Chugur, province of Hualgayoc, Cajamarca is of poor condition [13], [14].

According to the CERA protocol (Ecological Quality of High Andean Rivers) [5],[7], only the P-3 sampling station that corresponds to the Quencho ravine was cataloged as a reference point, where it showed the best environmental conditions during the entire season. conduct of the study. Finally, according to the evaluations using benthic macroinvertebrates, the use of the CERA index is recommended as it is the most appropriate for the evaluation of rivers in Peru. Which are above 3000 meters above sea level, where the dominant plant formations in the punas of the Andes, allow studying the structure of riparian vegetation and does not condition the structure of the macroinvertebrate community.

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