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Analysis of the water quality index of the Escalera river applying the ICA-PE methodology in the periods 2015-2018

Análisis del índice de calidad del agua del rio Escalera aplicando la metodología ICA- PE en los periodos 2015-2018

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ABSTRACT

The objective of the research was to apply the methodology for the determination of the ICA-PE water quality index in the Escalera river of the Huachocolpa district in the periods of 2015 and 2018, the samplings carried out were given 2 points (REsca1 and REsca2), For data collection, it was based on mathematical simulation, documentary analysis and registration, at the sampling points the concentrations of aluminum, arsenic, cadmium, copper, iron, manganese, lead and zinc were determined, these parameters exceeded the environmental quality standards. Water (ECA-AGUA) was later categorized according to the ICA-PE water quality index, of which for 2015 it was of good quality obtaining a value of 73.14 and for 2018 its quality decreased to regular reaching a value of 61.85 . The results obtained show that the quality of water is decreasing in its path that runs through the Escalera river, due to the different anthropogenic activities that take place around it, altering its quality and reducing its capacity for self-purification.

Keywords: *Water quality index, variation, physical-chemical parameters, inorganic parameters, microbiological parameters.*

RESUMEN

La investigación tuvo como objetivo aplicar la metodología para la determinación del Índice de calidad de agua ICA- PE en el rio Escalera del distrito de Huachocolpa en los periodos de 2015 y 2018, los muestreos realizados se dieron el 2 puntos (REsca1 y REsca2), para la recolección de datos se basó en la simulación matemática, análisis documental y fichaje, en los puntos de muestreo se determinaron las concentraciones de aluminio, arsénico, cadmio, cobre, hierro, manganeso, plomo y zinc estos parámetros superaron los estándares de calidad ambiental del agua (ECA-AGUA) posteriormente se categorizo según el índice de calidad de agua ICA-PE del cual para el año 2015 fue de calidad buena obteniendo un valor de 73.14 y para el año 2018 su calidad descendió a regular llegando al valor de 61.85. Los resultados obtenidos demuestran que la calidad de agua va disminuyendo en su trayectoria que recorre el rio Escalera esto a causa de las diferentes actividades antropogénicas que se desarrollan al alrededor de este alterando su calidad y reduciendo su capacidad de autodepuración.

Palabras clave: *Índice de calidad de agua, variación, parámetros físicos-químicos, parámetros inorgánicos, parámetros microbiológicos.*

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I. INTRODUCTION

Water is the component of nature of first necessity for living beings, essential for the balance and all life on the planet, considered as a key element for health and quality of life (Piqueras, 2015). The Earth, with its diverse and abundant forms of life, faces a serious water crisis in this twenty-first century(United Nations, 2003). Water quality can be compromised by the presence of infectious agents, toxic chemicals, or radiation(World Health Organization, 2017), thus causing water pollution, which is the alteration of the quality of water commonly generated by anthropic activity, making it inappropriate or dangerous for human consumption, industry, agriculture, fishing and recreational activities, as well as for animals domestic and natural life (Ramirez, 2014).

The mining industry is a fundamental productive activity for the macroeconomy of many countries; However, the negative and cumulative impact of the wrong management of its waste constitutes a serious problem for population health and the environment.(Roe deer, 2015), Over time it has been shown that this activity has caused serious environmental impacts due to the inadequate disposal of tailings, drainage of acidic waters and clearings, which are evacuated to the nearest river beds (Quecaño, 2018).

The contamination of water resources by mining is a problem that has been occurring in all surface water courses that are within the sphere of influence of mines in operation, closure or in abandonment both at the district, provincial or regional level. region that has resulted in the deterioration of water quality and the disappearance of hydrobiological species(Calla, 2010) and in recent years the rivers of Peru both on the coast and in the mountains have been contaminated as a result of the development of mining activity (Calla, 2010).

The alteration of the quality of the water is one of the most serious problems that the country suffers, since it creates an obstacle to be able to achieve an efficient and rational use of the resource, and consequently the supply is compromised both in quality and quantity, and therefore In connection with the health of people, livestock, agricultural activities and the conservation of the environment(National Water Authority, 2013).

Although it is true, the quality of its water changes naturally over time and its course, however, human activities irreversibly affect the physical, chemical and biological characteristics of the water (Guzman et al., 2011), due to these problems, water quality is considered as a variable that explains the degree of contamination that may exist in a body of water, this study is carried out through Environmental Quality Indicators (Jiménez and Galizia 2012). The Water Quality Index (ICA) basically consists of a more or less complex combination of a number of parameters, which serve as a measure of water quality. The index can be represented by a number, a range, a verbal description, a symbol, or a color. It can be used as a single frame of reference to communicate information on the quality of the affected environment and to assess the vulnerability or susceptibility of water to contamination. Currently it is widely used to know the quality of a water source and to prevent contamination through proposed solutions.(University of Pamplona, 2010).

The objective of this research is to evaluate the variation of the Water Quality Index, applying the methodology of the Peru Water Quality Index (ICA-PE), in the district of Huachocolpa, province of Huancavelica, during the period 2015 to 2018, With which it is sought to inform the population and the competent authorities of the results obtained so that they can make immediate decisions in the face of the possible deterioration of the water quality caused by the contamination of the mining activity and mining liabilities in the area under study.

In Peru, the evaluation of water quality is carried out by comparing the results of a set of physical, chemical and biological parameters with the values established in the ECA - Water according to the category of the corresponding surface water body; which determines its compliance or non-compliance, specifying only the critical parameters and their corresponding concentration. However, this evaluation is ambiguous when it comes to specifying or establishing the water quality level of the water resource, that is, if it has an excellent, good, fair, bad or terrible quality (National Water Authority, 2018); For this reason, the National Water Authority approved the Methodology of the Water Quality Index called ICA - PE, development of the procedure and application.

The application of this indicator with respect to quality has a single purpose to assess the quality of the water, it is subject to the comparison of the concentration of pollutants which will be related to environmental standards, in such a way the index reflects the number, frequency and magnitude by which the environmental standard for a group of specific variables is or is not reached in a given period (Yáñez, 2018); In other words, the application of this index is the simplest way to reflect how affected the water resource is; furthermore, its understanding and comprehension will be suitable for the general public. the frequency and magnitude by which the environmental standard for a group of specific variables is or is not reached in a given period (Yáñez, 2018); In other words, the application of this index is the simplest way to reflect how affected the water resource is; furthermore, its understanding and comprehension will be suitable for the general public. the frequency and magnitude by which the environmental standard for a group of specific variables is or is not reached in a given period (Yáñez, 2018); In other words, the application of this index is the simplest way to reflect how affected the water resource is; furthermore, its understanding and comprehension will be suitable for the general public.

II. MATERIALS AND METHODS

The research was of an applied type, explanatory level, the scientific, hypothetical-deductive method and the non-experimental, Longitudinal trend design were used (Hernández, 2014). The data collection and processing was carried out over a period of 4 years from 2015 to 2018 with the information from the database found in the virtual system

of the National Water Authority (ANA). For this, official information was collected from the database of the monitoring of surface sources carried out by the Local Water Administration of Huancavelica, these characteristics were first compared with the National Environmental Quality Standards (ECA) for Water, which for the present investigation corresponds to Category 3 Irrigation of Vegetables and Animal Drinks, Subsequently, the ICA-PE methodology was applied, which is based on the Canadian water quality index, in which it uses 3 factors that are the scope, frequency and amplitude (F1, F2 and F3) and in this way it was possible to verify how the water quality varies over time, for which use is made of 5 physical-chemical parameters, 10 inorganic parameters and 2 microbiological and parasitological parameters, making a total of 17 parameters, in which the concentration of each of They were compared with current regulations, in this case with Supreme Decree No. 004-2017-MINAM, which approves the Environmental Quality Standards (ECA) for Water. The instrument used was the data record sheet (Robledo, 2016).

Data processing and analysis techniques

For the processing and analysis of data on the concentration of the 17 parameters analyzed for water quality, the data were treated using descriptive statistics. Previously, the Shapiro Wilk normality test was carried out and finally the hypothesis test with the

Anova statistic with a significance of 5%, to evaluate the variation in water quality applying the ICA-PE methodology, and the Wilcoxon test with a significance of 5%, to analyze the concentration of the physical-chemical, inorganic and microbiological parameters in relation to the Environmental Quality Standards (ECA) for Agua del Río Escalera, in the district of Huachocolpa, province of Huancavelica, during the period 2015 -2018.

Application of Environmental Quality Standards - Water, for the Evaluation of Water Quality

Once the monitoring points were identified, the category assigned to the water body was verified according to Chief Resolution No. 202-2010-ANA and its amendments, in which it updates the classification of surface continental water bodies, the same one that locates the river Escalera within category 3-Irrigation of Vegetables and animal drinking, after which the monthly information was collected from the monitoring of water to the Escalera River for each year corresponding to the period 2015 - 2018 carried out by the ANA, data correspond to the following parameters:

- Chemical physical parameters: Chlorides, Conductivity, Biochemical Oxygen Demand (BOD5), Dissolved Oxygen (DO) and Hydrogen Potential (pH).
- Inorganic parameters: Aluminum, Arsenic, Boron, Cadmium, Copper, Iron, Manganese, Mercury, Lead and Zinc.
- Microbiological parameters: Thermotolerant Coliforms and Escherichi Coli Number.

Determination of the ICA - PE Water Quality Index

According to the National Water Authority (2018), once the historical data of each year was organized according to the time in which the water monitoring was carried out (dry season and wet season), the selection and registration was made in the files, The data corresponding to the results of parameters that have significance of affecting the quality of the water of the Escalera river, said results correspond to the comparison of each parameter with the ECAs.

Subsequently and according to the ICA-PE methodology, 3 factors were determined (F1 scope, F2 frequency, F3 amplitude), which were based on the previous comparison with the Environmental Quality Standards for water, Category 3: Irrigation of vegetables and animal drink. For the calculation process of the ICA-PE water quality index, it was carried out through the preparation of a Spreadsheet in Excel, which allowed to automate the entire process of calculating the mathematical formulas of the ICA-PE method:

- F1 - scope:

$$F1 = \frac{\text{Number of parameters that do not meet the ECAs water}}{\text{Total number of parameters to evaluate}} x100$$

- F2 - frequency:

$$F2 = \frac{\text{Number of parameters not met by ECAs water of the evaluated data}}{\text{Total number of data evaluated}} x10F20$$

Where:
Data = Monitoring results

- F3 - amplitude:

$$F3 = \left(\frac{\text{Normalized Sum of Surpluses}}{\text{Normalized Sum of Surpluses} + 1}\right) x100$$

Where the Normalized Sum of Surpluses (SNE):

$$SNE = \frac{\sum excedente}{\text{total data}}$$

Once the value of the factors (F1, F2, and F3) has been obtained, the Calculation of the Water Quality Index is carried out:

$$ICA - PE = 100 - \left(\frac{\sqrt{F1^2 + F2^2 + F3^2}}{3}\right)$$

Interpretation of the ICA-PE score

The For the development of the calculation of the water quality index, Microsoft Excel (spreadsheet) was used, where the data and mathematical formulas were entered to obtain the factors (F1, F2, and F3), finally obtaining the value of the water quality index, ICA - PE, the value of the index is presented as a dimensionless number between a range, which allows to establish scales in five ranges, which are levels of sensitivity that express and qualify the status of the quality of the water. water, such as Terrible, Bad, Fair, Good and Excellent (Table 1).

Table 1
Interpretation of the ICA-PE score.

ICA-PE	Classification	Description
90-100	Excellent	The quality of the water is protected with the absence of threats or damage. Conditions are very close to natural or desired levels.
75-89	Well	The quality of the water deviates a bit from the natural quality of the water. However, the desirable conditions may be with some threats or minor damage.
45-74	Regular	The quality of natural water is occasionally threatened or damaged. The quality of the water is often far from desirable values. Many of the uses need treatment.
30-44	Bad	Water quality does not meet quality objectives, conditions are often threatened or damaged. Many of the uses need treatment.
0-31	Appalling	Water quality does not meet quality objectives, it is almost always threatened or damaged. All uses need prior treatment.

Source: National Water Authority (2018)

III. RESULTS

The ICA - PE Water Quality Index during the months that covers the 2015-2018 period was very varied because it ranges from a quality indicator of 42 to 92, where it was determined that the ICA - PE in the last month of In 2016 it had the lowest value, reaching a bad level indicator, on the contrary, in March 2017 the highest ICA - PE was registered, which reached a good level according to the ICA - PE methodology established by the Authority. Local of the Water (Figure 1).

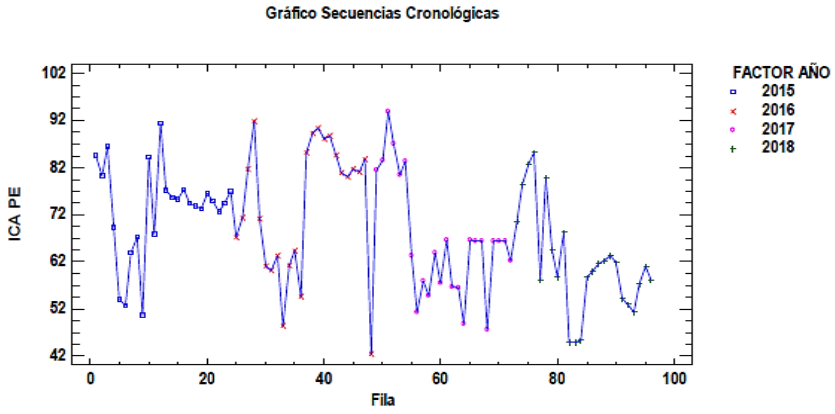

Figure 1
Chronological sequences with respect to the ICA - PE during the period 2015 – 2018.

According to the analysis of each sampling point (REsca1 and REsca2), it is obtained that the highest and lowest value in terms of quality is found in the monitoring point REsca2, where it reached high points during the year. 2016 and the lowest point in 2018 (Figure 2). It should be noted that at the REsca2 monitoring point in 2016 the ICA - PE was good, while in 2018 the water quality was decreasing since from a good Quality Index it became regular, this possibly due to the mining liabilities that are still in the area and to the mining activity that to date is operating.

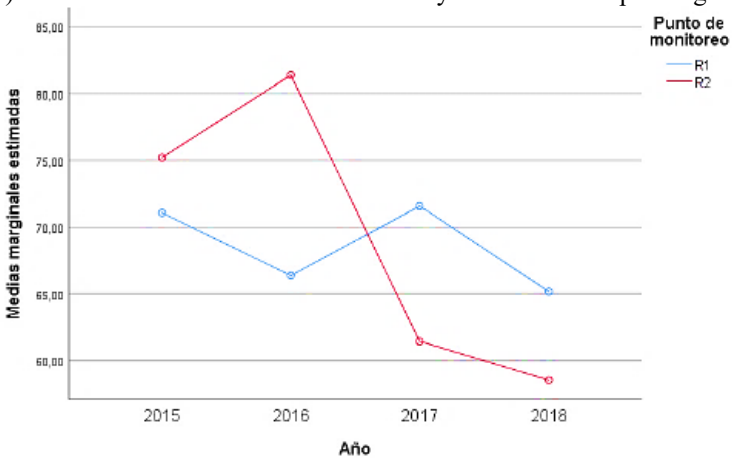

Figure 2
Marginal means of the ICA –Pe of the two monitoring points REsca1 and REsca2.

According to Figure 3, a general graph of both sampling points (REsca1 and REsca2) is shown, verifying that in the years 2015 to 2016 the ICA - PE had a positive trend, it should be noted that ICA-PE of the Escalera river during that period It was improving, however from 2016 to 2018 the trend line was negative, so in the last 3 years the quality of the water has deteriorated, possibly due to the mining liabilities that still exist as well as the mining activity that until the date is developing.

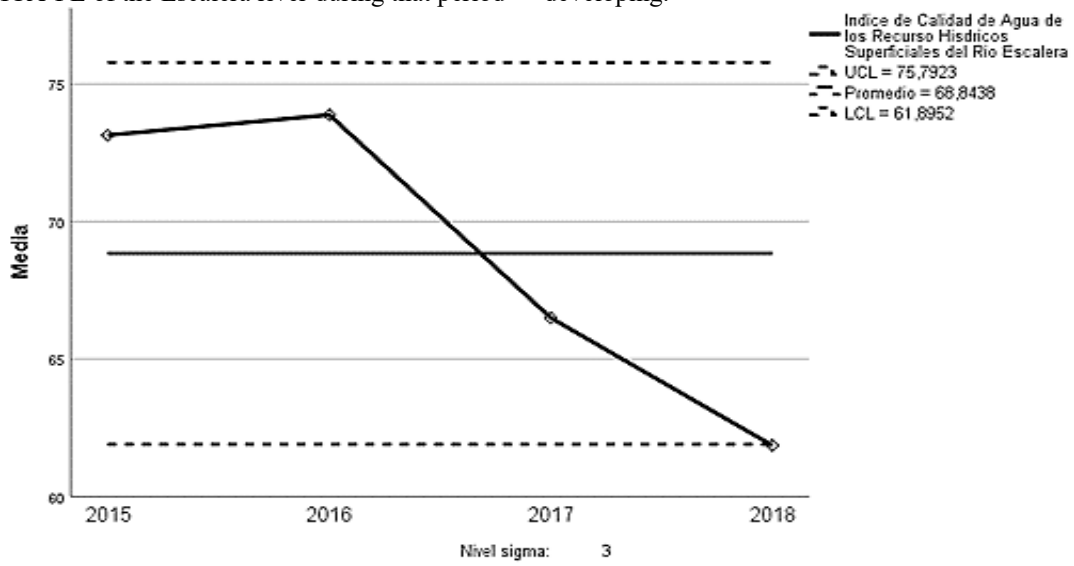

Figure 3
ICA - PE of the Escalera river and its variation in the period 2015 – 2018.

According to the indicators of the methodology applied by the ICA-Pe, the quality of the water in the Escalera river has been decreasing over the years, however, it has remained in the favorable range during the first three years under study, observing a great decrease in 2018 (Table 2).

Table 2
Summary of Results obtained and their variation throughout the period 2015 – 2018.

YEARS	ICA Pe -río Escalera	Indicator	Indicator
2015.	73.1417	65-79	Good
2016	73.8833	65-79	Good
2017.	66.4958	65-79	Good
2018	61.8542	45-64	Regular

IV. DISCUSSION OF THE RESULTS

Regarding the General Objective, the research has shown that there is a variation of the Water Quality Index, applying the ICA-PE methodology in the Escalera river during the 2015-2018 period, this due to the fact that on average the water quality for the year 2015 has a value of 73.14 with a good quality indicator and as the years go by in 2018 it presents a value of 61.85 with a regular quality indicator, therefore this variation is contrasted with the research work developed by Carrillo and Urgiles (2016), which determined the variation of the ICA from the analysis of 9 parameters established by the NSF method during the month of May until the month of November of the same year in the Mazar and Pindiling rivers, where they found significant variation, said variation tends to decrease from (good quality) to (medium quality).Likewise, Guzmán, et al.(2011), points out that, in general, the quality of the water of the San Pedro river throughout the state of Aguascalientes was variant, seriously declining in a deteriorated ICA according to the IGCA methodology, so it showed that it is almost always far from the adequate levels for use agricultural. On the other hand Chávez(2015)In his research, he obtained that the values of the parameters measured in the Cazones River reflected a water quality index of 63.94 units, which, according to the quality index according to the Brown-NSF methodology indicates Medium Quality; Likewise, significant differences were shown both in climatological seasons and between the sampled stations, obtaining higher indices in the northern season, followed by the dry season and finally the rainy season. The aforementioned results coincide with the results obtained in this research since there was a significant variation of the ICA - Pe, in the Escalera river, which varied from (good quality) to (regular quality) during the period 2015-2018.

Regarding the first specific objective: to analyze the concentration of the physical-chemical parameters in relation

to the Environmental Quality Standards (ECA) for Agua del Río Escalera, in the District of Huachocolpa, Province of Huancavelica, during the period 2015-2018. contrasts that in the research work carried out by Minaya (2017), with respect to dissolved oxygen they obtained values of 4.3 mg / L and 4.7 mg / L, so they do not meet environmental quality standards and in terms of BOD5 concentrations , pH, electrical conductivity I mention that they are within the ECAs for category 3; Likewise, Teves (2016) found that chloride concentrations in the second sampling campaign are close to 70 mg / L and are higher than in the first campaign, with values of 46 mg / L,environmental quality standards. On the other hand, Giovanny (2017), in his research determined that dissolved oxygen (DO) and chemical and biochemical oxygen demand (BOD5), recorded a result in BOD5 of 47.5 mg / l, a result obtained by the presence of organic matter coming from the sewage that probably leaches to the Subachoque river, increasing its organic load and favoring its proliferation.To this end, said results coincide with the results obtained in this research since none of the data recorded for chlorides exceeded the ECA-water for category 3 during the years 2015-2018 and with respect to the other physicochemical parameters, it was necessary to 96 data recorded most of the data do not exceed the ECA-water for category 3, for electrical conductivity only two concentrations of 2630 us / cm and 2960 us / cm were recorded that exceed the ECA-water, but most of the data do not exceed said regulations. Regarding the concentrations of BOD5 and dissolved oxygen, 16 data were obtained, 9 concentrations of BOD5 and dissolved oxygen, respectively, the aforementioned regulations.

Regarding the second specific objective: analyze the concentration of inorganic parameters in relation to the Environmental Quality Standards (ECA) for Water from the Escalera River, in the District of Huachocolpa, Province of Huancavelica, during the period 2015-2018, Luna (2019) indicates that the zinc parameter is the only parameter that is elevated with concentrations of 2.50 mg / L and 4.26 mg / L, this due to the washing of the soil and geology and / or the anthropogenic activities that occur in the area surrounding the Asana River; Other investigations such as that of Silva (2018), determined that in all seasons of the year, lead concentrations were found to be in excess of the ECA-Water values in categories 1A-2 and 3 for the Puyango River; In the same way, Flores (2016) identified that lead was the only parameter that exceeded the ECA-water for category 3 in the Rio Grande and, in general, aluminum with higher concentrations, followed by iron, manganese and zinc, while the parameters with the lowest total concentration were mercury, cadmium and arsenic, this in the monitoring stations close to where mining activities are carried out. Mosquera (2016) determined that the concentrations for mercury exceed the permissible value by the regulations (0.002 mg / l), oscillating between 0.5 - 34 µg / l approximately in the Chato river since in the vicinity of the monitoring stations the mining activity is greater (presence of dredgers and backhoes). On the other hand, Castillo and Medina (2014), determined that lead, cadmium, arsenic, iron, manganese, zinc and copper are found in high concentrations in all the monitoring stations and in both periods studied (wet and dry), this because they probably come from mining activity. Shut up(2010)After the analytical comparison of the results obtained in his research with the ECA-water for category III, he obtained that the elements that reflected the greatest environmental risk in the waters of the Rímac River in the San Mateo sector are cadmium, manganese, lead, iron and arsenic these because of the mining activity near this sector. In the present investigation, the majority of inorganic parameters that exceed the Environmental Quality Standards for Water were obtained, including aluminum, arsenic, cadmium, copper, iron 65, manganese, lead and zinc.

I determine that the total coliforms in the Asana River, is below that established in the environmental quality standards (ECA) for water, category 3, subcategory D-1 irrigation of vegetables, like Minaya (2017), obtained that the microbiological parameters do not exceed the environmental quality standards, which coincides with the data recorded in this research work, since the 96 data recorded during the year 2015-2018, no data exceeds said regulations for thermotolerant coliforms; Regarding the presence of numbers of escherichia coli, 12 data exceed the ECA-water for category 3 which was registered in 2015. It is observed in the results that the majority of microbiological parameters do not exceed the environmental quality standards of water for category 3.

V. CONCLUSIONS

There is significant variation of the Water Quality Index according to the ICA-Pe methodology during the period 2015 to 2018, said variation was decreasing through the years, according to the evaluation it was determined that from 2016 to 2018 the trend line was negative in this sense, in the last 3 years the quality of the water has deteriorated, possibly caused by the existing mining activity in the study area and the mining liabilities that still persist to date.

From the data obtained regarding the physicochemical, inorganic and microbiological parameters analyzed in the Escalera river during the years 2015 to 2018, it is concluded that the physicochemical and microbiological parameters do not exceed the Environmental Quality Standards for category 3 water, however the inorganic parameters that exceed the Environmental Quality Standards are: in the first place with the highest number of data exceeded in the samplings is zinc, followed by the parameters of lead, manganese, iron, copper, cadmium, arsenic and finally aluminum; In conclusion, these results did have an impact when determining the ICA-PE water quality index for each year.

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