EVALUATION OF THE GENERATED IMPACT BY THE CITY OF MONTERIA ABOUT WATER QUALITY IN THE SINU RIVER THROUGH BIOINDICATION AND ESTIMATION OF ICA-NSF, ICA-ROJAS AND ICAUCA INDEXES

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ABSTRACT

The Sinu River is the main watershed of the Department of Cordoba and the primary water source for Monteria City, in recent years, due to demographic growth, mining and industrial development, a lot of pressure has been made over the natural resources, and that is the main reason why it is necessary to make studies and researches that evaluate the impact of human activities around water quality. This research frames the evaluation of water quality by bio-indication and estimation of the ICA-NSF, ICA-ROJAS and ICAUCA indexes over 8 sampling through the river, from Jaraquiel to Garzones.

1. INTRODUCTION

In the city of Monteria, the Sinu River is a common element but of great importance for the patrimonial legacy of the city, since the municipality uses resources such as water, sediments and fish, in addition it is an item of ecological tourism of the city And around it are built important constructions for the continent since on its banks is the second longest linear park in Latin America. The water quality of the Sinu River can be in trouble because a significant part of the city's commerce is adjacent to the river, as well as surrounding buildings and communities living on the riverbank

The water quality problems of the Sinu River have increased due to the population growth along the riverbank, the economic development and the lack of permanent control of the water body, which is why there is a deterioration in the quality of the water Basin. At present the population that has a direct association with the river does not know the degree of disturbance that the quality of the water suffers due to the activities that develop around him. The collected information allowed to quantitatively determine the contamination, through the indexes of water quality and bio-indication by aquatic macroinvertebrates. For this, analyzes of physicochemical and microbiological parameters for the ICA-NSF, ICA-ROJAS and ICAUCA were also carried out. Used the BMWP method to estimate water quality from the identification of aquatic macroinvertebrate families, the latter taking into account the diversity of families indirectly, as well as being economical and quick to use, and has therefore been used in Different watersheds in the country, relating them to the sources of pollution

2. CONCEPTUAL FRAMEWORK

At present water is considered as an essential resource that requires the maximum attention of the States for being indispensable for the preservation of life and to be exposed to the deterioration, sometimes irreversible, caused by an irresponsible and intensive use of the resource. In the evaluation and evaluation of water quality, several methodologies have been used, including: comparison of the variables with current regulations; The ICA indicators where, from a group of measured variables, a value is generated that qualifies and qualifies the source, water quality is measured according to different parameters by which the degree of alteration of the natural qualities is quantified and It is classified for a particular use. The ICA has become a key instrument for transmitting information on the quality of water resources to competent authorities and the general public. The ICA is a composite indicator that integrates information of several parameters of water quality and presents different methodologies according to its author. In the case of our project we used the ICA-NSF (1970): The National Sanitation Foundation (NSF) created an ICA variable known as the NSF Water Quality Index, considered classifying characteristics that must present the source of collection for its destination for human consumption ". ICA-Rojas (1991): Rojas adapted the ICA-NSF to the specific conditions of the Cauca River, reducing the number of parameters that make it based on the analysis of their behavior in time and space and modifying the percentage weights Assigned to each parameter according to their level of importance in the evaluation of the Cauca river water quality. ICAUCA (2004): The ICA-Rojas was adapted to the environmental conditions of a section of the Cauca River. It was based on the river water quality behavior in this section and on the revision of different ICA's developed worldwide Of which the parameters, subscripts and equations to be considered in the same were defined. The ICA is a mathematical tool for quality and can be used to transform large amounts of water quality data into a single measurement scale

2.1. WATER QUALITY INDEX –ICA

The assessment of water quality can be understood as the assessment of its chemical, physical and biological nature in relation to natural quality, human effects and possible uses. In order to simplify the interpretation of their monitoring data, there are water quality indexes (ICA) and pollution indexes (ICO), which reduce a large number of parameters to a simple expression of easy interpretation among technicians, environmental managers and the general public. The main difference between them is in the form of evaluating the pollution processes and the number of variables taken into account in the formulation of the respective index. In simple terms, an ICA is a unique number that expresses the quality of the water resource by integrating the measurements of certain parameters of water quality and its use is increasingly popular to identify the trends integrated to the changes in the quality of the water. Water (towers, and others, 2009).

The general assessment of water quality has been the subject of multiple discussions regarding its application to the regulation of water resources in the world since it considers criteria that do not always guarantee the expected result for regions with different characteristics. As a consequence, many countries have developed studies and indicators to apply their own evaluation criteria, so that their applicability corresponds to their requirements and needs (towers, and others, 2009).

The ICA-NSF consists of eight physicochemical variables and a biotic element: fecal coliforms, the estimate of this index is oriented to the assessment of the quality of surface waters for human consumption worldwide. At the national and regional levels, different studies have been developed to develop or adapt ICA according to the environmental characteristics of some surface sources. Rojas adapted the ICA-NSF to the specific conditions of the Cauca River, reducing the number of parameters that make it based on the analysis of their behavior in time and space and modifying the percentage weights assigned to each parameter according to its level of importance in the assessment of water quality of the Cauca River (Torres, et al., 2009)

The CVC and the University of Valle adapted ICAUCA to the environmental conditions of the Cauca River in the Salvajina - La Virginia section, which was based on the river water quality behavior in this section and on the revision of different developed ICA at a global level from which parameters, subscripts and equations to be considered were defined. (Torres, and others, 2009).

The importance of AAIs is not only limited to the evaluation of the quality of surface sources. In the country, Decree 1575 of 2007 considers the ICA as one of the basic instruments to guarantee the quality of the water for consumption, regulating the Risk Index of the Quality of the Water for Human Consumption - IRCA that measures the degree of risk of occurrence Of diseases related to the non-compliance of the physical, chemical and microbiological characteristics of the water for human consumption once it has been subjected to different treatment processes that guarantee its treatment (Torres, and others, 2009).

Chart 1. Physicochemical and microbiological parameters according to ICAS: ICA-NSF, ICA Rojas and ICAUCA (towers, and others, 2009)

Country	**United States**	**Colombia**	
Index	ICA-NSF	ICA-Rojas	ICAUCA
Parameter			
DO	X	X	X
Ph	X	X	X
DBO	X	X	X
Nitrates	X		
Fecal Coliforms	X	X	X
Temperature	X		

Turbidity	X	X	X
Total Dissolved Solids	X	X	X
Suspended Solids			X
Color			X
Total Nitrogen			X
Phosphates	X		
Total Phosphorus			X

The calculation structure of the majority of the ICA is based on the normalization of the parameters that conform them according to their concentrations, for its later weighting according to its importance in the general perception of the water quality; Is calculated by integrating the weights of the parameters through different mathematical functions. To calculate the three indices we use the weighted geometric average in which the weights give importance to the scores and they are all weighted according to the importance of the weights and then multiplied

$$ICA = \sum C_i W_i \qquad \textit{Equation 1}$$

C_i: Quality of the ith parameter obtained from the respective quality chart, depending on its concentration or measurement
W_i: Weighted value corresponding to the ith parameter, attributed as a function of the importance of that parameter for the overall conformation of the quality, a number between 0 and 1

The weighting (ponderation) of each parameter has a lot to do with the importance of the intended uses and the incidence of each variable in the index. In the case of ICA applicable to surface waters it would seem that the higher weight should be given to the parameters OD, BOD, nitrates, suspended solids and total coliforms. In the case of ICA applicable to drinking water sources, N-NO3, color, arsenic and boron should also be weighed. Chart 2 shows the weights assigned to the parameters that make up the ICA, according to the degree of importance within each one (Torres, et al., 2009)

Chart 2. Relative weights assigned to the parameters that make up the ICAS: ICA-NSF, ICA Rojas and ICAUCA

Parameter	**Index**		
	ICA-NSF	ICA-Rojas	ICAUCA
DO	0,17	0,25	0,21
pH	0,11	0,17	0,08
DBO	0,11	0,15	0,15
Nitrates	0,10		
Fecal Coliforms	0,16	0,21	0,16
Temperature	0,10		

Turbidity	0,08	0,11	0,07
Total Dissolved Solids	0,07	0,11	0,07
Suspended Solids			0,05
Color			0,05
Total Nitrogen			0,08
Phosphates	0,10		
Total Phosphorus			0,08

Chart 3 shows the 5 water quality classification ranges which vary according to each index

Chart 3. Classification of ICAS: ICA-NSF, ICA Rojas and ICAUCA

Code	Physicochemical indexes of wáter quality					
	ICA NFS		ICA ROJAS		ICAUCA	
	Range	Classification	Range	Classification	Range	Classification
1	0-25	Very bad quality	0-20	Very bad quality	0-20	Very bad
2	26-50	Bad quality	21-35	Inadequate	21-35	Inadequate
3	51-70	Medium quality	36-50	Accepable	36-50	Acceptable
4	71-90	Good quality	51-80	Good	51-80	Good
5	91-100	Excellent quality	81-100	Óptimal	81-100	Óptimal

2.2. PHYLUM ARTROPODA.

Arthropods constitute the largest Phylum in the animal kingdom. This group is characterized by the presence of articulated appendages, exoskeleton composed of chitin and its segmentation, a feature strongly suggested by a common ancestor with the annelids. The Hexapoda Class contains more than 750,000 species, the morphology of which is composed mainly of three pairs of legs, wings embedded in the medial or thoracic region of the body, antennae and compound eyes (Barnes, 1996)

The success of insects is reflected in the large number of species and individuals and their adaptive radiation (Roldán, 2003). Although essentially terrestrial animals and virtually occupy all the niches of that environment, they have also colonized aquatic habitats and are only missing from the subtidal marine zone. This success can be attributed to several factors, although certainly the evolution of flight gave these animals a notable advantage over other groups of terrestrial invertebrates, which greatly favored dispersal, predator flight and access to food in addition to Favorable environmental conditions. Likewise, characteristics such as size, high reproduction rate, various eating habits, varied development patterns (metamorphosis) and defense mechanisms are strategies that make it one of the most ecologically adaptive groups (Barnes, 1996)

2.2.1. BIOLOGICAL INDEX BMWP (Biological Monitoring Working Party score)

The Biological Monitoring Working Party (BMWP) was established in England in 1970 as a simple and rapid method to assess water quality using macroinvertebrates as bioindicators. The reasons for this were basically economic and for the time required to invest. The method only requires reaching the family level and the data are qualitative (presence or absence). The score ranges from 1 to 10 according to the tolerance of the different groups to organic pollution. The most sensitive families such as Perlidae and Oligoneuriidae receive a score of 10; however, the most pollution-tolerant, for example, Tubificidae, receive a score of 1. The sum of all scores for all families provides the total BMWP score (Roldan, 2003).

According to Roldan, 2003, bioindication in Colombia dates back to the 1970s with the work of Roldán, et al. (1973), when for the first time a study of macroinvertebrate fauna was carried out as indicators of the degree of contamination Of the Medellín River. Later Matthias and Moreno (1983) carried out a physicochemical and biological study of the same river using macroinvertebrates as indicators of water quality. Bohórquez and Acuña, (1984) carried out the first studies for the sheet of Bogota. Roldán (1988) publicly the first guide for the identification of aquatic macroinvertebrates in the department of Antioquia, and then verified its application for most neotropical countries. Also in 1992 he published the book Fundamentals of Neotropical Limnology and later adapted the BMWP system to evaluate the quality of water in Colombia through the use of aquatic macroinvertebrates. Zúñiga de Cardoso (1997) made an adaptation of this methodology for some basins of the cauca valley. Reinoso (1998) conducted a study of the River Combeima in the department of Tolima. Afterwards, Zamora (1999) adapted the BMWP index for the evaluation of the quality of the epicontinental waters in Colombia, and finally, Roldán (2001) adopted the system for the Piedras Blancas basin in the department of Antioquia, see Chart 4.

Chart 4. Biological Water Quality Index – Index BMWP/Col (Roldan, 2003)

BMWP/Col	
FAMILIES	**SCORE**
Anomalopsychidae, Atriplectididae, Blepharoceridae, Calamoceratidae, Ptilodactylidae, Chordodidae, Gomphidae, Hidridae, Lampyridae, Lymnessiidae, Odontoceridae, Oligoneuriidae, Perlidae, Polythoridae, Psephenidae	10
Ampullariidae, Dytiscidae, Ephemeridae, Euthyplociidae, Gyrinidae, Hydrobiosidae, Leptophlebiidae, Philopotamidae, Polycentropodidae, Xiphocentronidae	9
Gerridae, Hebridae, Helicopsychidae, Hydrobiidae, Leptoceridae, Lestidae, Palaemonidae, Pleidae, Pseudothelpusidae, Saldidae, Simuliidae, Vellidae	8
Baetidae, Caenidae, Calopterygidae, enagrionidae, Corixidae, Dixidae, Dryopidae, Glossosomatidae, Hyalellidae, Hydroptilidae, Hydropsychidae, Leptohyphidae, Naucoridae, Notonectidae, Planariídae, Psychodidae, Scirtidae.	7
Aeshnidae, Ancylidae, Corydalidae, Elmidae, LibeJlulidae,	6

Limnichidae, Lutrochidae, Megapodagrionidae, Sialidae, Staphylinidae	
Belostomatidae, Gelastocoridae, Mesoveliidae, Nepidae, Planorbiidae, Pyralidae, Tabanidae, Thiar idea	5
Chrysomelidae, Stratiomyidae, Haliplidae, Empididae, Sphaeridae	4
Lymnaeidae, Hydrometridae, Noteridae, Dolichopudidae, Ceratopogonidae, Glossiphoniidae, Cyclobdellidae, Hydrophilidae, Physidae, Tipulidae	3
Culicidae, Chironomidae, Muscidae, Sciomyzidae, Syrphidae	2
Tubificidae	1

According to the BMWP / Col there are five kinds of water quality resulting from adding the score obtained by the families found in a given ecosystem. The total of the points are designated as BMWP / Col. Values. According to the score obtained in each situation, the different classes of water are rated, assigning each one a specific color, Table 5. This color is the one that is then used to mark the rivers and streams in the map of the studied region see table (RoldAn, 2003)

Chart 5. Biological Water Quality – Index BMWP/Col (Roldan, 2003)

CLASS	QUALITY	BMWP/Col	MEANING
I	GOOD	>150 101-120	Very clean to clean water
II	ACCEPTABLE	61-100	Lightly polluted water
III	DOUBTFUL	36-60	Medium poluted wáter
IV	CRITICAL	16-35	Very polluted water
V	VERY CRITICAL	<15	Strongly polluted wáter

3. METHODOLOGICAL DESIGN

3.1. STUDY AREA

The study area is comprised along the Sinu River, from the village of Jaraquiel to the village of Monzon in the city of Monteria, Cordoba-Colombia, with 8 sampling points, with the highest anthropic influence.

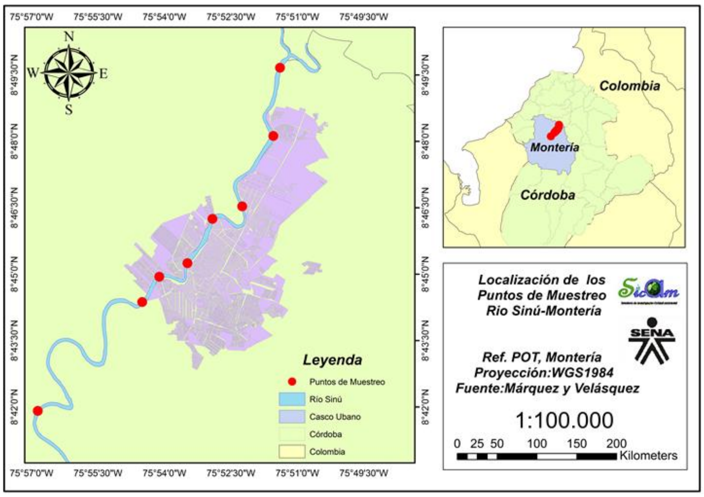


Image 1. Section comprised between the Corregimientos of Jaraquiel and Garzones in the Municipality of Montería, Córdoba Colombia

Chart 6. Geo-located sampling points

Sampling Points	Sampling Place	Geographic Coordinates	
		N	O
Point 1	Municipality Jaraquiel	8° 41’ 54.58’’	75° 56’ 51.47’’
Point 2	Income of Proactiva wáter treatment plant	8° 44’ 16.37’’	75° 54’ 39.98’’
Point 3	Between Rancho Grande and Caracoli neighborhoods	8° 44’ 56.49’’	75° 54’ 7.05’’
Point 4	24th street	8° 45’ 14.78’’	75° 53´28.76’’
Point 5	Sucre	8° 46’ 15.05’’	75° 52’ 54.91’’
Point 6	Northern Car Wash	8° 46’ 32.02’’	75° 52’ 14.53’’
Point 7	Mocari	8° 48’ 7.66’’	75° 51’ 34.43’’
Point 8	Garzones	8° 49’ 40.07’’	75° 51’ 23.54’’

3.2. METHODOLOGY

3.2.1. Diagnose

A field inspection was carried out by direct observation, where points of interest were selected from economic activities carried out in the vicinity of the sampling station. They served as a spatial standard for the collection of samples of aquatic macroinvertebrates and natural water. The documentary information was collected where the location of the point was registered with names related to nearby references, for each point geographic coordinates were registered with a Garmín GPS and in turn were taken as objectively verifiable evidence of the visit to the river system.

3.2.2. Field Phase

Five sampling campaigns were carried out, in which natural water and macroinvertebrates were sampled at the 8 selected points, every two months, following a sampling plan

6.2.3. Laboratory Phase

The water samples were analyzed for the determination of physicochemical parameters, following a rigorous chain of custody, with standardized analytical procedures that allowed to generate reliable results, analyzing the parameters:% dissolved oxygen saturation, faecal coliform NMP / 100ml, pH , Biochemical Oxygen Demand (BOD5), Nitrates, Phosphates, Deviation of equilibrium temperature, Turbidity, Dissolved Solids, Suspended Solids, Total Phosphorus, Color, Total Nitrogen. Samples of macroinvertebrates, previously preserved in ethyl alcohol, were also identified by means of taxonomic keys, following a rigorous examination of individuals to generate reliable family level identification results, with the use of stereoscope, Petri dishes and entomological tweezers.

3.2.4. Information Analysis

The ICA-NSF, ICA-Red and ICAUCA Indices were calculated from the results of the analysis of physicochemical parameters determined in the laboratory to water samples. In the case of biological samples the BMWP Index adapted for Colombia was estimated from the assessment of the identification of aquatic macroinvertebrates.

By means of the result of the two indices the quality of the water of the river was deduced. Using the software PrimerEV 5 for the estimation of ecological indexes and the similarity between sampling points.

4. RESULTS AND DISCUSSION

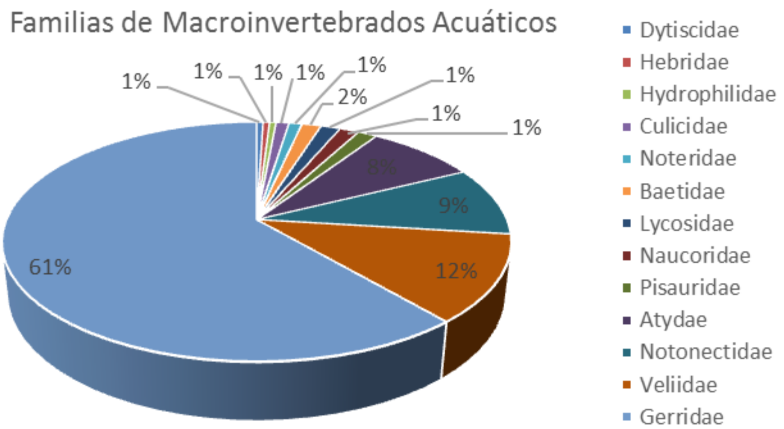
After all the classification analyzes of each sample collected at the selected stations in the section of the Sinu River bed, the following matrices were elaborated showing the taxonomic groups identified (Chart 7)

Chart 7. Families of aquatic macroinvertebrates identified in the section Jaraquiel-garzones.

Phylum	Class	Order	Family
Arthropoda	Insecta	Coleoptera	Dystiscidae
			Hydrophilidae
			Noteridae
			Noteridae
		Diptera	Culicidae
		Ephemeroptera	Baetidae
			Baetidae
		Hemiptera	Gerridae

				Naucoridae
				Veliidae
				Gerridae
				Notonectidae
				Veliidae
				Gerridae
				Veliidae
				Gerridae
				Veliidae
				Gerridae
				Hebridae
				Naucoridae
				Veliidae
				Gerridae
				Notonectidae

The family that presented the greatest abundance during the sampling was Gerridae with 125 individuals and the ones of smaller abundance were Dytiscidae, Hebridae, Hydrophilidae with one individual each, Graph 1.



Graph 1. Aquatic Macroinvertebrates Families

The BMWP Colombia index was calculated according to the families of macroinvertebrates identified and the sum of the values corresponding to each one, according to the results obtained for the points of Jaraquiel, Proactiva Bocatoma, Caracoli, Transito and Garzones Values obtained locate the water quality as CRITIC what corresponds to highly polluted waters, in the case of the Mocari point the water was categorized as DUDOSA corresponding to moderately contaminated Waters (Chart 8).

Chart 8. Index BMWP/Colombia for 6 sampling points

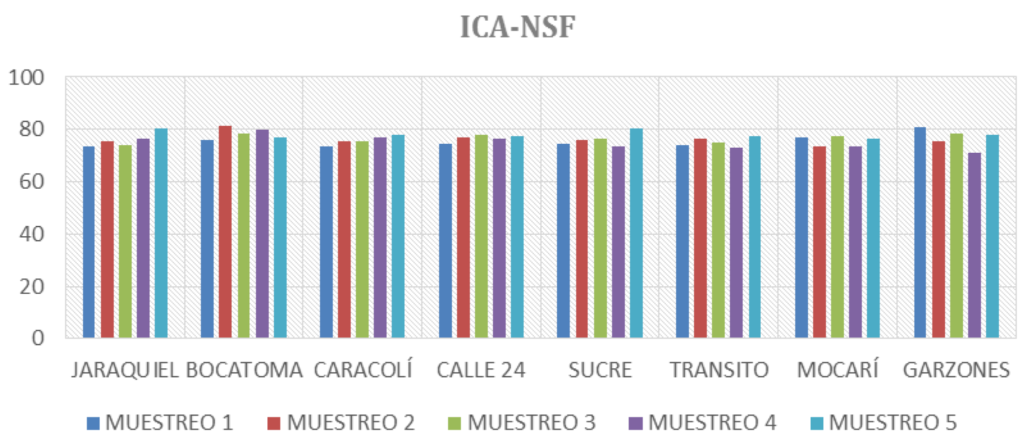
Sampling Point	Phylum	Class	Order	Family	Score	BMWP Colombia	Quality	Meaning
Jaraquiel	Arthropoda	Insecta	Hemiptera	Gerridae	8	23	CRITICAL	Very polluted water
				Naucoridae	7			
				Veliidae	8			
Bocatoma Proactiva	Arthropoda	Insecta	Coleoptera	Dystiscidae	9	32		
			Hemiptera	Gerridae	8			
				Notonectidae	7			
				Veliidae	8			
Caracolí	Arthropoda	Insecta	Hemiptera	Gerridae	8	16		
				Veliidae	8			
Transito	Arthropoda	Insecta	Hemiptera	Gerridae	8	16		
				Veliidae	8			
Mocarí	Arthropoda	Insecta	Coleoptera	Hydrophilidae	3	47	DOUBTFUL	MODERATELY POLLUTED WATER.
				Noteridae	4			
			Diptera	Culicidae	2			
			Ephemeroptera	Baetidae	7			
			Hemiptera	Gerridae	8			
				Hebridae	8			
				Naucoridae	7			
				Veliidae	8			
Garzones	Arthropoda	Insecta	Coleoptera	Noteridae	4	26	CRITICAL	Very polluted water
			Ephemeroptera	Baetidae	7			
			Hemiptera	Gerridae	8			
				Notonectidae	7			

Chart 9. ICA Results for every point.

SAMPLING	POINT	JARAQUIEL	INTAKE	CARACOLÍ	24TH STREET	SUCRE	TRANSITO	MOCARÍ	GARZONES
1	**ICA- NSF**	73,5	75,9	73,3	74,3	74,5	74,0	76,8	81,1
	ICA-ROJAS	73,8	70,8	71,5	71,4	72,8	73,6	77,1	79,2
	ICAUCA	64,2	66,5	64,1	66,6	63,2	63,6	67	74,1
2	**ICA- NSF**	75,3	81,2	75,7	76,9	75,8	76,3	73,7	75,4
	ICA-ROJAS	73,6	77,8	74,9	72,9	73,2	76,7	73,3	74,9
	ICAUCA	68,2	73	69,7	67,1	67,1	66,3	62,8	64,2
3	**ICA- NSF**	74,1	78,4	75,3	77,9	76,3	75,2	77,3	78,6
	ICA-ROJAS	77,4	76,8	75	72,2	75,9	75,5	76,6	76,9
	ICAUCA	71	71,8	69,4	66,5	69,2	69,6	67,6	67
4	**ICA- NSF**	76,5	79,8	76,7	76,3	73,6	73	73,6	71,1
	ICA-ROJAS	77,1	77,8	75,6	75,5	74,4	75,9	74,8	77,8
	ICAUCA	71,4	72,8	65,4	65	68,6	67,3	66,4	70,6
5	**ICA- NSF**	80,4	76,7	77,7	77,4	80,2	77,4	76,4	77,9
	ICA-ROJAS	77,6	78,7	74	73,3	77,5	76,5	73,7	77,7
	ICAUCA	69,2	73,6	68,5	69,2	68,6	67,5	65,5	66,2

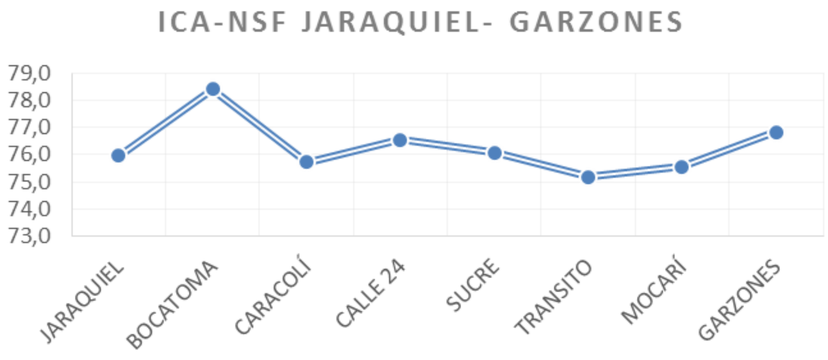
ICA- NSF

Chart 9 shows the consolidation of the five samples taken and the determination of the physico-chemical parameters to the water samples taken in the field, according to these results of the estimation of the water quality index ICA-NSF and the results Graph 2 was obtained.
According to the estimation of the ICA-NSF index for each sampling performed in the Rio Sinu, an average value of 76.3 is generally shown for each sampling point, showing its highest value at sampling1, sampling point Garzones with one Value of 81.1 and the lowest value was obtained for sampling 4, sampling point Garzones with a value of 71.1 as can be seen in Figure 2



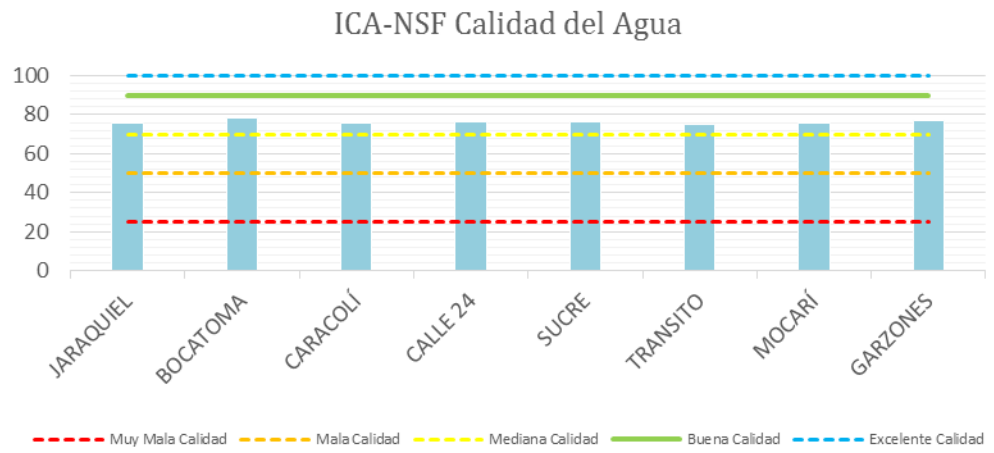
Graph 2. Results of the ICA-NSF Index for the eight sampling points.

In general, the estimated ICA-NSF index for the Jaraquiel-Garzones section had its highest value for the point BOCATOMA, registering a value of 78.4 and the lowest value point was TRANSITO with 75, 2 Graph 3.



Graph 3. Results of the ICA-NSF Index for the section of the sampled river.

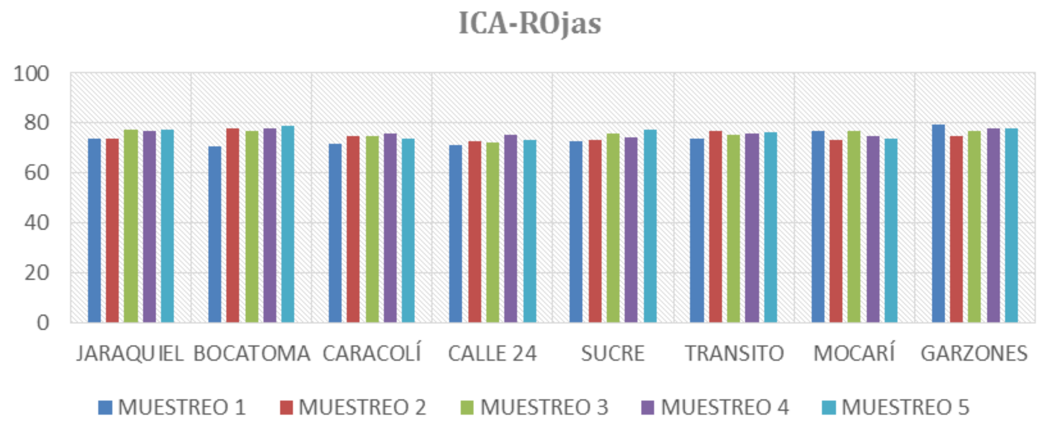
According to the value obtained by the ICA-NSF index of the Jaraquiel-Garzones section, the water quality of the Sinu River is in the 71-90 range, which classifies it as GOOD QUALITY Graph 4.



Graph 4. Water quality of the Jaraquiel-Garzones section Index ICA-NSF

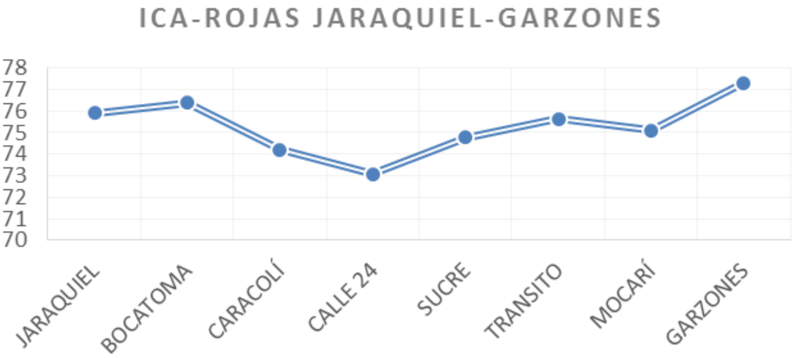
ICA-ROJAS

According to the estimation of the ICA-Rojas index for each sampling performed in the Rio Sinú, an average value of 75.3 is usually shown for each sampling point, showing its highest value at sampling1, sampling point Garzones with one Value of 79.2 and the lowest value was obtained for the same sampling at the sampling point Bocatoma with a value of 70.8 as can be seen in Figure 5.



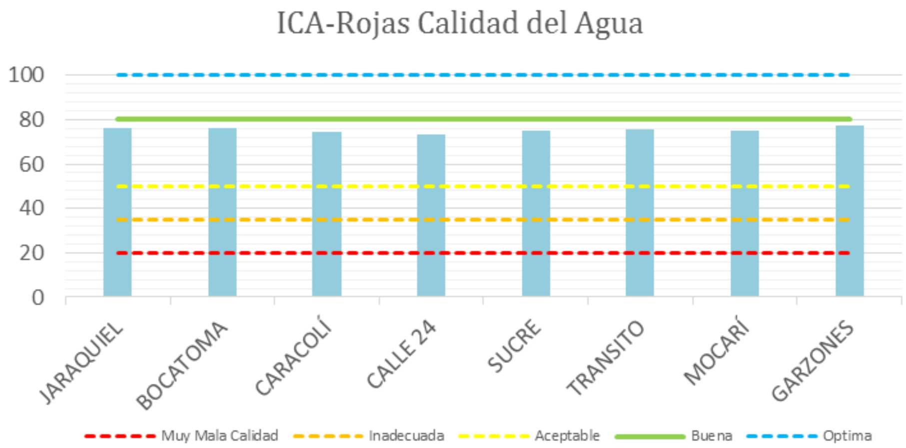
Graph 5. Results of the ICA-Rojas Index for the eight sampling points.

In general, the estimated ICA-Rojas index for the Jaraquiel-Garzones section had its highest value for Garzones, registering a value of 77.3 and the lowest value point was 24th street with 73.06 Graph 6



Graph 6. Results of the ICA-Rojas Index for the section of the sampled river.

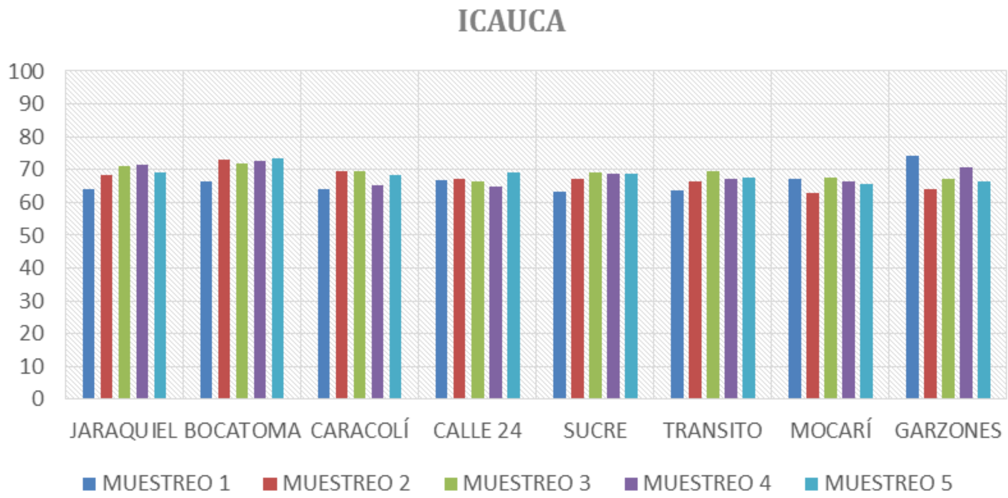
According to the value obtained by the ICA-Rojas index of the Jaraquiel-Garzones section, the water quality of the Sinú River is in the 51-80 range, which classifies the water quality of the Sinu River as BUENA Graph 7.



Graph 7. Water quality of the Jaraquiel-Garzones section Index ICA-Rojas

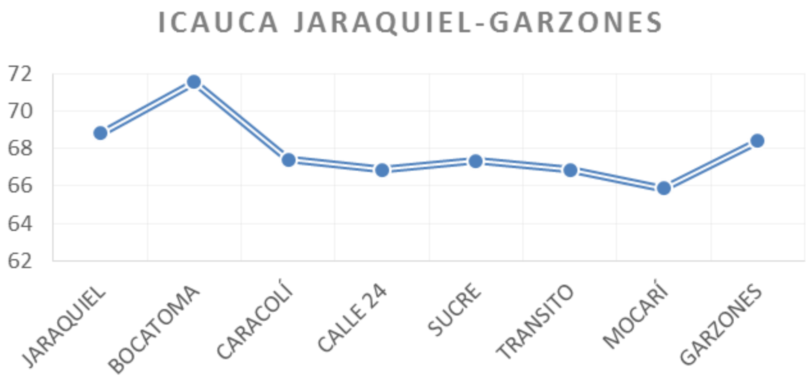
ICAUCA

According to the estimation of the ICAUCA index for each sampling performed in the Sinu River, an average value of 67.89 is usually shown for each sampling point, showing its highest value at sampling1, sampling point Garzones with a value of 74.1 and the lowest value was obtained for sampling 2 at the sampling point Mocarí with a value of 62.8 as can be seen in Figure 8



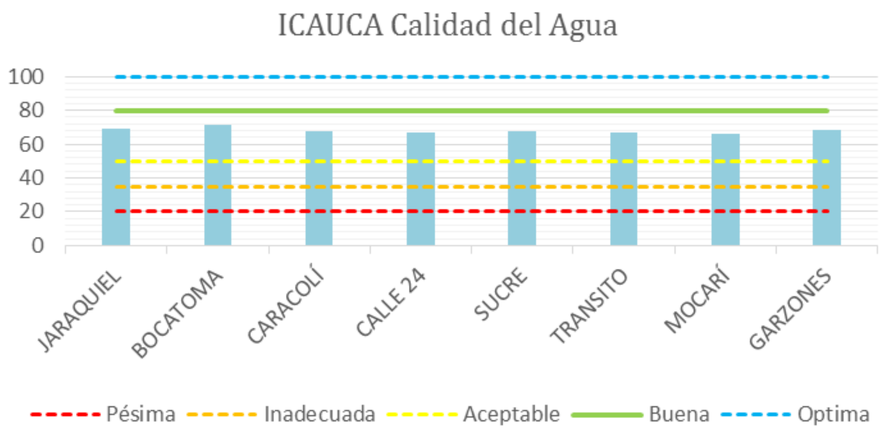
Graph 8. Results of the ICAUCA Index for the eight sampling points.

In general, the estimated ICAUCA index for the Jaraquiel-Garzones section had its highest value for the Bocatoma point, registering a value of 71.54 and the lowest value point was Mocarí with 65.86 Graph 9.



Graph 9. Results of the ICA-Rojas Index for the section of the sampled river.

According to the value obtained by the ICAUCA index of the Jaraquiel-Garzones section, the water quality of the Sinu River is in the 51-80 range which classifies the water quality of the Sinu River as BUENA Graph 10.



Graph 10. Water quality of the Jaraquiel-Garzones section Index ICAUCA

The clustering range for the sampling points was between 98.0 and 100, showing a very homogeneous group Image 2.

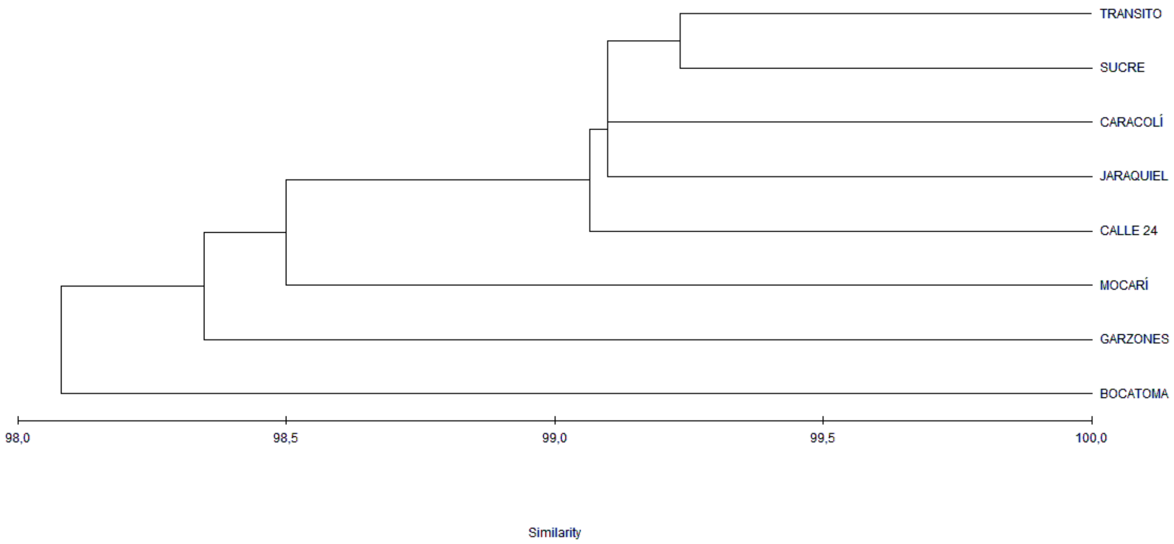


Image 2. Dendogram for the eight sampling points in the Jaraquiel-Garzones section.

5. CONCLUSION

From the average behavior of the evaluated ICA, it is observed that according to the ICA-NSF the Sinu River presents good quality at all the sampling points. The ICA-Rojas and ICAUCA indices show a trend similar to that of the ICA-NSF classifying the water quality as good, however, we observed that the middle points, where the river is being more impacted by the various discharges it receives from the Anthropic activities among which the discharges of domestic wastewater and sand mining and gravel are highlighted, the value of the indices tend to decrease their value a little. In general, the evaluated ICA reflects a good quality of the water of the river, especially in the points of Jaraquiel and Bocatoma that are located before the area of influence of the city of Montería and therefore less prone to be contaminated.

In the case of the BMWP Colombia index, a total of 13 families were identified, of which the most abundant during the sampling was Gerridae and those of smaller abundance were Dytiscidae, Hebridae, Hydrophilidae, also according to the obtained results it was that for the Points of Jaraquiel, Proactiva Bocatoma, Caracolí, Transito and Garzones the values obtained locate the quality of the water as CRITIC what corresponds to highly polluted waters, in the case of Mocarí the water was categorized as DUDOSA corresponding to moderately contaminated Waters.

Given the importance of the Sinu River and its high use as a source of supply for domestic, industrial and agricultural consumption by a large number of municipalities in Cordoba, it is important to consider plans for environmental education and adequate management of water resources since, while it is true The water quality according to the evaluated ICA is good, it is better to prevent than to remedy, so it is very important to implement environmental policies that favor the preservation and care of the Sinú River in the Jaraquiel-Garzones section, especially in the areas Where activities of sand extraction, gravel and where there are settlements of houses that do not have the basic sanitation services since these activities are those that have the greatest impact on the quality of the water. In addition, it is worth considering the development or adaptation of an index that involves parameters representative for the region on the presence of substances that cause health risk in this source, such as pesticides, fertilizers, heavy metals, among others, for the purpose To have a specific index for the river Sinu that allows to estimate the variation in the time and space of the parameters that compose it and the comparison of these with the current regulations, allowing a more specific and integral evaluation of the river.