Water quality in the lower section of Córdoba River (Magdalena, Colombia), using the ICA-NSF

Calidad del agua de la parte baja del río Córdoba (Magdalena, Colombia), usando el ICA-NSF

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Received: 18 April 2018 - Accepted: 23 August 2018

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Key words:

parameter physicochemical; water quality index; water resource; Neotropical river

Abstract

The evaluation of the water quality of fluvial sources through the analysis of physical, chemical and microbiological variables is considered as a tool that allows to know the status of contamination. One of the forms to evaluate these systems is through the integration of environmental variables in indexes as the ICA-NSF. Therefore, the objective of this study was to evaluate the physicochemical quality of the lower part of the Córdoba River through the ICA-NSF index and analyze the most common pesticides. Six sampling stations were defined, in each station, physical, chemical and microbiological parameters were measured. In addition, the level of concentration of the main pollutants was determined, considering the impact they cause on the river and the water quality was established through the water quality index (ICA-NSF) during the dry and rainy periods between the 2010 and 2011. The ICA-NSF varied between 52.6 during the rains in the "Muelle carbonífero" and 72.4 in the dry period in "Paso de los anillos". That indicated that the water quality was classified between regular and good, respectively. From the evaluated variables, the fecal coliforms showed high values in the six stations (between 2974 and 4940 NMP/100 mL), records that exceed the limits accepted for human consumption and the protection of flora and fauna by the Colombian legislation. The results showed a temporal variation (between climatic periods) and a high spatial uniformity. Any samples showed presence of organochlorine pesticides. The results showed that the temporal variation (rainy vs. dry seasons) was the best descriptor to reflect the water quality of the lower part of the Cordoba River.

Palabras clave:

parámetros fisicoquímicos; índice de calidad del agua; recurso hídrico; río Neotropical

Resumen

La evaluación de la calidad del agua de fuentes fluviales a través del análisis de variables físicas, químicas y microbiológicas es considerada como una herramienta que permite conocer su estado de contaminación. Una de las formas de evaluar estos sistemas es a través de la integración de variables ambientales mediante índices como el ICA-NSF. Por tanto, el objetivo de este trabajo fue evaluar la calidad fisicoquímica de las aguas del río Córdoba en su parte baja a través del índice ICA-NSF y analizar los plaguicidas organoclorados más comunes. Se definieron seis sitios de muestreo, en cada uno de estos se midieron parámetros físicos, químicos y microbiológicos. Además, se determinó el nivel de concentración de los principales contaminantes, considerando el impacto que causan en el río y se estableció la calidad del agua durante los periodos de sequías y lluvias entre el 2010 y el 2011. El ICA-NSF varió entre 52,6 durante las lluvias en "Muelle carbonífero" y 72,4 en el periodo seco en "Paso de los anillos". Lo anterior indica que la calidad del agua categorizó entre regular y buena, respectivamente. De las variables evaluadas, los coliformes fecales mostraron altos valores en los seis sitios (entre 2974 y 4940 NMP/100 mL), registros que sobrepasaron los límites permisibles para el consumo humano y la protección de flora y la fauna por la legislación colombiana. Los resultados mostraron una variación temporal (entre periodos climáticos) y una alta uniformidad espacial del río en los sitios de muestreo. En ninguno de los muestreos se encontraron residuos de plaguicidas organoclorados. Los resultados evidenciaron que la variación temporal (periodos de lluvias vs. sequías) reflejó de mejor manera los cambios en la calidad del agua del río Córdoba en su parte baja.

DOI: http://dx.doi.org/10.21676/23897864.2510

julio - diciembre de 2018

Introduction

Water is World Heritage, as an element of nature and as an indispensable resource for economic-productive activities (Parra, 2009). The use and management of water sources is a challenge for institutions, authorities, social groups and other entities responsible for the conservation of water quality in various natural systems. This is why it is essential to know the dynamics of environmental variables that can change the normal conditions of the system, such as the physical and chemical quality that can affect health (OMS, 2006; Díaz *et al.*, 2018). From a microbiological point of view, the quality of water in natural streams and distribution networks can change rapidly in space and time (Torres *et al.*, 2008). However, a significant alteration of the microbiology of the system can negatively impact the biota and the sanitary quality of the water (Camacho *et al.*, 2009; Castro *et al.*, 2014). Coliforms are abundant and almost exclusive of fecal matter, the characteristics of survival and the ability to multiply outside the intestine are also observed in drinking water, so it is commonly used as an indicator of fecal contamination in water; the higher the number of coliforms in water, the higher the probability of being in front of a recent corruption (Camacho *et al.*, 2009).

The chemical composition of a river's water is determined by several factors such as precipitation, geology, the solubility of rocks or materials, terrestrial vegetation, evaporation processes, biological processes and pollution or discharges of human origin that are in the basin (Toro *et al.*, 2002). Therefore, the evaluation of water quality is usually done using appropriate analytical techniques for each case. In this way, the results of these determinations will be representative (Barrenechea, 2004; Torres *et al.*, 2009). In order to facilitate the interpretation of chemical, physical and biological data, more and more environmental agencies, universities and institutes turn to water quality and contamination indexes (ICA and ICO), which through mathematical expression, which represents all the evaluated parameters allow the evaluation of the water resource (Ball and Church, 1980; Samboni-Ruíz *et al.*, 2007). In Colombia, some works have been carried out that have applied ICA in Andean rivers. Of these, those of Behar *et al.* (1997), Jiménez and Vélez. (2006), Montoya *et al.* (2011), Forero-Céspedes *et al.* (2013), Bustamante *et al.* (2014) and Valverde-Solís *et al.* (2015). In the Magdalena Department, only one work is registered in which they evaluate the physical and chemical quality of water in rivers such as the Manzanares (Romero *et al.*, 2011).

The quality of water can be used to make a diagnosis, since it is a process of total evaluation of the physical, chemical and biological nature of water; in relation to natural quality, human effects and intentional uses, particularly those that may affect human health, and that of aquatic systems (Chapman, 1996). The evaluation of the quality of water resources is usually done through studies that incorporate spatial and temporal variables, the first variable is usually done through an altitudinal gradient or considerable gradual changes in an ecosystem, by selecting an area representative of the object of study. While in the temporal evaluation in tropical ecosystems, the contrast of the climatic periods is indispensable, because they contribute in a significant way to the biological and environmental structure of the ecosystems, which affects the interpretation of the results that can be obtained (Roldán and Ramírez, 2008; Zúñiga and Cardona, 2009).

The use of pesticides to combat plant diseases includes organochlorine compounds, such as DDT and Aldin, whose action may take close to twenty years. In water, water is detected as a component of pollution, little used in much of the world. During the Stockholm Convention on Persistent Organic Pollutants (POPs) in May 2001, the elimination of these components was approved. In principle, pesticides DDT, aldrin, dieldrin, endrin, heptachlor, methoxychlor, toxaphene, endosulfan, and hexachlorobenzene (BHC) and other chlorinated compounds such as polychlorinated biphenyls (PCBs), dioxins and furans are identified as POPs. In Colombia, the use and sale of organochlorine insecticides in the cultivation of tobacco and coffee were banned through Resolution 447 of December 6, 1974, and 209 of May 12, 1978, respectively, issued by the Ministry of Agriculture.

The objective of this work was to evaluate the quality of water in the lower part of the Córdoba River, from the analysis of physical and chemical variables, and biological (total and fecal coliforms), in addition to the integration of the water quality index ICA- NSF. It is expected that the water reflects a better quality during the rainy periods because the precipitations act as diluents of the pollutants. On the other hand, during periods of drought the reduction of the flow favors the concentration of said pollutants and with it the reflection of the worst water quality conditions.

Materials and methods

Area of study

The Córdoba river basin has an area of 125 km^2 (Pro-Sierra, 1991). It is born in the western sector of the Serrania de San Lorenzo of the Sierra Nevada de Santa Marta (SNSM) at an approximate altitude of 1900 m. The river flows in its upper and middle course through a narrow valley in the shape of a "V." In its lower part, it advances through a narrow strip of land about 4 km until it empties into the Caribbean Sea (sector La Punta de Córdoba) 2.5 km north of the municipality of Ciénaga (Cadavid, 1985). The average monthly multiannual temperature is 28 ° C (Minambiente, 2005); The minimum average monthly flow in March is 1.60 m^3/s, and in October it is 12.53 m^3/s. During 2009 the average multi-year precipitation of the municipality of Ciénaga reached the value of 731.3 mm. The climate of the basin is characterized by having a water deficit for almost three months of the year (CORFAS, 1990).

The Córdoba river basin is considered one of the most important water sources of the Magdalena Department, because its waters are used for agriculture, fishing, tourism and, mainly, the consumption of the inhabitants of the municipality of Ciénaga and other neighboring towns (CODECI, 1996). Activities such as agriculture and tourism continually generate discharges of agrochemical waste (fertilizers and pesticides), fats, oils, detergents, plant residues, animal and human excretions that reach the river through several runoff routes (CODECI, 1996), which they end up negatively affecting the quality of the river's water.

Collection and processing of samples

In each of the six sampling sites, four campaigns were carried out, covering the periods of drought (08/11/2011 and 03/20/2012) and rains (12/10/2010 and 11/10/2011). All the sites were georeferenced, described and nominated according to their location (table 1). A straight section of approximately 100 m with uniform water flow was selected in each place where some physical and chemical variables such as pH, conductivity, dissolved oxygen, and temperature were measured by using a WTW 350i/set 2F40 multi-parameter equipment -114BOE Flow rates were measured with the help of a floating object (Hudson, 1997). Additionally, in each site, three water samples were taken, which were refrigerated in the field at 4 ° C and transported to the Water Quality laboratory of the Universidad del Magdalena for analysis.

The determination of organochlorine water pesticides was performed in a gas chromatograph (GC) HP 6890 Series PLUS, coupled to an electron capture detector (ECD). The column used in the DB-5 5% - phenol-poly (methylsiloxane) analysis, 30 m x 0.25 nm x 0.25 µm. The injection was done in splitless mode employing the solid extraction technique - liquid with hexane-acetone for sediments, and solid extraction - liquid with acetonitrile at room temperature and agitation -. The determination of total and fecal coliforms was performed using the standard method of NMP in multiple tubes (APHA, 1998). The estimation of the nitrates was made by the reduction method with Cd-Cu/colorimetry. The nitrites were evaluated with the application of Sulfanilamide/colorimetry, and the evaluation of phosphorus was applied to the ascorbic acid method (Murphy and Riley, 1962).

The Water Quality Index (WQI) of the National Sanitation Foundation - NSF of the United States was calculated by assigning specific weights defined by Brown *et al.* (1970) and using the multiplicative weighted function (WQIm) as follows:

$$ICA_m = \prod_{i=l}^{9}(Sub_i^{w_i})$$

Where wi: weight assigned to each parameter weighted between 0 and 1. Subi: subscript of parameter i. The Subi were found using the operating curves for the parameters established according to the procedure designed by Brown *et al.* (1970). The variables selected for the WQI were: fecal coliforms, pH, BOD5 nitrates, phosphates, temperature, turbidity, dissolved solids, and dissolved oxygen.

This index considers the water quality categories with their corresponding score as follows: Very Bad with values between 0 and 25; Bad between 26 and 50; Average between 51 and 70; Good between 71 and 90 and Excellent between 91 and 100.

Analysis of data

Dispersion graphs were made to know the trend of the environmental variables along the localities for each sampling. The WQI-NSF was calculated following the recommendations of Brown *et al.* (1970), to know the water quality in the sites and during the samplings. Finally, an nMDS, spatial scaling analysis was carried out between the sampling dates to know the association of environmental variables during climatic periods (drought and rainfall). This analysis was carried out in the R program (R Development Core Team, 2002).

Table 1. Description of the sampling sites of the lower part of the Córdoba River.

Localitie	Name of the localities	Altitude (m)	Coordinates (UTM)	Localitie Description
1	Paso de los anillos	40	11°01'22.9"N 74°12'21.6"W	The dumping of agrochemicals by runoff was observed. It is frequented by residents of the sector and domestic animals, and by tourists during the weekends.
2	Puente Córdoba	27	11°01'46.5"N 74°12'14.4"W	There are vegetable and fruit crops, mainly: lemon, mango, zapote guava, cassava, and corn. There is a high number of residents near the river. Discharges of construction waste were observed. On the site, they frequented domestic and wild animals. Agrochemicals are also discharged through runoff routes.
3	Finca la India	20	11°02'04.8"N 74°13'08.5"W	It presented fragmented vegetation dominated by shrubs and small plants, located on the banks. Irrigation water discharge was observed. The bed of the river presented solid material and sediments that are intensively removed and extracted.
4	Finca el Confite	10	11°02'11.4"N 74°14'17.5"W	Banana plantations predominated in which agrochemicals were applied. The bed of the river presented solid material and sediments. Frequent domestic discharges from washing and bathing of farmers and visitors were observed.
5	Muelle carbonífero	7	11°02'23.3"N 74°14'23.9"W	The washing of clothes, animals, and vehicles was observed on the site; besides, the dumping of agrochemicals, the bath of farm workers and the charcoal quay installed near the sampling site.
6	Desembocadura	3	11°02'29.3"N 74°14'11.0"W	It is a sector very close to the mouth of the river, the rocky material is smaller than those found in the other sectors, and the vegetable and animal residues contained in the water system are notorious.

Results

Physical, chemical and microbiological variables

Site one showed the highest flow (14 m^3/s) during the rainy periods, while in the periods of drought the average flow was 3.1 m^3/s. Very high values were observed in the BOD during the first rainy period (10.75 to 17.56 mg/L), compared to the second period (3.12 mg/L to 9.88 mg/L), similar tendency to that found during periods of drought (figure 1a). The greatest variation in the records of dissolved oxygen in the water was observed in the rainy periods, which were between 5.5 and 8.2 mg/L, while in the dry periods it was lower (4.11 and 6.51). mg/L) (figure 1b). The pH values were higher in the first rainy period (figure 1c). While the temperature showed a spatial tendency, in such a way that the sites one, two and three had greater variability; On the other hand, sites four, five and six were very similar (figure 1d).

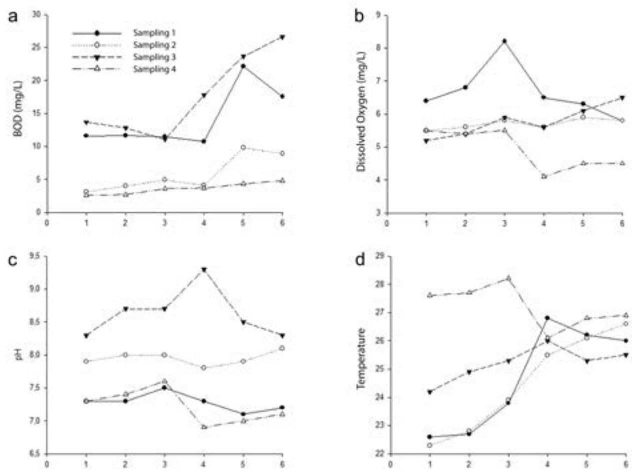

Figure 1. Spatial and temporal variation of a) BOD, b) dissolved oxygen, c) pH and d) temperature in the Córdoba River. The numbers indicate the sampling localities listed in table 1.

Concerning nutrients, in site six the highest nitrate values (0.90 mg/L) were presented in the first rainy period, and the lowest (0.39 mg/L) in the second dry period (figure 2a). Regarding nitrites, in the first rainy period a range of 0.05 to 0.11 mg/L NO_2 was found, the second dry period showed little variation (0.12 and 0.23 mg/L NO_2), The second rainy period was between 0.08 to 0.17 mg/L NO_2 and the second dry period showed the most significant variation (from 0.009 to 0.21 mg/L NO_2). The values of total coliforms (figure 2b) showed that the first rainy period included values between 855 - 4750 NMP/100 mL and the second between 845 - 4560 NMP/100 mL. The first period ranged between 3895 - 5035 NMP/100 mL, and in the second result, it was between 4028 - 8398 NMP/100 mL (figure 2c and 2d). The pesticide analysis did not show detectable levels of organochlorines above the minimum level of the method used (< 0.1 mg/L), which include the following: lindane, heptachlor, aldrin, heptachlor epoxide, trans chlordane, Endosulfan I, cis-chlordane, Dieldrin, 4.4-DDE, Endrin, Endosulfan II, 4.4DDD, Endosulfan Sulfate, 4.4 DDT and Endrin Ketone (Annex 1).

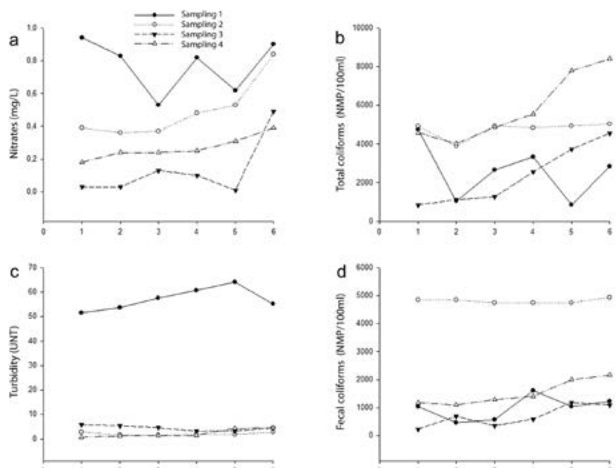

Figure 2. Spatial and temporal variation of a) nitrates, b) total coliforms, c) turbidity and d) fecal coliforms in the Córdoba River. The numbers indicate the sampling sites listed in table 1.

The nMDS analysis showed that the environmental variables valued in the lower part of the Córdoba River registered a behavior shaped by the climatic periods and not by the location of the sites (figure 3). However, each sample was grouped independently, and this indicates that the environmental conditions during each sampling were particular and that the second period of drought presented the highest values in nutrients and coliforms, a fact that placed it in the nMDS distant from the other samplings.

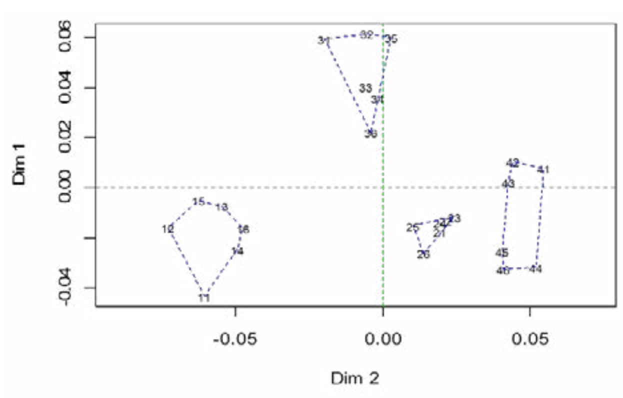

Figure 3. Management analysis by nMDS of the study localities, according to the climatic periods sampled in the lower part of the Córdoba River.

WQI-NSF

The quality of the water in all the localities, during both climatic periods, presented an WQI-NSF categorized as Regular, with the exception of the sites from one to four during the sampling carried out on March 20, 2012, where water quality was categorized as Good The values of the ICA-NSF were higher during the period of drought, which ranged between 60.3 and 72.4. While during the rains the values were between 52.6 and 63.6. The highest values of the WQI-NSF in both climatic periods were observed in site one (Paso de Los Anillos) and the lowest in site five (Muelle Carbonífero) (table 2).

Discussion

The results of this work show that there are no significant variations in water quality conditions (assessed through the WQI-NSF) when comparing the values of the physical and chemical variables between the localities, but between the climatic periods. The previous indicates that the changes in the environmental descriptors of the river were promoted mainly by the influence of climatic variability and not by the anthropic activities that are carried out along the evaluated section. This can be a response to the purification capacity of the system.

Invemar Redcam (2003) recorded pH values between 6.5 and 7.50 in fluvial systems of the department of Magdalena. The pH values observed in the river were close to neutral and in some cases slightly basic ≈ 9 units. These values exceed the maximum value established in decree 1594 of 1984 updated by resolution 2115 of 2007 of decree 1575 for human consumption. These results are probably related to activities of abundant removal of calcareous material that takes place in the middle stretch of the river that can be washed away by the rains. The fecal coliforms presented in the four measurements indicate that in all the sites, the values exceed the limits established by Colombian legislation for human consumption and that established by the CE-CCA/89 for aquatic life (200 MPN/100 mL). However, the data are very similar to those recorded in the lower part of the Manzanares River (Romero *et al.*, 2011) and the Meléndez and Cali rivers (Behar *et al.*, 1997).

The low values of dissolved oxygen detected at localities five and six during the first two samples are related to the high BOD value at these sites. These sites are located in a sector near the mouth of the river, where wastewater is discharged from washing clothes and vehicles. Despite this, BOD values are considered acceptable, indicating contamination (Pacheco, 2006). The washing of clothes and vehicles and the discharges of wastewater that was carried out in the study localities contribute to the increase of the content of organic matter in this sector of the river, which in turn decreases the amount of oxygen dissolved in the water, necessary for aerobic biochemical oxidation of organic substances present in water (Barón *et al.*, 2003; Rivera *et al.*, 2004; Rúa, 2015). The highest nitrate and iron values (table 3) that were observed during the first rainy period, at site one, may be due to the natural mineralization of the water body and the geology of the basin. On the other hand, turbidity values in the first and third sampling were higher than the limit established by Colombian legislation for human consumption (2 NTU). These values in the rainy period are mainly due to the number of suspended solids, the product of the dragging of living and dead matter from the settlements in the surroundings of the rivers (Caballero, 2007; Romero *et al.*, 2011).

Table 2. Values and their respective category of the WQI calculated in the lower part of the Córdoba River.

Date	Period	Locality	WQI – NSF Value	Category	Color
10/12/2010	Rains	Paso de los anillos	54.6	Regular	
		Puente Córdoba	57.7	Regular	
		Finca la India	57.0	Regular	
		Finca el Confite	54.5	Regular	
		Muelle carbonífero	52.6	Regular	
		Desembocadura	53.2	Regular	
11/08/2011	Drought	Paso de los anillos	66.1	Regular	
		Puente Córdoba	65.1	Regular	
		Finca la India	64.8	Regular	
		Finca el Confite	65.2	Regular	
		Muelle carbonífero	60.3	Regular	
		Desembocadura	61.6	Regular	
10/11/2011	Rains	Paso de los anillos	63.6	Regular	
		Puente Córdoba	61.9	Regular	
		Finca la India	63.4	Regular	
		Finca el Confite	62.1	Regular	
		Muelle carbonífero	59.1	Regular	
		Desembocadura	60.1	Regular	
20/03/2012	Drought	Paso de los anillos	72.4	Good	
		Puente Córdoba	72.2	Good	
		Finca la India	71.2	Good	
		Finca el Confite	70.3	Good	
		Muelle carbonífero	67.9	Regular	
		Desembocadura	68.5	Regular	

Table 3. Average values of the physical and chemical variables evaluated in the six study sites during the two climatic periods. The numbering corresponds to the name assigned to each sampling site in table 1. D: period of drought, Rs: Rainy season

Variable	Locality											
	1		2		3		4		5		6	
	D	Rs	D	Rs	D	Rs	D	Rs	D	Rs	D	Rs
Alkalinity (mg/L $CaCO_3$)	56.6	60.4	46.6	61.0	40.1	56.7	56.2	57.9	61.9	61.2	82.9	103.5
conductivity (µS/cm)	89.7	112.1	66.0	98.8	100.1	97.7	125.4	104.4	120.4	100.0	120.5	100.3
True color (UPC)	18.8	18.8	9.4	14.1	14.1	14.4	23.6	14.7	18.8	13.2	19.1	19.1
Total Hardness (mg/L $CaCO_3$)	61.9	60.1	43.7	45.8	46.6	48.6	47.3	53.4	44.0	55.7	55.8	67.0
DQO (mg/L O_2)	18.5	19.2	18.0	22.6	21.5	21.1	25.3	20.4	29.9	21.3	35.2	24.3
DBO (mg/L O_2)	2.9	7.4	3.4	7.8	4.3	8.3	4.0	7.4	7.1	16.0	6.9	13.3
Dissolved oxygen (mg/L O_2)	5.6	6.0	5.6	6.2	5.7	7.0	4.9	6.1	5.3	6.1	5.2	5.8
pH (units)	7.6	7.6	7.7	7.7	7.8	7.8	7.4	7.6	7.5	7.5	7.6	7.7
Total Iron (mg/L)	0.1	0.3	0.1	0.3	0.1	0.3	0.1	0.3	0.1	0.4	0.1	0.3
Nitrites (mg/L NO_2)	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.2	0.1	0.2	0.1
Nitrates (mg/L NO_3)	0.3	0.7	0.3	0.6	0.3	0.5	0.4	0.7	0.4	0.6	0.6	0.9
Phosphates (mg/L PO_4)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total Solids (mg/L)	94.5	355.0	104.7	409.0	105.2	280.0	113.4	397.0	137.4	287.0	146.4	309.0
Suspended Solids (mg/L)	13.1	12.8	16.5	159.7	17.2	80.7	22.3	136.7	21.3	54.1	20.0	105.1
Dissolved solids (mg/L)	98.7	112.7	95.0	103.5	88.6	117.0	96.4	115.4	114.9	156.2	121.4	112.1
Cloudiness (UNT)	1.8	27.2	1.5	27.7	1.5	29.6	1.6	31.3	3.1	33.0	3.6	28.9
Temperature (°C)	26.1	23.4	26.5	23.8	27.0	24.6	26.3	26.4	26.3	25.8	25.9	25.3
Total Coliforms (NMP/100mL)	4760	4845	3962	2470	4902	3800	5197	4085	6365	2898	6717	3943
Fecal coliforms (NMP/100mL)	3012	4845	2974	4845	3021	4750	3078	4750	3373	4750	3553	4940

Although fertilizers, insecticides, and fungicides are used in several sectors of the lower Córdoba River, the nitrate and phosphate values do not indicate contamination of the system. The increase in the use of fertilizers with high nitrogen content has led to a higher concentration of nitrates in both surface and groundwater since the high solubility of this compound means that it is quickly released from the soil and carried to the rivers by the waters of runoff (Mendiguchía, 2005). It is likely that a large part of nitrate and phosphate waste will be concentrated near the mouth of the Córdoba River. According to the criterion established for the diagnosis and evaluation of the water quality of the Córdoba River, the water corresponding to the different sampling sites is not suitable for human consumption because it presents high values of fecal coliforms, BOD and turbidity. They exceed the limits established in the Colombian legislation and other countries, but suitable for the use and protection of flora and fauna, according to Decree 1076 of 2015.

The values of the WQI-NSF that were recorded during the second dry period, where most of the localities showed a "good" quality of water, maybe reflecting the standard conditions of the system, because of the samplings of the first period of drought performed in a Girl year . It is likely that the results obtained on 08/11/2011 influenced the material drags from the river banks and upstream, which caused the increase of some variables such as BOD, nitrates and fecal coliforms (Romero *et al.*, 2011). In the lower part of the Córdoba River, no evidence of contamination was found due to the significant presence of organochlorine compounds residues that affect human health and the survival of flora and fauna species.

Finally, the integrated assessment of the bodies of water should be considered, in such a way that other indices of physicochemical quality (such as the mineral pollution index (ICOMI, by its acronym in Spanish), contamination by suspended solids (ICOSUS by its acronym in Spanish) and trophic pollution (ICOTRO by its acronym in Spanish)) and ecological contamination (BMWP/Col and EPT) are included. With the above, it is proposed that: 1) you can fully know the health status of these systems (Forero-Céspedes *et al.*, 2013), 2) you can make adjustments and validations of according to the local conditions and types of contaminants that are evident in the sites of interest (Zúñiga and Cardona, 2009; Montoya-M *et al.*, 2011) and 3) the analyzes respond to the main stressors identified in each location.

Conclusion

The lower part of the main channel of the Córdoba River showed a quality of water categorized as Regular and Good, a fact that was confirmed with the physical and chemical variables valued, which did not show values that exceeded importantly the ranges allowed by the national legislation for natural water sources with recreational use and protection of aquatic flora and fauna. The results of fecal coliforms indicate microbiological contamination of the system as the channel approaches the mouth of the river, especially during periods of drought. The physicochemical variables of water were related to climatic periods, but not to spatial variables of the section. These results show that the water quality of the Córdoba River in its low section is not considered as a risk for the biota of the system and that the values of the variables recorded in this work were consistent with those recorded in the Manzanares River by Romero (2011), whose river, like Córdoba, is located on the same side of the SNSM.

Acknowledgments

To Bienvenido Marín, Luis O. Duarte, Robert Melo Lora, Santiago González Rojas, Deimer Fontalvo and Denis Alonso for the contribution they made to the document. To Isaac Romero Borja, for the support in the laboratory analyzes. To María del Carmen Zúñiga, for the revision of the manuscript. To anonymous reviewers for comments to improve work.

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How to cite: Fontalvo-Julio, F.A. y Tamaris-Turizo, C.E. 2018. Calidad del agua de la parte baja del río Córdoba (Magdalena, Colombia), usando el ICA-NSF. *Intropica* 13(2):101-111. DOI: http://dx.doi.org/10.21676/23897864.2510.