DOI: 10.24850/j-tyca-14-06-06

Articles

Water quality for recreational use of the Río Ctalamochita, Córdoba, Argentina

Calidad de agua para uso recreativo del Río Ctalamochita en Villa María, Córdoba, Argentina

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Abstract

The Río Tercero or Ctalamochita along Villa María city, Córdoba, Argentina, is used for recreational purposes, among others. The aim of this work was to evaluate the quality of water for that use in the section that runs through the city, through the microbiological and physicochemical analysis and water quality index (WQI) of the Canadian Council of Ministers of the Environment. Seasonal sampling was performed in three points of the city (ingress, center and end) between October 2017 and September 2018. Total coliforms, thermotolerant coliforms and *Escherichia coli* were determined. In addition, temperature (°C), pH, turbidity (UNT), total dissolved solids, biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen, nitrates and nitrites were recorded. The results showed that in 60 % of the samples the total coliforms exceeded the allowed limit, however, in the total of samples the thermotolerant coliforms were acceptable by the normative and in the determination of *E. coli*, only one value exceeded the limit set up by Health Canada. The WQI was "Good" for two of the sites studied, while downstream, while in Barrancas del Río, it was "Marginal" (WQI = 62.2). Therefore, it is concluded that in the studied areas, the recreational use of water from the Río Ctalamochita would not imply a risk to the human health. However, the factors that produce the WQI decrease, after crossing the city, should be identified if improvements are to be achieved in that area.

Keywords: River water, physicochemical parameters, microbiological parameters, *Escherichia coli*, water quality index.

Resumen

El Río Tercero o Ctalamochita a lo largo de la ciudad de Villa María, Córdoba, Argentina, es utilizado con fines recreativos, entre otros. El objetivo de este trabajo es evaluar la calidad del agua para tal uso en el tramo correspondiente a la ciudad, a través del análisis de variables microbiológicas, fisicoquímicas y del índice de calidad de agua (WQI) del Canadian Council of Ministers of the Environment. Para ello se realiza el muestreo del río aguas arriba, en puntos intermedios y aguas abajo en distintos momentos del año, abarcando un periodo de dos años (de octubre 2017 a septiembre 2018). Se determinaron coliformes totales, coliformes termotolerantes y *Escherichia coli*. Además, se registraron la temperatura, pH, turbiedad, sólidos totales, demanda biológica de oxígeno (DBO_5), demanda química de oxígeno, oxígeno disuelto, nitratos y nitritos. Los resultados muestran que los coliformes totales superaron el límite permitido en el 60 % de las muestras; los coliformes termotolerantes son acordes con la normativa en el 100 % de las muestras y la determinación de *E. coli*; sólo un valor supera el límite establecido. El WQI resultante es "Bueno" para dos de los sitios estudiados, mientras que aguas abajo, en Barrancas del Río, es "Marginal" (WQI = 62.2). Se concluye que en las zonas estudiadas, el uso recreativo no implicaría un riesgo para la salud humana. Sin embargo, es importante identificar los factores que influyen en el decrecimiento del WQI luego de

atravesar la ciudad y las posibilidades de actuación sobre los mismos, si se quieren lograr mejoras en dicho tramo.

Palabras clave: agua de río, parámetros físico químicos, parámetros microbiológicos, *Escherichia coli*, índice de calidad de agua.

Received: 07/05/2021

Accepted: 04/20/2022

Published online: 07/07/2022

Introduction

Aquatic ecosystems (rivers, streams, lakes, lagoons, reservoirs and aquifers) provide numerous benefits and services, such as water for human and animal consumption, food production, electricity generation, habitat for aquatic life, among others (UNEP, 2017).

At present, exponential population growth has generated an increase in anthropic activities, which are responsible for many of the alterations suffered by surface water bodies, and water quality problems are increased by the multipurpose use of these systems (Bazán, 2006). In general, surface waters are subject to pollution of natural origin, entrainment of particulate and dissolved material, presence of natural and anthropogenic organic matter, sewage and domestic water discharges, agricultural runoff, effluents from industrial processes, among others (Torres, Cruz, & Patiño, 2009; Carnicelli *et al*., 2018).

To assess the quality of a particular water body it is necessary to establish the uses for which the water body is destined (Karr, 1998; Naiman & Bilby, 1998; Boccolini, Oberto, & Corigliano, 2005). Acuña-del-Pino, Abramovich, Meyer, Haye and Gilli (1998), for example, indicate that the bacteriological quality of water for recreational use is not the same as for human consumption. Nevertheless, these are parameters that should be considered since there have been cases where recreational waters have played an important role in transmitting pathogens, with an increased risk of bacterial infections, including Shigella spp and Escherichia coli. But also infections by parasites such as Giardiasis (Acuña-del-Pino *et al*., 1998).

Normally, the potential risk of exposure to physical-chemical parameters is lower than the risk caused by bacterial microorganisms in recreational waters. The concentrations of physicochemical variables (pH, temperature, dissolved oxygen, salinity, total solids and organic matter) generally present in water are not significantly elevated to cause chronic disease (WHO, 2003). Nevertheless, lifeguards, prefects, tactical divers, rescuers, aquaculturists, fishermen and beach service personnel should be taken into account, since they are the population group with the greatest exposure in recreational environments.

The Río Tercero o Ctalamochita basin covers an area of approximately 9580 km2. The upper basin is regulated by a system of reservoirs that generate electric power for the province of Córdoba and other cities in the centre of the country, which also acts as a regulator and conditions the runoff flow in the Río Tercero (Ctalamochita) (Lenarduzzi, 2013; Carnicelli *et al*., 2018).

The Río Tercero (Ctalamochita) riverbed runs approximately 300 km long in a west-east direction (Ochoa *et al*., 2016). Along its course, it crosses numerous localities, including the tourist centres of the mountainous region, up to the confluence with the Saladillo River (Cossavella *et al*., 2013; Carnicelli *et al*., 2018). It is a source of drinking water in the southern and eastern parts of the province of Córdoba (Harguinteguy, Gudiño, Arán, Pignata, & Fernández-Cirelli, 2019) it is used for irrigation, aggregate extraction, recreation and fishing. Nevertheless, it is used as a receiving body for the final disposal of industrial wastewater and sewage treatment plants (Cossavella *et al*., 2003).

Therefore, water resource management requires monitoring to record the variability of water quality (Betancur-Vargas, Campillo-Pérez, & García-Leoz, 2011). Furthermore, by using different indexes, changes in water quality can be assessed from a single unifying variable, in contrast to considering many parameters (Chapman, 1996; Debels, Figueroa, Urrutia, Barra, & Niell, 2005; Carnicelli *et al*., 2018).

The purpose of this research is to evaluate the quality of water for recreational use in the Río Ctalamochita, in the section corresponding to the city of Villa María, Córdoba, through microbiological and physicochemical parameters and to determine the water quality index

(WQI) according to the "Canadian Council of Ministers of the Environment".

Methodology

In the development of this work, the study area and the regulations related to the evaluation of river and recreational water quality are delimited. Based on this, the parameters to be analyzed and the techniques to be used are defined, and the results are evaluated and compared with current legislation. Finally, the WQI and its suitability for recreational purposes are determined.

Area of study

Three sampling points are selected from the Río Tercero in its course through the city of Villa María (Figure 1). The first site is located at the entrance of the city in the area called "Puente Andino" (PA) (Lat. 32°25'2.91 "S, Long. 63°18'16.30 "W). The second is located in the middle part of the river course and is called "Bajada calle Entre Ríos" (BE), (Lat. 32° 25' 15.79 "S, Long. 63° 15' 15.55 "W). Finally, the third is located after crossing the city at the access to the "Barrancas del Río" (BR) neighborhood (Lat. 32° 25' 50.85 "S, Long. 63° 13' 23.31 "W).

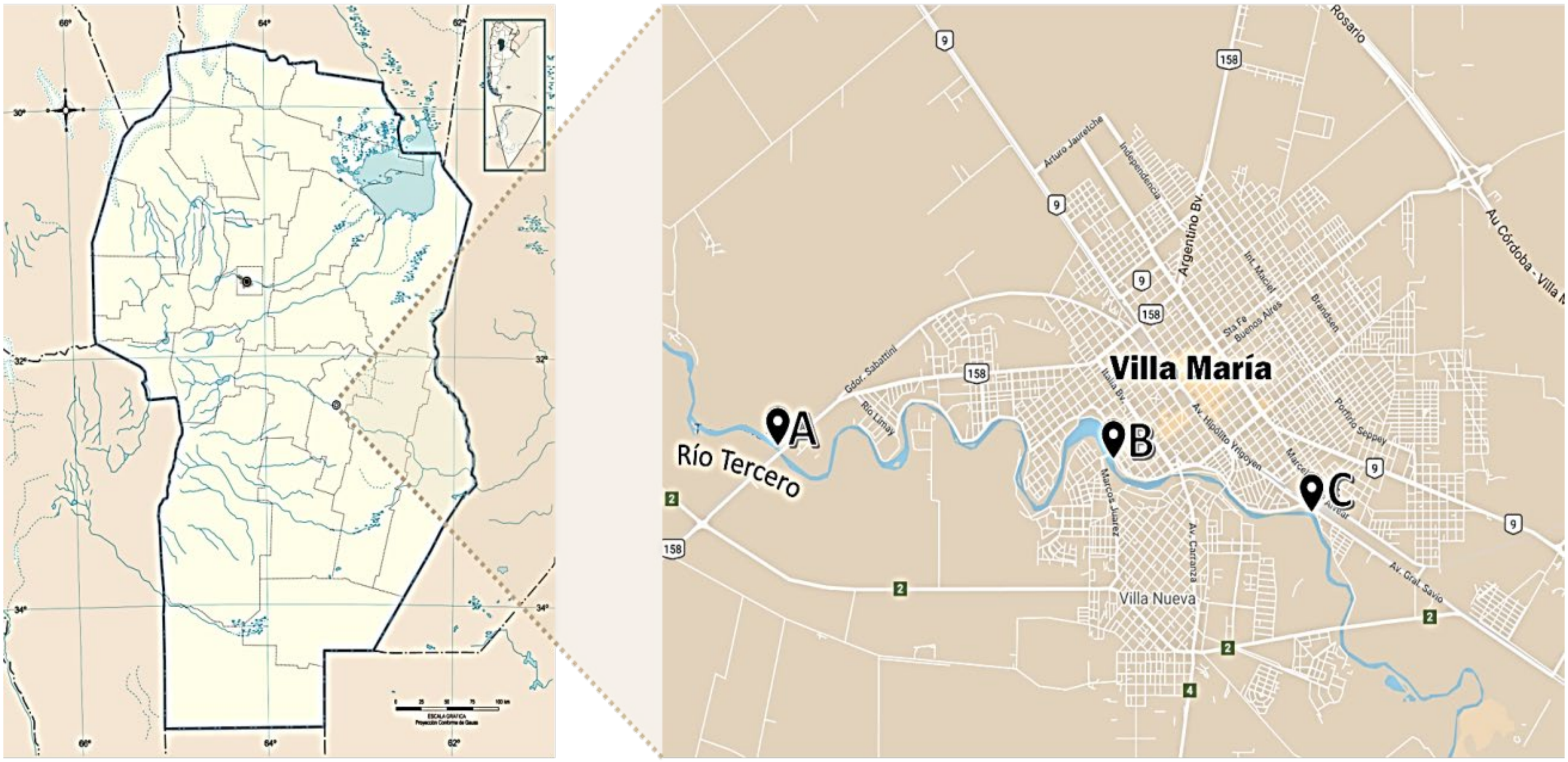

Figure 1. Location of sampling points. City of Villa María, Córdoba, Argentina.

Five samplings are performed from October 2017 to September 2018, being 10/2017, 04/2018, 06/2018, 08/2018 and 09/2018.

Legislation, parameters and reference values

Exposure levels for different recreational activities are established by the Ministerio de Salud de la República Argentina, where swimming, wading and windsurfing are the recreational activities with a high impact, with a pattern of exposure through ingestion or inhalation (Ministerio de Salud, 2017).

In addition, Table 1 and Table 2 provide a compilation of the reference parameters indicated in different sources. As for microbiological parameters, total coliforms, faecal coliforms, thermotolerants and Escherichia coli are recommended (Saracho, Segura, Moyano, Rodríguez, & Carignano, 2006; Ministerio de Salud, 2017; Health Canada, 2012).

Table 1. Reference values for microbiological determinations.

Analysis	Recommended limit	Reference
Total coliforms	1000 MPN/100 ml	Brandalise *et al*. (2012); López-Sardi, García, Reynoso, González and Larroudé (2016)
Thermotolerant coliforms	1000 MPN/100 ml	WHO (2003)
E. coli	≤ 400 *E. coli*/100 ml	Health Canada (2012)
	Excelent: 500 /100 ml	EU (2006)
	Good: 1000/100 ml	
	Maximum:235/100 ml	EPA US (2006)

Table 2. Reference values for physico-chemical determinations.

Analysis	Recommended limit	Reference
Temperature (°C)	-	No recommended limit

Analysis	Recommended limit	Reference
pH	5 a 9	Health Canada (2012)
Turbidity (NTU)	5 NTU	López-Sardi *et al.* (2016)
	50 NTU	Health Canada (2012)
Total solids (mg/l)	≤500 mg/l	López-Sardi *et al.* (2016)
BOD (mg/l)	≤30 mg/l	López-Sardi *et al.* (2016)
COD (mg/l)	≤250 mg/l	MAA y SP, 2016 - limit for effluent suitable for discharge to surface waters.
Dissolved oxygen (mg/l)	5 a 9 mg/l	Health Canada (2012)
Nitrates (mg/l)	≤ 10 mg/l	MAA y SP (2016), límite para efluente apto para vertido de aguas superficiales
Nitrites (mg/l)	≤ 1 mg/l	MAA y SP (2016), límite para efluente apto para vertido de aguas superficiales

The presence of Pseudomonas aeruginosa in this research is not performed, since the microbiological analysis of water for recreational use does not include this parameter. It is an indicator used for drinking water quality because it is an aerobic bacterium highly resistant to chlorination required by drinking water distribution systems. In addition, Pseudomonas aeruginosa develops in the presence of little organic matter, which makes its presence very frequent in surface waters and it is an opportunistic pathogen that causes infection (generally intrahospital) in immunosuppressed persons.

The presence of enteropathogens in recreational waters is also contributed by multiple sources such as the occasional dumping of untreated or partially untreated sewage, waste generated from water sports events and boating, including the direct contribution of waste to the beach sand by bathers and animal waste. Other sources of human-caused fecal contamination include near-shore septic tanks, which percolate directly to water tables and then drift into recreational waters (Ministerio de Salud, 2017).

Table 1 and Table 2 provide a compilation of the reference parameters indicated in various sources. As for microbiological parameters, total coliforms, faecal coliforms, thermotolerants and Escherichia coli are recommended (Saracho *et al*., 2006; Ministerio de Salud, 2017; Health Canada, 2012). Multiple sources also contribute to the presence of enteropathogens in these recreational waters under study, such as overturning of storm drains, waste generated by navigation; the direct contribution of waste by bathers and animals present in them. In addition, there are other sources of fecal contamination of human origin, such as septic tanks near the coast, due to the proximity of the population that resides there.

In addition, Table 2 indicates that it is necessary to evaluate at least the referenced parameters such as temperature, pH, turbidity, total solids, biological oxygen demand (BOD5), chemical oxygen demand (COD), dissolved oxygen, nitrogen, nitrates and nitrites (Cattaneo & López-Sardi, 2016; Health Canada, 2012).

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Materials and methods

The techniques used are those established by Standard Methods for the Examination of Water and Wastewater (APHA-AWWA, 2017).

- For pH determination, the following method is used APHA-4500-H^+ A ans B, using a pH-meter Hanna HI 9025. In turbidity the APHA -2130 A and B measuring with Hanna HI 88713.
- For total solids the APHA-2520 A and B; for BOD the APHA 5210 using heads (Velp BOD Sensor System), recording values for five consecutive days.
- COD is performed by APHA 5220 A, B and C, using a HACH DR 6000 spectrophotometer for the readings.
- Nitrates are determined using the ultraviolet spectrophotometric method APHA-4500-NO_3^-
- For nitrites, the colourimetric method APHA- 4500-NO_2^- B is used.
- Regarding the microbiological variables mentioned above, both for the detection of total coliforms and thermotolerants, the fermentation method is used in multiple tubes (three tubes) (Collins & Taylor, 1969). The presence of E. coli is identified by the indole production test in peptonized water at 44.5 + 0.2 °C for 24 hours (ISO 9308-1, 2000).

Estimation of the Water Quality Index

The Water Quality Index (WQI) of the Canadian Council of Ministers of the Environment is estimated based on parameters established according to the use assigned to the water body under study.

The parameters used for the calculation are detailed in Tables 1 and 2. The WQI is obtained from the determination of the scope (F1), frequency (F2) and amplitude (F3), whose values are determined as follows.

- Scope F1: percentage of parameters that do not meet the reference value (defined according to water use) at least once, in the time period analyzed (failed parameters), with respect to the total number of parameters used (Equation (1)):

$$F1 = \frac{N° \, of \, failed \, parameters}{N° \, total \, parameters} \quad (1)$$

- Frequency F2: percentage of individual tests that gave results different from the guide (failed tests), out of the total number of tests performed in the period studied. Test refers to the laboratory analyses performed for each parameter (Equation (2)):

$$F2 = \frac{N° \, of \, failed \, parameters}{N° \, total \, tests \, performed} \quad (2)$$

- Amplitude F3: magnitude by which the result of each test deviates from the conformity criterion or limit value (Equation (5)). To obtain it, the excursions were calculated (Equation (3)), which are the number of times that the value of a parameter exceeds its reference value. Subsequently, the normalized summation of the excursions (sne) is performed according to Equation (4):

$$exc = \frac{unacceptable\ value}{limit\ value} - 1 \quad (3)$$

$$sne = \frac{\sum exc}{N°\ total\ tests\ performed} \quad (4)$$

$$F3 = \frac{sne}{0.01 * sne + 0.01} \quad (5)$$

After the values have been obtained according to Equations (1) to (5), the index is calculated according to the following equation (Equation (6)):

$$WQI = 100 - \frac{\left(\sqrt{F1^2 + F2^2 + F3^2}\right) * 100}{173.2} \quad (6)$$

The interpretation of the results was established according to CCME and the categories are detailed in Table 3.

Table 3. Water quality index (WQI) categories established by the Canadian Council of Ministers of the Environment (CCME).

Index value (CCME WQI)	Category
95-100	Excellent
80-94	Good
65-79	Acceptable
45-64	Marginal
0-44	Poor

Statistical analysis

For data analysis, the assumptions of normality (Shapiro-Wilk test) and homogeneity of variances (Levene's test) were tested. Subsequently, the variables that met the assumptions were analyzed with parametric tests, while those that did not were treated with nonparametric tests.

Comparisons (one-way ANOVA or Kruskal Wallis) were made between sampling sites and between dates (seasons of the year) for each variable studied. When significant differences were recorded, a posteriori tests were performed. Statgraphics Centurion XVI Version 16.1.03 and InfoStat Version 2011 were used for data analysis.

Results

The values obtained in the microbiological determinations are shown in Table 4 and those of the physicochemical parameters in Table 5 and Table 6.

Table 4. Results of microbiological analyses.

Sampling location	**Sampling/date**	**Total coliforms**	**Thermotolerant coliforms**	***Escherichia coli***
		(MPN/100 ml)		
Puente Andino (PA)	10/2017	9 300	400	400
	04/2018	15 000	300	300
	06/2018	70	30	30
	08/2018	9 600	30	40
	09/2018	240	9	15
Bajada calle Entre Ríos (BE)	10/2017	9 300	300	300
	04/2018	4 300	300	300
	06/2018	390	70	30
	08/2018	230	30	30
	09/2018	240	23	9
Barrancas del Río (BR)	10/2017	46 000	300	300
	04/2018	39 000	300	300
	06/2018	4 600	70	70
	08/2018	11 000	930	2 400
	09/2018	2 400	75	75
Reference		1 000	1 000	< 400 (Canada) 1 000 (US)

Table 5. Results of physicochemical parameters.

Sampling location	Sampling/ date	Temperature (°C)	pH	Turbidity (NTU)	Total solids (mg/l)
Puente Andino (PA)	10/2017	19	8.2	21.6	294
	04/2018	20	7.7	4.71	232
	06/2018	8.8	7.5	7.18	245
	08/2018	12.9	7	5.46	226
	09/2018	16	7	1.64	242
Bajada calle Entre Ríos (BE)	10/2017	19	8,0	10.1	267
	04/2018	20	7,8	5.15	223
	06/2018	9.4	7	3.75	229
	08/2018	13.4	7	4.77	221
	09/2018	17.1	7	3.42	241
Barrancas del Río (BR)	10/2017	20	8.3	11.3	270
	04/2018	20	7.8	6.82	232
	06/2018	9.4	7	10.4	224
	08/2018	13.6	7	4.79	215
	09/2018	17.3	7	3.28	254
Reference		-	5 to 9	50	≤ 500

Table 6. Results of physicochemical parameters.

Sampling location	Sampling / date	BOD	COD	Dissolved oxygen	Nitrates	Nitrites
		(mg/l)				
Puente Andino (PA)	10/2017	ND	ND	7.6	7	0.005

Sampling location	Sampling / date	BOD	COD	Dissolved oxygen	Nitrates	Nitrites
		(mg/l)				
	04/2018	3.2	54	8.2	5	0.014
	06/2018	ND	4	9.8	7	0.005
	08/2018	ND	ND	8.4	3.53	0.005
	09/2018	ND	ND	8.2	3.22	0.005
Bajada calle Entre Ríos (BE)	10/2017	ND	ND	7.6	5	0.005
	04/2018	3.2	45	8.2	5	0.013
	06/2018	ND	6	10.3	7	0.005
	08/2018	ND	ND	8.4	3.66	0.005
	09/2018	ND	ND	8.2	3.29	0.005
Barrancas del Río (BR)	10/2017	ND	ND	7.9	7.9	0.005
	04/2018	5.4	45	8.2	8.2	0.017
	06/2018	ND	6	9.7	9.7	0.007
	08/2018	ND	ND	8.4	8.4	0.005
	09/2018	ND	ND	8.2	8.2	0.005
Reference		≤3	≤250	5 to 9	≤10	≤0.3

Of all the variables analyzed, only nitrates showed statistically significant differences between the sites studied ($F = 10.48$; $p = 0.002$).

In the case of total coliforms, although there were no statistically significant differences ($F = 2.73$; $p > 0.05$) between the sites, it should be noted that the number of colonies found in BR were higher than those obtained in the other sites (PA and BE) during the entire period under study.

Regarding thermotolerant coliforms and *E. coli* it is of interest to note that in Puente Andino (PA) and Bajada calle Entre Ríos (BE) presented analogous behavior, with minimums in the June and September 2018 samples; while in Barrancas del Río (BR) an extreme upper value was recorded in the August 2018 sample.

Nevertheless, no statistically significant differences were found between the dates studied for thermotolerant coliforms and E. coli ($F = 7.40$, $p > 0.05$; $F = 7.93$, $p > 0.05$, respectively).

The results of the physicochemical parameters show that the water temperature coincides with the seasonal variation, with minimum values during the cold months and maximum values during the months with higher temperatures. In all sites pH shows decreasing values during the samplings, the maximums are observed during October 2017 and April 2018, showing significant differences in relation to the other dates ($F = 42.42$; $p = 0.0001$). Regarding turbidity, the maximum value is recorded during September 2017 (Figure 2), showing significant differences only with the values of August and September 2018 ($F = 5.45$; $p = 0.0136$).

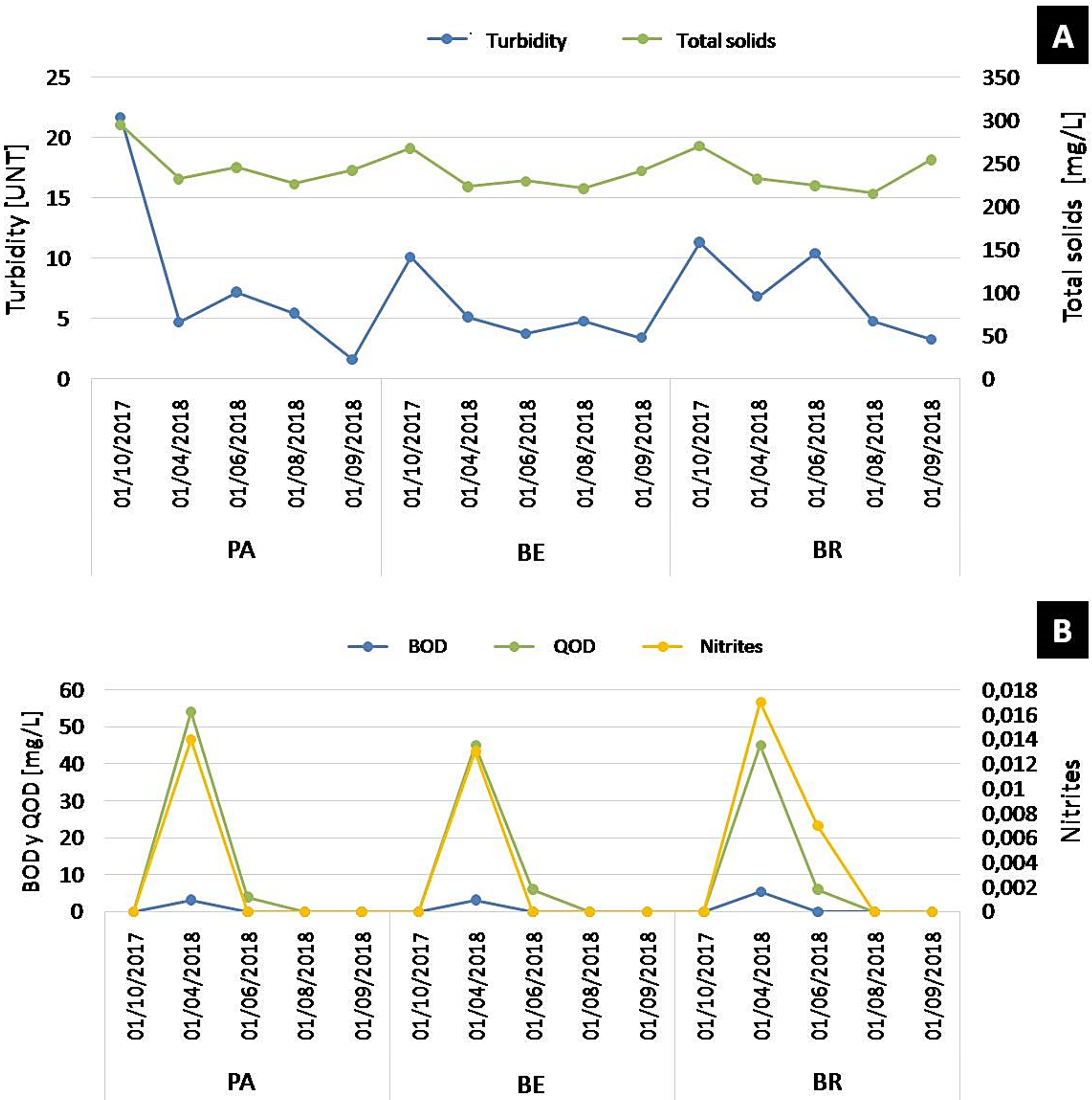

Figure 2. Analysis of physicochemical parameters: (A) Turbidity and total solids, (B) BOD, COD and Nitrites. Locations: Puente Andino (PA), Bajada calle Entre Ríos (BE), Barrancas del Río (BR).

As can be seen in Figure 2, the concentration of total solids varies between 215 and 294 mg/l, the maximum value being recorded in October 2017, showing statistically significant differences with respect to the rest of the periods analyzed ($F = 16.24$; $p = 0.0002$).

Dissolved oxygen shows a maximum during June 2018 (Figure 2) with statistically significant differences with respect to the other dates analyzed ($F = 81.10$; $p = 0.0001$).

Regarding nitrates, as previously mentioned, there were differences between the sites sampled, with maximum levels in Barrancas del Río (BR). Nevertheless, there were no differences between the periods analyzed ($F = 0.90$; $p > 0.05$). Nitrites, COD and BOD generally presented values below the detection limit of the equipment used; therefore, no statistical comparisons were made for these variables (Table 5 and Table 6).

The Water Quality Index (WQI) values are detailed in Table 7. Based on the results obtained, the water in the Puente Andino (PA) and Bajada Calle Entre Ríos (BE) areas belonged to the "Good" category, while that of the Barrancas del Río (BR) site corresponded to "Marginal".

Table 7. Water Quality Index (WQI) values. F1: scope, F2: frequency, F3: amplitude.

Sampling point	F1	F2	F3	WQI	Category
Puente Andino	0.364	0.091	29.266	83.102	Good
Bajada calle Entre Ríos	0.273	0.073	17.678	89.792	Good
Barrancas del Río	0.364	0.145	65.382	62.250	Marginal

Discussion

All the variables analyzed in this work (physicochemical and microbiological) show a variation along the section of the Río Tercero in the area under study, and in the different periods analyzed, which evidences the dynamics of the natural aquatic environments and their close relationship with the anthropogenic impact.

From the analysis of the results in terms of the recommended limits, it is observed that for pH and turbidity all values are within the limits established by Health Canada (2012). The turbidity results are lower than those recorded by Carnicelli *et al*. (2018), for the same study area, as well as those recorded by López-Sardi *et al*. (2016), for the province of Buenos Aires. Total dissolved solids were below the established limit (500 mg/l) and coincide with those reported by Martínez-de-Fabricius, Luque, Lombardo and Bruno (2007) for the Río Cuarto. In addition, 73.33 % of the values obtained in this work were lower than the value recorded by López-Sardi *et al*. (2016), for a lagoon environment in the province of Buenos Aires. López-Sardi *et al*. (2016), mention that BOD values above 30 mg/l could indicate contamination or eutrophication. Nevertheless, in this work, lower values are recorded, with a maximum of 5.4 mg/l. These results indicate that the anthropogenic impact on the Río Ctalamochita is not relevant in the analyzed section and that the COD values are all below the recommended limit for effluents suitable for surface water discharge, which is 250 mg/l (MAA y SP, 2016).

For dissolved oxygen, all values were within the limits recommended by Health Canada (2012), except for the sample obtained during June 2018, being at all three sampling points the maximum value for the site. Because the solubility of gases in water is inversely proportional to temperature, it is reasonable that dissolved oxygen during colder months is increased. The values obtained for nitrates and nitrites are below the maximum values allowed for effluents suitable for discharge into surface waters (≤10 and ≤0.3 mg/l, respectively) (MAA and SP, 2016). Moreover, our results coincide with the range of values recorded by Martínez-de-Fabricius *et al*. (2007) for the Río Cuarto, Córdoba. In this sense, the physicochemical parameters indicating contamination (COD, BOD, nitrites) do not reveal a significant degree of organic matter contamination.

Regarding microbiological parameters, total coliforms show values between 70 and 46 000 MPN/100 ml, which resulted lower than what was recorded by por Bertrand, Monferrán, Mouneyrac and Amé (2018), for the region. Nevertheless, the results found in this work are sometimes higher than the maximum recorded by Brandalise *et al*. (2012) for the San Roque and Los Molinos reservoirs, in the province of Córdoba (1300 and 1400 MPN/100 ml, respectively). The total count values of thermotolerant microorganisms are significantly below the maximum limit (1 000 MPN/100 ml), established by the World Health Organization (WHO).

Finally, in contrast to the limits established by European Union (EU), the value obtained for E. coli is "Acceptable". Except for what was recorded in Barrancas del Rio (BR) during August 2018 (maximum value=2400 CFU/100ml) and the results obtained are considered

"EXCELLENT", without considering the previously mentioned value. Nevertheless, when considering the maximum value established by United States Environmental Protection Agency (EPA) (235 CFU/100ml), our results repeatedly exceeded this limit (Table 5).

The water quality index (WQI), in reference to the water quality index (WQI) categories established by the Canadian Council of Ministers of the Environment (CCME), (Table 3) is "Good" for two of the sites studied, suggesting that the waters are suitable for recreational use. Nevertheless, at the Barrancas del Río (BR) site, a WQI = 62.2 was obtained, which is within the "Marginal" category. This decrease in WQI could be associated with the discharge of effluents from industries located in the study area. This observation was also made by Bertrand *et al*. (2018), in a study in a larger sampling surface area, where they recorded a decrease in the quality index along the course of the Río Tercero or Ctalamochita. Bertrand et al. (2018), though, used a different procedure to estimate the water quality index, which makes the index calculated in this work not strictly comparable.

Conclusions

Based on the research conducted in this work, the following conclusions can be inferred:

- In most cases, the physicochemical parameters studied show behaviour in accordance with seasonal or spatial variations and are within the limits established by the various international standards analyzed.

- Regarding microbiological parameters, it was observed that 66.67 % of the total coliform values recorded exceeded the limit established as "Acceptable" (1 000 MPN/100 ml) by the existing regulations. Nevertheless, thermotolerant coliforms were lower, in all samples, than the limit established by WHO.
- The values found for E. coli are below the limit set by Health Canada (≤ 400/100 ml), except for the value obtained in BR during August 2018. Nevertheless, if the value established by EPA (235/100ml) is considered almost half of the values exceed this limit.
- Since national regulations regarding the recreational use of water bodies (lotic and lentic) in Argentina take as reference values those established by international organizations (WHO, Health Canada, EU, USEPA), it is necessary to establish specific guide levels in accordance with the activities carried out in the region of the city of Villa María**.**

The main contribution to the knowledge of the river water quality in the section under study is the following:

- Based on the results of the water quality index (WQI), a decrease is observed as the Ctalamochita riverbed advances, which means that water quality is deteriorating and this could be directly associated with the impact of anthropic activities. Therefore, it is essential to raise awareness among the population (users) regarding the consequences of their actions, especially those associated with industrial activities, whose repercussions are more accentuated.

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