WATER QUALITY IN THE TORCA, SALITRE, AND FUCHA RIVER BASINS, FOR REGIONAL WATER ASSESSMENT (RWA)

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ABSTRACT

This article presents the results of the study conducted for the Regional Water Assessment (RWA) by the Water, Sewerage and Sanitation Company of Bogotá (EAB acronym in Spanish) on the Torca, Salitre, and Fucha basins in 2016, monitoring points were selected to determine water quality in terms of physical, chemical, and microbiological parameters, and to establish the indicators of Índice de Calidad del Agua (ICA, Colombian standard), Water Quality Index (WQI), Potential Alteration Index of Water Quality (IACAL in Spanish) and Macroinvertebrates as Indicators of or Water Quality (MWQ).

The results were compared with the current regulations of national quality objectives and the District Department of the Environment (SDA). It was found that the water quality of urban basins, such as Torca, Salitre, and Fucha, has a high potential pollution alteration index, due to the high value of BOD_5 and COD of the population and industrial factors.

The determination of the RWA water quality indicators led to determine the current state of the basins' water quality.

Keywords: Quality; RWA; ICA; WQI; IACAL; MWQ.

INTRODUCTION

The determination of water quality corresponds to the main basins of the city of Bogotá, the rivers Torca, Salitre, and Fucha, from their source in the eastern hills to its confluence in the Bogotá River.

Water quality in the regional water assessment (RWA) was established through the ICA, IACAL, WQI, and MWQ indicators, in accordance with historical records and monitoring points agreed with the Water Supply, Sewerage and Sanitation Company of Bogotá (EAB, acronym in Spanish), to determine the current water quality status.

To calculate the indicators, monitoring networks of each of the basins were checked to determine historical indices and compare them with monitoring campaigns. Because of that, it was found that Bogotá's records are more rigorous than in the other basins, since the calculation of the ICA and WQI indices showed an acceptable quality for the high part of the basins and in the middle and lower parts very poor and poor qualities were found (Sánchez Londoño, 2017).

For the IACAL a high value was found, due to BOD_5 and COD coming from demographic and industrial factors.

Regarding MWQ, the Torca basin has a Very Critical water quality that places it as Heavily Polluted Waters, Salitre and Fucha presents a deterioration in their quality from the highest part towards the mouth, quality conditions start as Critical which corresponds to Highly Polluted Waters and Very Critical conditions near the mouth, characteristic of Heavily Polluted Waters.

METHOD

The selection of monitoring points in the study basins was chosen according to the following criteria:

Cartography: Several monitoring points were identified according to the area of each basin and their sub-sectors (high, middle, and lower basins).

Field work: Easy access to the identified points was considered, specific characteristics of the water masses for sample relevance, and being downstream from mixing zones with important discharges.

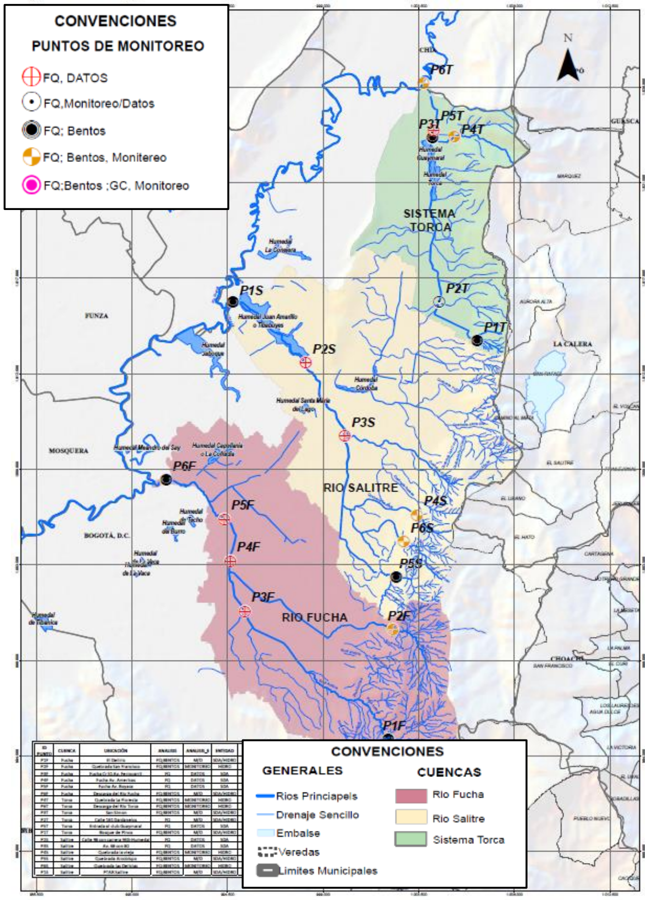
In each identified point, three monitoring campaigns were carried out; the first, developed in dry hydrological conditions, in a period between February 29 and March 10, 2016; the second, carried out under rainy hydrological conditions, which was carried out from April 18 to 27, 2016; and the third, developed under rainy hydrological conditions, from May 23 to June 2, 2016, at the same points of campaign 1.

In Figure 1, the location of the monitoring points of the studied basins is presented.

Samples taken in the field for each studied basin were refrigerated for preservation until the end of the monitoring, following the protocols of Laboratorio Consultoría y Servicios Ambientales CIAN, CAR's Environmental Laboratory and IDEAM's monitoring guides.

At each monitoring point, samples of physical, chemical, microbiological (BOD_5, COD, TSS, TP, TN, FOG, MBAS, and CF), and biological (Benthic-Macroinvertebrates) parameters were taken to the laboratory. *In situ*, values of T °C, EC, pH, and DO were taken.

Figure 1. Location of the monitoring points of Fucha, Salitre, and Torca basins



Basin	Name	North	East
Salitre	Brook La Vieja	1005857.16	1003422.01
	Brook Las Delicias	1004597.74	1002805.64
	Brook Arzobispo	1002939.00	1002435.83
	Salitre WWTP	1015920.202	994755.82
Fucha	El Delirio	995290.44	1002066.16
	Fucha River discharge	1007500.90	991605.41
	Brook San Francisco	1000472.42	1002284.87
Torca	San Simón	1023611.73	1004148.43
	Brook La Floresta	1023683.06	1005188.71
	Bosque de Pinos	1014062.50	1006252.57
	Street 161 Dardanelos	1015874.08	1004466.27
	Torca river discharge	1026185.81	1003723.07

Source: EAB- Hidrocuencas Consortium, with cartographic base from IGAC (2016).

Water quality indices

Índice de calidad de agua (ICA Colombian standard). It is a number (between 0 and 1) that indicates the degree of quality of a body of water in terms of human welfare, regardless of its use. (IDEAM, n.d.)

Calculation Methodology ICA is calculated from the concentration data from eight parameters (DO, TSS, COD, EC, TN, TP, pH, and CF), which are assigned a value that is extracted from quality graphs or equations, between a range of 0 - 1. The index is calculated as the weighted multiplication of the parameters, according to what was presented in ENA 2010 (IDEAM, 2010):

$$ICA = \sum 0{,}16 I_{DO} + 0{,}14 I_{TSS} + 0{,}14 I_{COD} + 0{,}14 I_{EC} + 0{,}14 I T_P / T_N + 0{,}14 I_{pH} + 0{,}14 I_{CF}$$

Once the indices values are obtained, ICA is calculated and qualified according to Table 1 matrix.

Table 1. ICA rating matrix

ICA Score		
Minimum	**Maximum**	**Rating**
0.00	0.25	Very bad
0.26	0.50	Bad
0.51	0.70	Regular
0.71	0.90	Acceptable
0.91	1.00	Good

Source: ENA 2010 (IDEAM, 2010).

Water Quality Index (WQI). CCME-WQI (Canadian Council of Ministers of the Environment Water Quality Index) is used by the District Department of the Environment (SDA) as a tool to determine the state and degree of compliance with the objectives for the main rivers of the city of Bogotá.

Calculation Methodology WQI is calculated from the concentration data of ten parameters (OD, BOD_5, COD, TSS, TN, TP, pH, MBAS, CF, FGO) (SDA, 2008):

$$WQI = 100 - \left(\frac{\sqrt{F1^2 + F2^2 + F3^2}}{1.732}\right)$$

F1, F2, and F3 variables are then calculated, representing different approaches to determine water quality.

Water quality objectives. They were based on Resolution 5731 of 2008, corresponding to ten parameters (DO, pH, BOD_5, COD, TN, TP, CF, FOG, TSS, and MBAS), as shown in table 2.

Table 2. Water quality objectives for Torca, Salitre, and Fucha basins

Parameter	Unit	Torca sections		Sections Salitre				Sections Fucha			
		I	II	I	II	III	IV	I	II	III	IV
OD	mg/L	5	2	8	5	2	2	8	5	0.5	0.5
BOD_5	mg/L	5	100	5	60	100	100	5	40	60	60
COD	mg/L	30	250	30	90	250	250	30	90	180	160
TN	mg/L	2	20	2	10	20	20	1.5	10	l0	10
TP	mg/L	0.2	1	0.2	1	1	1	0.1	1	1	1
TSS	mg/L	10	60	10	30	60	60	10	25	30	30
FOG	mg/L	10	10	10	10	10	10	10	10	10	10
Fecal coliforms	NMP/ 1000 mL	1,E+04	1,E+05	1.00 E+04	1.00 E +05	1,00 E +05	1.00 E +05	1.00 E +02	1.00 E +05	1.00 E +05	1.00 E +05
pH	Unit	6.5	6.5-8.5	6.5	6.5-8.5	6.5	6.5	6.5-8.5	6.5	6.5-8.5	6.5- 8.5
MBAS	mg/L	0.5	1	0.5	1	1	1	0.5	1	1	1

Source: Resolution 5731 of 2008.

Once the value of WQI has been determined, the quality of the point being evaluated can be classified according to the categories shown in table 4.

Table 4. WQI rating matrix

Minimum	Maximum	Rating
0	44	Poor
45	64	Marginal
65	79	Regular
80	94	Good
95	100	Excellent

Source: (SDA, 2008).

Index of Potential Alteration of Water Quality (IACAL). It measures the potential alteration of the water quality in a determined territory, from the contaminant load that is poured on the hydric resource in this area.

Calculation Methodology IACAL is calculated according to the methodology proposed by IDEAM (2010; 2014) that is, taking into account the pollutant loads of total suspended solids (TSS), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total nitrogen (TN) and total phosphorus (TP), measured in tons/year that are generated in a given basin. By knowing the existing pollutant loads of these five parameters in the studied basins, as well as the water supply available in this area, it is possible to calculate, on a scale of 1 to 5, how susceptible the water available is to be contaminated with these agents. The ratings that can be obtained after calculating IACAL are shown in table 5.

Table 5. IACAL rating index

Rating	Qualitative IACAL
1	Low
2	Moderate
3	Medium high
4	High
5	Very High

Source: (IDEAM, n.d.)

To calculate it, the total contaminant load (K), expressed in tons/year in each territory, must be determined according to the following equation:

$$K = K_P + K_{IND} + K_C + K_{SG} + K_Z$$

Where:
K_P: Polluting load coming from the population in t/year.
K_{IND}: Polluting load coming from the industry in t/year.
K_C: Polluting load coming from the coffee benefit in t/year.
K_{SG}: Polluting load from cattle slaughter in t/year.
K_Z: Polluting load coming from other economic activities in t/year.

Macroinvertebrates as Indicators of or Water Quality (MWQ) It is an index that represents the biological quality conditions of a course or body of water. It varies between below 15 and above

150. The higher the water quality the better. It is calculated on an annual basis or as determined by the regional authority.

Calculation Methodology. MWQ is calculated according to the methodology proposed by IDEAM (2010) based on sampling and identification of aquatic macroinvertebrates (benthic) at the family level, with presence/absence annotation in each sample. Classification of families found according to their level of tolerance to pollution, on a scale from 1 to 10. Table 6 shows the ratings that can be obtained after calculating MWQ.

Table 6. Rating categories of the MWQ

TYPE	QUALITY	BMWP/Col	MEANING	COLOUR
I	Good	> 150, 101 - 120	Very clean waters	Blue
II	Acceptable	61–100	Evidence of pollution effects	Green
III	Uncertain	36 - 60	Moderately polluted waters	Yellow
IV	Critical	16-35	Very polluted waters	Orange
V	Very Critical	<15	Strongly contaminated waters critical situation	Red

Source: EAB-ESP-EPAM S.A. (2014). Synthesis Document

The calculation is determined from the following equation:

$$MWQ = \Sigma (Fi * Pi)$$

Where:
Fi = Macroinvertebrate family present.
Pi = Score of each family (between 1 and 10).

FINDINGS AND DISCUSSION

Physical, chemical, microbiological, and biological parameters in the Torca basin

ICA. The results of ICA data correspond to the 2010-2015 period, in which the historical behavior is almost similar for the entire basin in all periods. Table 6 summarizes the values of ICA at all points in the most recent period available.

Table 6. ICA results in the Torca basin, year 2015

Basin		Torca	ICA Summary, year 2015			
N.°	**Point**	**Sector**	**Year**	**Semester**	**Numeric WQI**	**Qualitative WQI**
1	Bosque de Pinos	I	2015	I	0.80	Acceptable
2	Cl. 161 Dardanelos	I	2015	I	0.41	Bad
3	San Simón	II	2015	I	0.38	Bad
4	Club Guaymaral Entrance	II	2010	II	0.41	Bad

Source: EAB- Hidrocuencas consortium.

As it can be observed, the only point in the basin where there is an acceptable water quality is in **Bosque de Pinos**, because at this point the community respects and conserves the natural conditions of the water flow. At the other points, where the channel has been channeled and has received discharges from the city, a poor water quality rating is obtained.

The calculated ICA for the three monitoring campaigns registers a very similar behavior to the historical one. The monitored points of the high part of the basin (Bosque de Pinos and La Floresta Brook) have an acceptable quality, while in the middle and lower parts, the quality oscillates between regular and bad. (table 7).

Table 7 ICA results in the Torca basin, average campaigns

Basin		Torca	ICA summary, average			
N.°	**Point**	**Sector**	**Year**	**Semester**	**Numeric ICA**	**Qualitative ICA**
1	Bosque de Pinos	I	2016	I	0.76	Acceptable
2	Quebrada La Floresta	I	2016	I	0.71	Acceptable
3	Calle 161 Dardanelos	II	2016	I	0.53	Regular
4	San Simón	II	2016	I	0.38	Bad
5	Mouth	II	2016	I	0.40	Bad

Source: EAB- Hidrocuencas consortium.

WQI. The WQI results data correspond to the 2010-2015 period, in which the historical behavior is almost similar for the entire basin in all periods. WQI values of all points in the most recent period available are summarized in table 8.

Table 8 WQI results in the Torca basin, year 2015

Basin		Torca	WQI summary, year 2015			
Nº	**Point**	**Sector**	**Year**	**Semester**	**Numeric WQI**	**Qualitative WQI**
1	Bosque de Pinos	I	2015	I	71.69	Regular
2	Cl. 161 Dardanelos	I	2015	I	5.47	Poor
4	San Simón	II	2015	I	12.84	Poor
5	Club Guaymaral Entrance	II	2010	I	20.67	Poor

Source: EAB- Hidrocuencas consortium.

As observed, the WQI index showed similar results to the ICA.

The calculated WQI for the three monitoring campaigns registers a very similar behavior to the historical one. The monitored points of the high part of the basin, compared with the historical one, showed a variability between regular and marginal, and in the middle and lower parts of the basin, they had a poor quality.

IACAL. For the calculation of the indicator, secondary information was used according to the hydraulic sectors of the basin, analyzing them from the demographic and industrial loads, because in this area no coffee crops, livestock slaughter or other economic activities were reported. (See table 9).

Table 9. Summary of polluting loads in the Torca basin

Polluting loads		BOD t/year	COD t/year	COD-BOD t/year	TSS t/year	TN t/year	TP t/year	Total t/year
K_P	Fraction connected to the sewer system that pours directly into the Torca system	4237.05	9533.35	5296.31	6355.57	706.17	282.47	16,877.56
	Fraction connected to the sewer that pours into the Salitre basin	442.48	2395.29	1952.81	505.31	260.37	104.15	3265.12
	Fraction connected to septic tank	12.24	24.48	12.24	7.33	-	-	31.81
K_{IND}	Fraction connected to the sewer system that pours directly into the Torca system	588.54	810.67	222.12	411.63	-	-	1222.30
	Fraction connected to the sewer that pours into the Salitre basin	148.06	220.92	72.85	61.19	-	-	282.10
K		**5428.37**	**12,984.71**	**7556.34**	**7341.02**	**966.55**	**386.62**	**21,678.90**

Source: EAB- Hidrocuencas Consortium.

In all hydraulic sectors of the Torca basin, IACAL is rated as very high, which means that throughout this area, the pollutant load exerted by the demographic and industrial sectors is very large except in the high area of the basin.

MWQ. For the calculation of the indicator, information collected in the field of macroinvertebrate families was used, as shown in Table 10.

Table 10. MWQ Calculation in the Torca basin

Order	Family	Environmental tolerance Pi	Campaign 1 February 2016 (Fi)	Campaign 2 April 2016 (Fi)	Campaign 3 May 2016 (Fi)	Xfi	MWQ=ΣFi*P Annual
Bosques de Pinos							
Hypolobocera sp	Pseudothelpusidae	8	1	0	0	0	3
Chironominae	Chiromidae	2	1	1	1	1	2
Dactylobaetis sp	Baetidae	7	0	0	1	0	2
Physa sp	Physidae	3	0	1	1	1	2
TOTAL							9
Brook La Floresta							
Chironominae	*Chiromidae*	2	1	1	1	1	2
Dactylobaetis sp	*Baetidae*	7	1	1	0	1	5
Physa sp	*Physidae*	3	1	1	1	1	3
sp	*Glossiphoniidae*	3	1	0	1	1	2
TOTAL							12
San Simón							
Chironominae	*Chiromidae*	2	1	1	0	1	1
Physa sp	*Physidae*	3	1	1	0	1	2
Stilobezzia sp	*Ceratopogonodae*	3	0	1	0	0	1
TOTAL							4
Torca Mouth							0

Note**:** No specific river beds or streams were monitored**.**

Source: EAB- Hidrocuencas consortium.

The Torca basin has a Very Critical water quality that places it as Heavily Polluted Waters.

Physical, chemical, microbiological, and biological parameters in the Torca basin

ICA. The results of ICA data correspond to the 2006-2015 period, in which the historical behavior is almost similar for the entire basin in all periods. Table 11 summarizes the ICA values at all points in the most recent period.

Table 11. ICA results in the Salitre basin, year 2015

Basin		Salitre	WQI summary, year 2015			
N.°	**Point**	**Sector**	**Year**	**Semester**	**Numeric WQI**	**Qualitative WQI**
1	Brook Arzobispo	I	2015	I	0.75	Acceptable
2	Av. 68 with Cl. 80	III	2015	I	0.32	Bad
3	Wetland Cl. 98 Cra. 94G	IV	2015	I	0.32	Bad
4	Salitre WWTP	IV	2015	I	0.36	Bad

Source: EAB- Hidrocuencas consortium.

As observed, the only point in the basin where acceptable water quality is found is in Brook **Arzobispo**, in which the natural conditions of the water flow are conserved. At other points, where it has been channeled and has received discharges from the city, a bad water quality rating is obtained.

The ICA calculated for the three monitoring campaigns was carried out at high points in the basin and the lower part, while in the middle part only historical data were used. In table 11, it is observed that the water quality at the high gorges of the Salitre basin is still conserved, except that of Las Delicias, which presented flow only in winter season with a regular quality and Salitre WWTP point, corresponding to the discharge of the basin, bad quality.

Table 11. ICA results in the Torca basin, campaigns average

Basin		Salitre	ICA summary, average			
N.°	**Point**	**Sector**	**Year**	**Semester**	**Numeric ICA**	**Qualitative ICA**
1	Brook La Vieja	I	2016	I	0.76	Acceptable
2	Brook Las Delicias	I	2016	I	0.69	Regular
3	Brook Arzobispo	I	2016	I	0.74	Acceptable
4	Salitre WWTP	IV	2016	I	0.35	Bad

Source: EAB- Hidrocuencas consortium.

WQI. Historical WQI data correspond to the 2006-2015 period, in which the historical behavior is almost similar for the entire basin in all periods. (See table 12).

Table 12. WQI results in the Salitre basin, year 2015

N.°	Point	Sector	Year	Semester	Numeric WQI	Qualitative WQI
1	Quebrada Arzobispo	I	2015	I	67.42	Regular
2	Av. 68 with Cl. 80	III	2015	I	4.19	Poor
3	Wetland Cl. 98 Cra. 94G	IV	2015	I	8.55	Poor
4	Salitre WWTP	IV	2015	I	3.55	Poor

Source: EAB- Hidrocuencas consortium.

The WQI calculated for the three monitoring campaigns shows a very similar behavior, where the monitored points from the high part, compared with historical data, showed a variability between regular and marginal and a poor quality in the lower part of the basin.

IACAL. To calculate the indicator, secondary information was used according to the hydraulic sectors of the basin, analyzing them from the demographic and industrial load, because in this area no coffee crops, livestock slaughter, and other economic activities were reported, as shown in table 13.

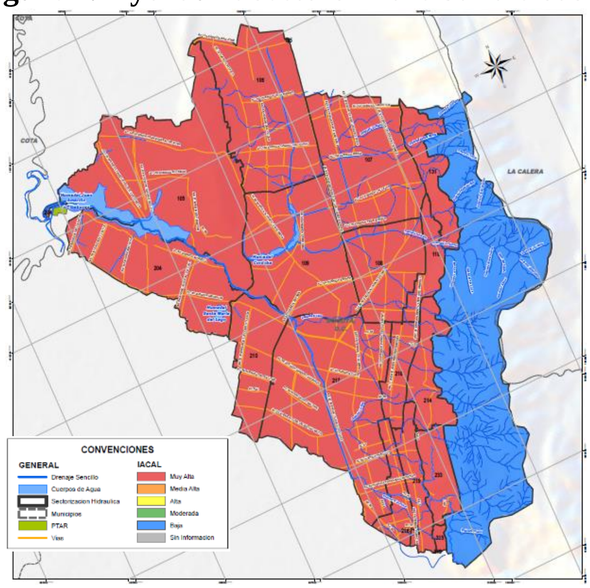
Table 13. Summary of pollutant loads, Salitre basin

Polluting loads	BOD t/year	COD t/year	COD-BOD t/year	SST t/year	NT t/year	PT t/year	Total t/year
K_P	14,752.3	33,192.6	18,440.3	22.128.4	2458.7	983.5	58,763.2
K_{IND}	5493.4	7952.9	2459.5	4817.0	-	-	12,769.8
K	20,245.6	41,145.4	20,899.8	26,945.3	2458.7	983.5	71,533.0
Salitre WWTP removal	11,888.5	-	-	19,514.6	-	-	-
% of remaining contaminant load	41.28%	100.00%	100.00%	27.58%	100.00%	100.00%	56.10%
Final K	8357.2	41,145.4	20,899.8	7430.7	2458.7	983.5	40,129.9

Source: EAB- Hidrocuencas consortium.

IACAL results for the hydraulic sectors of the Salitre basin are presented below (figure 2).

Figure 2. Hydraulic sectors in the Salitre basin



Source: EAB- Hidrocuencas consortium, with cartographic base from IGAC (2016).

As observed, all the hydraulic sectors are illustrated in red, corresponding to a very high IACAL, and the high part, which is not within any hydraulic sector and has no population or industries that potentially contaminate the water, is illustrated in blue, corresponding to a low IACAL.

MWQ. For the calculation of the indicator, information collected in the field of macroinvertebrate families was used, as shown in Table 14.

Table 14. Calculation of MWQ in the Salitre basin

Order	Family	Environmental tolerance Pi	Campaign 1 February 2016 (Fi)	Campaign 2 April 2016 (Fi)	Campaign 3 May 2016 (Fi)	Xfi	MWQ=ΣFi*P Annual
Brook La Vieja							
Psephenops	Psephenidae	10	1	0	1	1	7
Hyalella sp	Hyalellidae	7	1	1	0	1	5
Atopsyche sp	Hydrobiosidae	9	1	1	1	1	9
Atanatolica sp	Leptoceridae	8	1	0	0	0	3
Dactylobaetis sp	Baetidae	7	1	1	1	1	7
sp	Glossiphoniidae	3	1	0	1	1	2
Chironominae	Chiromidae	2	1	1	1	1	2
TOTAL							**34**
Brook Las Delicias							
sp	Tubificidae	1	0	1	0	0	0
Atopsyche sp	Hydrobiosidae	9	0	0	1	0	3
Dactylobaetis sp	Baetidae	7	0	1	1	1	5
Coryphaeshna sp	Aeshnidae	6	0	1	0	0	2
Chironominae	Chiromidae	2	0	1	1	1	1
Hyalella sp	Hyalellidae	7	0	1	0	0	2
TOTAL							14
Brook Arzobispo							
Atopsyche sp	Hydrobiosidae	9	1	1	1	1	9
Atanatolica sp	Leptoceridae	8	1	1	1	1	8
Triplectides sp	Leptoceridae		1	0	0	0	
Coryphaeshna sp	Aeshnidae	6	0	1	1	1	4
Chironominae	Chiromidae	2	1	1	1	1	2
Stilobezzia sp	Ceratopogonodae	3	0	0	1	0	1
TOTAL							24
Salitre WWTP							0

Note**:** No specific river beds or streams were monitored**.**

Source: EAB- Hidrocuencas consortium.

The Salitre basin shows a deterioration in its water quality from the highest part towards its mouth, with critical quality conditions that corresponds to Very Polluted Waters and near the mouth presents very critical conditions characteristic of Heavily Polluted Waters.

Physical, chemical, microbiological, and biological parameters in the Torca basin

ICA. Historical ICA data correspond to the 2006-2015 period, in which the historical behavior is almost similar for the entire basin in all periods. (See table 15).

Table 15. ICA results in the Fucha basin, year 2015

Basin		Fucha	ICA Summary, most recent period			
N.°	**Point**	**Sector**	**Year**	**Semester**	**Numeric ICA**	**Qualitative ICA**
1	El Delirio	I	2015	I	0.80	Acceptable
2	Railroad Av.	III	2015	I	0.33	Bad
3	Av. Americas	III	2015	I	0.32	Bad
4	Av. Boyacá	IV	2015	I	0.32	Bad
5	Mouth	IV	2015	I	0.26	Bad

Source: EAB- Hidrocuencas consortium.

As observed, **El Delirio** is the only point in the basin where there is an acceptable water quality, because the natural conditions of the water flow are conserved. At the other points, where it has been channeled and has received discharges from the city, a bad water quality rating is obtained. The middle part was not monitored, because the SDA has historical records.

WQI. Historical WQI data correspond to the 2006-2015 period, in which the historical behavior is almost similar for the entire basin in all periods. (See table 16).

Table 16. ICA results in the Fucha basin, year 2015

Basin		Fucha	WQI summary, year 2015			
N.°	**Point**	**Sector**	**Year**	**Semester**	**Numeric WQI**	**Qualitative WQI**
1	El Delirio	I	2015	I	63.47	Marginal
2	Av. Ferrocarril	III	2015	I	6.73	Poor
3	Av. Americas	III	2015	I	6.90	Poor
4	Av. Boyacá	IV	2015	I	5.43	Poor
5	Mouth	IV	2015	I	7.93	Poor

Source: EAB- Hidrocuencas consortium.

The WQI calculated for the three monitoring campaigns shows a very similar behavior, where the points monitored from the high part compared with the historical one, registered a marginal quality and in the lower part of the basin, they had a poor quality.

IACAL. To calculate the indicator, secondary information was used, according to the hydraulic sectors of the basin, analyzing them from the population, industrial, and livestock slaughter load, because in this area coffee crops and other economic activities were not reported. (See table 17).

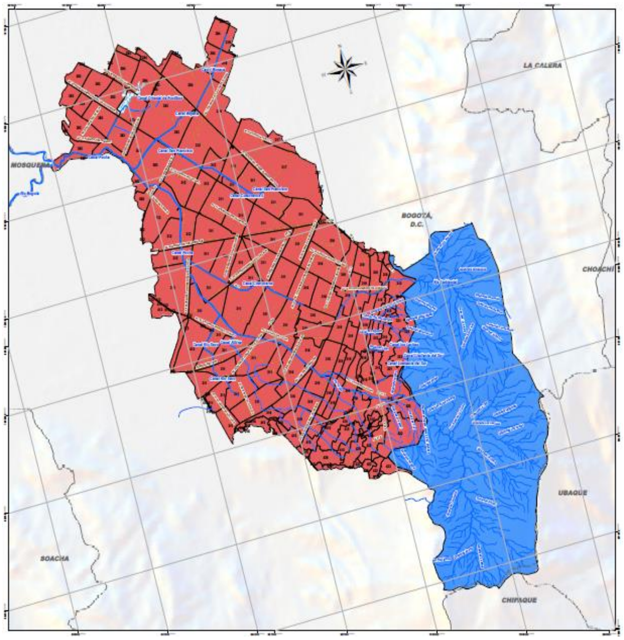
Table 17. Summary of polluting loads in the Torca basin

Polluting loads	BOD t/year	COD t/year	COD-BOD t/year	SST t/year	NT t/year	PT t/year	Total t/year
K_P	29,382.46	66,110.53	36,728.07	44,073.69	4897.08	1958.83	117,040.13
K_{IND}	23.102.36	32,819.77	9717.41	11,806.94	0.00	0.00	44,626.71
K_{SG}	5.4	10.56	5.16	2.4	-	-	23.52
K_C	-	-	-	-	-	-	-
K_Z	-	-	-	-	-	-	-
K	**52,490.22**	**98,940.86**	**46,450.64**	**55,883.03**	**4897.08**	**1958.83**	**161,690.36**

Source: EAB- Hidrocuencas consortium.

Figure 3 shows the results of IACAL for the hydraulic sectors of the Fucha river basin.

Figure 3. Hydraulic sectors in the Fucha river basin.



Source: EAB- Hidrocuencas consortium, with cartographic base from IGAC (2004).

As observed, all the hydraulic sectors are illustrated in red, corresponding to a very high IACAL, and the high part, which is not within any hydraulic sector and has no population or industries that potentially contaminate the water, is illustrated in blue, corresponding to a low IACAL. Because in this sector of the Eastern hills there is no industry or population, IACAL obtains the best possible rating.

MWQ. For the calculation of the indicator, information collected in the field of macroinvertebrate families was used, as shown in Table 18.

Table 18. Calculation of IMA in the Fucha basin

Order	Family	Environmental tolerance Pi	Campaign 1 February 2016 (Fi)	Campaign 2 April 2016 (Fi)	Campaign 3 May 2016 (Fi)	Xfi	MWQ=ΣFi*P Annual
Brook San Francisco							
Stilobezzia sp	Ceratopogonodae	3	1	0	1	1	2
Chironominae	Chiromidae	2	1	0	0	0	1
Atanatolica sp	Leptoceridae	8	1	1	1	1	8
Atopsyche sp	Hydrobiosidae	9	1	1	0	1	6
sp	Tubificidae	1	1	0	0	0	0
Hyalella sp	Hyalellidae	7	1	1	0	1	5
sp	Tubificidae	1	0	0	1	0	0
Hyalella sp	Hyalellidae	7	0	0	1	0	2
TOTAL							24
Brook El Delirio							
Chironominae	Chiromidae	2	1	1	1	1	2
Atanatolica sp	Leptoceridae	8	1	1	0	1	5

Order	Family	Environmental tolerance Pi	Campaign 1 February 2016 (Fi)	Campaign 2 April 2016 (Fi)	Campaign 3 May 2016 (Fi)	Xfi	MWQ=ΣFi*P Annual
Atopsyche sp	Hydrobiosidae	9	1	1	0	1	6
sp	Tubificidae	1	0	0	0	0	0
Baetodes sp	Baetidae	7	0	1	1	1	5
Cylloepus sp	Elmidae	6	0	1	1	1	4
Coryphaeshna sp	Aeshnidae	5	0	0	1	0	2
TOTAL							24
Fucha Mouth							0

Note: No specific river beds or streams were monitored.

Source: EAB- Hidrocuencas consortium.

The Salitre basin shows a deterioration in its water quality from the highest part towards the mouth, with critical quality conditions that corresponds to Very Polluted Waters and near the mouth presents very critical conditions characteristic of Heavily Polluted Waters.

CONCLUSIONS

Torca Basin. The results obtained from the ICA and WQI agree with the reality of the basin. In the high part of the basin the water quality is acceptable because there are not so many discharges, while in its middle and lower parts its quality deteriorates due to the fact that currently no pre-treatment of the wastewater is done before being discharged into the Torca River, which is reflected in the results of the MWQ as Strongly Polluted Waters (Sánchez Londoño, 2017).

Salitre Basin. The results obtained from the ICA and WQI only maintain acceptable conditions in the upper basin because at that point no type of discharge is received. On the other hand, since Bogotá has no previous treatment of the wastewater before being dumped on the water of Salitre, as soon as the stream begins to receive discharges, it becomes contaminated. This is the determining factor for the quality of the water in the other points to be classified as bad (Sánchez Londoño, 2017).

Fucha Basin The results obtained from the ICA and WQI only maintain acceptable conditions in the upper basin because at that point no type of dumping is received. When the river meets the city, it begins to receive many discharges and wrong connections that have deteriorated the quality of the source (Sánchez Londoño, 2017).

In the case of MWQ, for the Salitre and Fucha basins, they present a deterioration in their water quality from the highest part to the mouth, there are critical quality conditions that correspond to Very Polluted Waters and very critical conditions near the mouth, characteristic of Heavily Polluted Waters.

Water from urban basins, such as Torca, Salitre, and Fucha, has a high IACAL, because of the high BOD_5 and COD coming from demographic and industrial factors.

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