Biological and Physiochemical Conditions of the Surface Waters of the Cauca River in the Urban Area of Popayán, Colombia[*]

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Abstract

The homes and companies located on the banks of the Cauca River have altered the conditions of the quality of the water generated by residual discharges. Therefore, this paper proposes to analyze the biological and physicochemical conditions of the surface waters that cross the urban area of Popayán, Colombia, and determine if they are suitable for human consumption. For this, an in-situ sampling was carried out in the two river stations. The two points were covered taking into account the dry and rainy seasons. At each point, the parameters were measured to calculate the contamination indicators. Likewise, Ph, diluted oxygen, conductivity and temperature parameters were measured, also other physicochemical parameters such as total alkalinity, total hardness, total phosphorus and suspended total solids were measured as well as the microbiological parameters like total coliforms. It was found that the water source contains high levels of pollutant load and that biological discharge is one of the main causes that alters the quality of the water for drinking. The number of macroinvertebrates in the river decreases by 48% as the river advances through the urban area of the city. According to the BMWP values, highly contaminated carbonated waters enter the urban area. However, due to the flow throughout the water source, the Cauca River can regulate the pollution load according to the result evidenced in the Icomi, Icomo, and Icosus indices.

Keywords: coliform; physicochemical conditions of sweet water, river-banks, biological discharges in rivers.

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Condiciones biológicas y fisicoquímicas de las aguas superficiales del río Cauca en el área urbana de Popayán, Colombia

Resumen

Los hogares y empresas ubicadas en la rivera del río Cauca han alterado las condiciones de calidad del agua debido al desecho de aguas residuales. Por lo tanto, este artículo propone analizar las condiciones biológicas y fisicoquímicas de las aguas superficiales que cruzan el área urbana de Popayán, Colombia, con el fin de determinar si son aptas para consumo humano. Para ello, se recolectaron pruebas *in situ* en ambas estaciones. Los dos puntos fueron cubiertos teniendo en cuenta las temporadas seca y lluviosa. En cada punto, los parámetros fueron medidos con el fin de calcular los indicadores de contaminación. De igual manera, el Ph, el oxígeno diluido, las conductividad y la temperatura fueron medidos; así como otros parámetros fisicoquímicos como alcalinidad total, dureza total, fósforo total y sólidos suspendidos totales. También se midieron parámetros biológicos como la presencia total de coliformes. Se encontró que la fuente de agua contiene altos niveles de carga contaminante y que la descarga biológica es una de las principales razones por las que se altera la calidad del agua para su consumo. El número de macroinvertebrados en el río disminuye en un 48 % a medida que el río avanza por el área urbana de la ciudad. De acuerdo a los valores de BMWP, aguas carbonatadas altamente contaminadas ingresan a la ciudad. Sin embargo, debido al flujo a través de la fuente hídrica, el río Cauca puede regular su carga contaminante según lo que se evidencia en los índices Icomi, Icomo e Icosus.

Palabras clave: coliformes; condiciones fisicoquímicas del agua dulce, riberas, descarga biológica en ríos.

1. INTRODUCTION

Sweet waters are a non-renewable resource; its annual availability is limited, and the demand is rising. Thus, the water footprint has exceeded sustainable levels, due to the lack of environmental awareness, which leads consumers to substitute more polluting products for others that generate a lower water footprint [1]. The valuation of macroinvertebrates become a good indicator to determine the quality of surface water through standardized references for its analysis and prevention of health risks for the communities that depend on the river [2].

Global research points those anthropogenic activities strongly influence the habitat conditions of rivers and the patterns of the surrounding landscape and, generally, bacteria associated with feces are found, becoming indicators of water contamination [3]. The authors also point out about the results of the bioindicators, in order to identify the causes of contamination on rivers considered threatened centers of biodiversity due to anthropogenic activity and generate a proposal about restructuring of the government management plans [4].

Therefore, the hydric sources contaminated due to feces flow into the oceans are directly affecting the aquatic life, causing a negative impact within the ecological, human and economic sector [5], but, in occasions it's not only due to anthropogenic actions but also to the feces generated by animals that are discharged into the rivers [6]. Likewise, the surface waters have been also highly contaminated by industrial effluents or sewage water; for example, an assessment has been carried out through physicochemical and biological parameters that demonstrate the alteration of the indicators on the biological oxygen demand, the total suspended solids, total nitrogen and the electric conductivity that compromise the use of the water for agricultural and industrial activities [7].

Other studies have shown that river contamination is even higher due to the presence of chemical and metal substances as well as microbial agents that all compromise the existence of industrial hydric sources [8]. In this regard, an investigation determined that in the valuation of surface waters, it's sometimes difficult to describe quality conditions due to the spatial variability of pollutants and the wide range of indicators that are identified through biological, physical and chemical parameters [9]. Also, the contamination of the urban rivers affects the fluvial ecosystem as well, which also lead to repercussion in the reservoirs that flow into the rivers again altering with higher impact the habitats and reducing the natural flow, scattering the living organism and affecting the physicochemical parameters [10].

Nowadays, authors keep suggesting a quantitative and qualitative research methodology in order to compare the observed loads in the rivers and thus minimize the environmental impact [8]. There are also other studies that evaluate through bio evaluation tools the anthropogenic pressure over the river taking into account the relationship between the composition, the chemical contamination of the sediments and the structure of the macroinvertebrate community [11]. Other research determined that climate change also affects the natural conditions of rivers as well as the flow of regimes of the water source and, consequently, compromises the taxonomic and functional diversity of freshwater, according to taxonomic and functional freshwater analysis [12].

Therefore, the studies focus on biomonitoring in freshwater to assess the ecological status and biodiversity of rivers using macroinvertebrates as bio indicators of disturbed water quality due to agricultural and urban activities that affect the sustainability of the water source [13]. Certainly, it's important to take into account the soil characteristics, the height level and the climate, since this allows a greater record of information on the conditions of the macroinvertebrate family and the richness of taxa and the effects on biodiversity due to anthropogenic activity [14].

To evaluate de quality of the water, some researchers utilize analysis in which correlation become one of the main factors in order to obtain more integral results about the microbiological parameters that indicate contamination caused by human or animal feces, the indicators of natural contamination and the physicochemical parameters [15]. There are also studies in which the physicochemical parameters showed encouraging findings regarding water quality, but in regard to biological results, they showed the presence of coliforms, which increases the presence of suspended solids [16]. Previous research has shown that microbiological and physicochemical tests besides identifying coliforms and levels of temperature, pH, dissolved oxygen and electrical conductivity among other parameters has also led to generating actions aimed at decontaminating rivers and trying to maintain their natural conditions.

Now, the valuation of the water source not only depends on the identification of the quality parameters but also on permanent monitoring through samples that verify the sustainability of the water source [17]. A study based on the physicochemical and biological parameters of a river proposes, based on quality management processes, the support of the government and stakeholders to mitigate the environmental impact generated by discharges on surface sources, achieving greater water sustainability [18].

On the Colombian territory, nucleus with precipitation exceeding 4,000 millimeters per year stand out, in the Pacific there are extremely rainy areas located in the

departaments of Cauca and Choco, in these areas the precipitation exceeds 10,000 milleters per year [19].

In the country, studies on coliforms have been carried out to establish the conditions of the water sources that run through the urban area of the cities, among those researches, there is on focus on physicochemical characterization of the water of the La Toma stream in the municipality of Neiva, Huila, which concludes that due to the impact on water quality, a conservation, restoration and protection program is required, under the responsibility of government entities [20].

Focusing in particular on the Cauca River, the urban head of the municipality of Popayán, it is considered the largest part of the department of Cauca with the higher water consumption levels; the water resource is used for domestic, industrial, livestock consumption and crop irrigation. In all its extension, the municipality is crossed by the great Cauca River basin, which, however, is not possible to use in this sector due to the fact that the Vinagre River connects its waters, into which residues from the Purace's sulfur mine fall. The Cauca River occasionally supplies water to the El Tablazo drinking water treatment plant [21].

In the local ambit, a study determined the environmental flow in the sub-basin of the Las Piedras River which after passing through Popayan city becomes the Cauca River; this, in correlation with physicochemical variables and water quality indices. One of the conclusions is that biotic integrity for the macroinvertebrate community allowed to identify that the study area has a good or excellent quality of the water resource, which is necessary to justify this result with the identification of the biotic quality index for a wide variety of communities that are specific to the studied riverbed [22].

There also exist processes for quick evaluation of environmental pollution, which is a practical way to assess the discharges produced by each generator or group of similar generating sources in a study area, which is based on the experience that has been widely documented in the past about nature and the quantity of pollutants generated with and without associated control systems [23].

2. MATERIALS AND METHODS

Study site

The study took place in the Cauca River within the urban perimeter of Popayán city.

Geo-reference

The city of Popayán is the capital of the Cauca department in Colombia and has a population of 328.139 habitants [24]. Its located at an altitude of 1.738 meters above

the sea level, with an average temperature of 19 ºC; its located at 2º27´north and 76º37´18´´west longitude of the Greenwich Meridian; the territorial extension is 512 Km² [25] (figure 1).
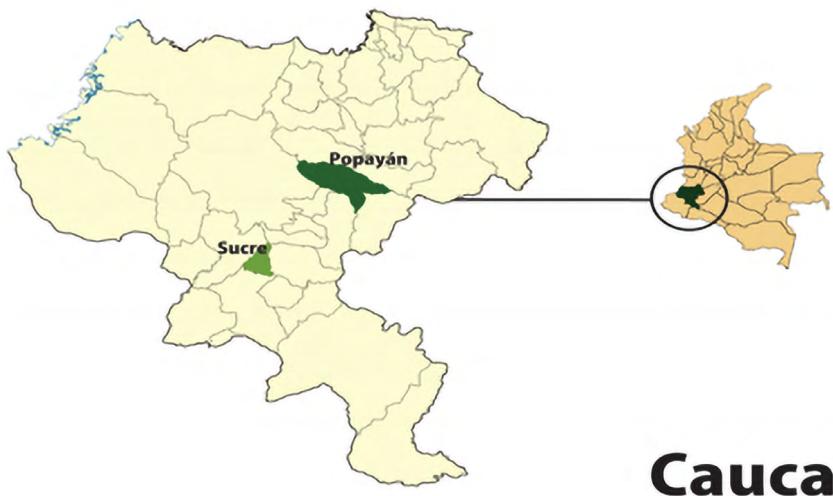

Figure 1: Location of Popayán city in Colombia
Source: [26].

Cauca River makes the journey through the urban area of Popayán city from east to west with a longitude of 10 Km; starts in the Gonzáles neighborhood and ends its path in the Valle el Ortigal neighborhood finally fed by the rivers Ejido and Molino which also go through the urban area (figure 2).
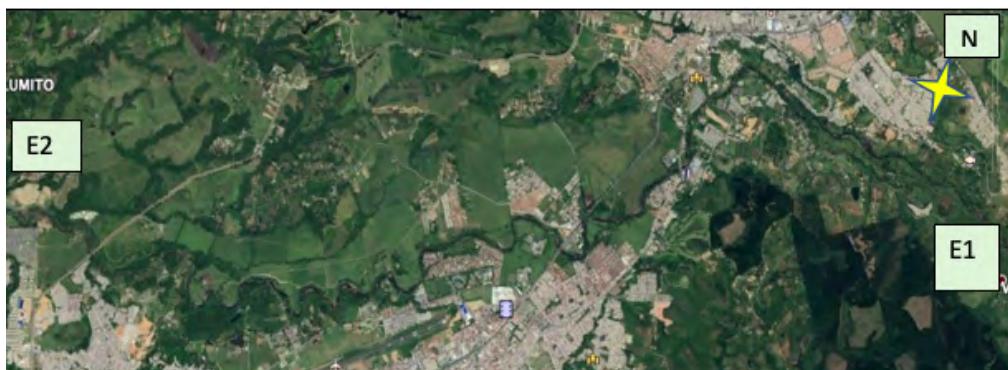

Figure 2. Location of the Cauca River in Popayán city
Source: Google Earth.

Physicochemical variables

The two sampling points were covered taking into account the dry and rainy seasons. At each point, only the parameters necessary to calculate pollution indices (ICOS) proposed by Ramírez and Viña were measured [27]. In situ, the pH, dissolved oxygen, conductivity and temperature parameters were taken; with a multiparametric probe; the other physicochemical parameters such as total alkalinity (ALKT), total hardness (DURT), total phosphorus (P_TOT), total suspended solids (SST), BOD5 (BOD) and total coliforms (COLT), were measured in the laboratory.

The indices allow us to quantify the degree of contamination of the water with respect to its general conditions and not to specific pollutants, since the fundamental properties of the waters are combined. For this reason, they are variables that are regularly determined in any limnological or environmental study, despite the fact that most of them are not even contemplated in national legislation, which is why they are of special interest [28].

Table 1. Qualification of the quality of the water according to the values taken by the ICOS

ICO	Grade of contamination	Range of color
>0,8 – 1,0	Higher	
>0,6 – 0,8	High	
>0,4 – 0,6	Medium	
>0,2 - 0,4	Low	
0 – 0,2	None	
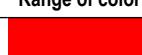
Source: own elaboration.

Structure and macroinvertebrates composition

The recollection and treatment method of the field samples were donde according to the established methodology by Roldán & Ramírez [29] to the biological analysis based on aquatic macroinvertebrates. In order to collect as many individuals as possible, each of the possible habitats were searched for the sampling points of each river. The collection was carried out with the flotation method, where the benthos network was used (Diameter: 500 microns; Size 25 cm x 40 cm) and was set against the current. The substrate was removed during a five-to-ten-minutes period, doing sampling on the different site micro-habitats; the collected individuals were deposited on 70 % alcohol jars. The samples were revised in the laboratory and got identified with the taxonomic identification guide.

Bio-indication of water quality

Based on the biological parameters to do spatial and temporal integration of the organisms and the structure of its community, the BMWP/col, consists of assigning a bio-indication value to each one of the macroinvertebrate taxonomic families [28]. The method only requires reaching the family level and the data are qualitative. The score ranges from 1 to 10 according to the tolerance of the groups to organic contamination. The most sensitive families receive a score of 10. On the other hand, the most tolerant to pollution receive a score of 1. The sum of the scores of all the families provides the total BMWP/Col score.

Analysis and treatment of the information

ICATEST program was implanted V 1.0 [30] to quantify the level of contamination on the river waters using the proposed indices of Ramírez et al. [26]; by ICOMI, mineral contamination index that includes the variables: conductivity, total hardness and alkalinity; ICOSUS contamination index by suspended solids and ICOMO contamination index by organic matter that involves the variables (BOD, total coliforms and percentage of oxygen saturation).

3.   RESULTS AND DISCUSSION

Structure and macroinvertebrates composition

The macroinvertebrate community at sampling points E1 and E2 of the Cauca River was represented by 50 individuals, belonging to 4 orders and 4 families (table 2). That is to say, the number of individuals decreases depending on the passage of the riverbed through the urban area of the city of Popayán. This is due, perhaps, to the extraction of fluvial material from the river,which causes a deterioration in the quality of water and prevents macroinvertebrate communities from developing.

Table 2. Taxonomic listing of the aquatic macroinvertebrate community present on the sampling points

River	Point	Class	Order	Family	Number Ind
Cauca	E1	Insecta	Dipteros	Chironomidae	18
			Trichoptera	Leptoceridae	15
Cauca	E2	Insecta	Basommatophora	Lymnaeidae	9
			Rhynchobdellida	Glossiphoniidae	8

Source: own elaboration.

The collection and abundance of macroinvertebrates in Station 1 was scarce; It was only possible to identify the Leptoceridae and Crironomidae, these are evidenced in figure 3.
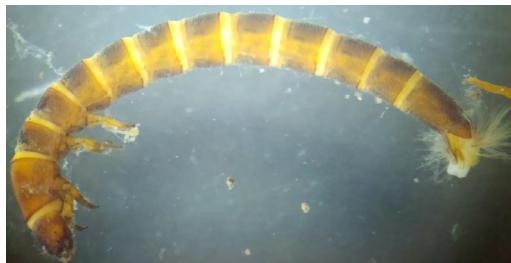

Family: Leptoceridae   Family:Chironomidae

Figure 3. Findings on the macroinvertebrates family found on the Cauca River station one

Source: own elaboration

In Station 2, two families of macroinvertebrates were identified: Tubificidae and Tipulidae.

Family:Glossiphoniidae   Family:Lymnaeidae   Family:Dolychopodidae

Figure 4. Families of macroinvertebrates found on the second station – Cauca River

Source: own elaboration.

Bio-indication of the quality of the water

Taking into account the families of aquatic macroinvertebrates present in the river, the BMWP/Col index was implemented as an average score by taxon, for the evaluation of the points of each body of water. According to the index, the points of the Cauca River (E1 and E2) are classified in class IV, being heavily polluted waters. The score is assigned based on the sensitivity to organic pollution and oxygen variations in the river. This water quality is corroborated with the physicochemical parameters reported in the points, since they presented low oxygen concentration values. It is important to note, that the Cauca River was classified as heavily polluted waters, due to the small amount of insects and families found in stations E1 and E2, which is caused by

the deterioration of the ecological niche and the exploitation that the river suffers before entering the city.

In the first station of the Cauca River (E1), there were waters with pollution effects. In the second station (E2), the water source is classified in class IV, that is, heavily polluted water (table 3).

Table 3. Taxonomic listing of the aquatic macroinvertebrate's community present on the sampling points.

Point	BMWP/Col Value	Meaning	Class
Cauca (E1)	10	Highly contaminated waters	IV
Cauca (E2)	10	Highly contaminated waters	IV

Source: own elaboration.

Physicochemical results

The results of the physicochemical and bacteriological variables analyzed during the study period for the Cauca River showed that the conductivity, alkalinity, total hardness, pH, dissolved oxygen, percentage of oxygen saturation and the BOD, showed few variations. However, the suspended solid variables and coliforms were the ones that showed the most variation.

The pH in the Cauca River, at the two sampling points, were similar (table 5): slightly acidic (E1: 4.67 and E2: 4.73), but their values are within the limits for the survival of aquatic organisms. (4.5 to 8.5), according to Roldán & Ramírez [29]. However, this variable can be related to the low abundance and richness of aquatic macroinvertebrates present at both sampling points. For this reason, an assessment of the ecological conditions of the Cauca River upstream from the E1 sampling point is necessary to establish the causes of the low representativeness of the aquatic macroinvertebrates.

Table 4. Average results of the physical and chemical parameters, taken In situ

River	Point	pH	DO%	T (°C)	Conductivity (µS)
Cauca	E1	4,67	72,5	13,23	44,2
	E2	4,73	71,7	14,5	77,8

Source: own elaboration

The alkalinity for points E1 and E2 of the Cauca River report values of <10 mg CaCO3 / L (table 5), below the maximum permissible alkalinity value (200 mg / l CaCO3), according to national standards in water quality. Therefore, the waters of the Cauca River can maintain and regulate ecological and productivity processes.

The low conductivity may be related to the lack of complex and stratified vegetation coverage in each of the two points.

Regarding the BOD values <10 mg / l found in the two sampling points, E1 and E2, the resilience and tolerance of the Cauca River can be observed to withstand the load of pollutants that are delivered to its waters during the passage through the urban area of the city: maintains stable physical and chemical values.

Table 5. Results of the physical and chemical parameters determined by the Environmental laboratory

Parameters	Points	
	Cauca E1	Cauca E2
Total Coliforms (NMP/100mL)	<1000	<1000
Total Alcalinity (mg CaCO3/L)	<10	<10
Total hardness (mg CaCO3/L)	71,06	78,66
Phosphorus (mgP-PO4/L)	<0,08	<0,08
Suspended solids (mg/L)	<20	22.50
DBO (mg/L)	<10	<10

Source: own elaboration.

The ICA results for the Cauca River allow us to infer that the waters before entering the urban area (E1) and after leaving the urban area of the city (E2) present an indicator for mineralization contamination of 0.067 and 0.12 respectively, and by suspended solids 0.037 and 0.048 respectively. However, the results of the ICOMO organic matter contamination indicator, report that the waters of the Cauca River, upon entering the urban area of the city of Popayán, present low contamination by organic matter; this increases its values when leaving the urban area but remains within the limits of low contamination of the ICOMO (Table 6). The ICOMO indicator on this river is clearly affected by the domestic and corporate sewage discharge, evidenced during the course of the field phase.

In relation to the variability of the diversity indices, BMWP and ICA, do not coincide and show that the Cauca River, from its arrival and passage through the urban area of the city of Popayán, presents good water quality conditions in physical and chemical parameters, but with the particularity of presenting a class of insects of the order: Dipteros, Trichoptera, Basommatophora and Rhynchobdellida with a consi- derable number of individuals belonging to the Chiromidae family (18), Leptoceridae (15), Lymnaeidae (9) and Glossiphoniidae (8) respectively, as with a BMWP indicator that categorizes it as heavily polluted water.

It should be taken into account that the total coliforms of stations E1 and E2 registered values lower than 1000 MPN / 100mL (table 6).

Table 6: Values of the aquatic pollution indices: ICOMI, ICOMO, ICOSUS
proposed by Ramírez and Viña [27]

River	Point	ICOMI	Quality indicators	ICOMO	Quality indicators	ICOSUS	Quality indicators
Cauca	E1	0,067	None	0,298	Low	0,037	None
	E2	0,12	None	0,391	Low	0,048	None

Source: own elaboration.

According to Decree 1594 of 1984, these values do not exceed the permissible limits for various uses. This situation may be due to the fact that, although municipal wastewater discharges occur and there are alterations to the landscape and the riverbed during its passage through the city, it still presents the necessary ecological conditions to maintain its physical integrity.

4. CONCLUSIONS

Regarding the macroinvertebrate family, the number of individuals decreases by 48 % as the river advances its route through the urban area of the city.

The hydric source tries to stabilize itself through the self-purification of the water course, diluting the biological pollutant load generated by anthropogenic actions.

Based on the results of the physicochemical parameters, the electrical conductivity may be related to the low vegetation coverage. It is suggested to carry out a study to identify the ecological conditions of the Cauca River prior to entering the urban area of the city, due to the existence of low abundance and richness of aquatic macroinvertebrates.

The current state of the Cauca river in regards to the results obtained in the BMWP/ Col values and what is registered by the ICOMI, ICOMO and ICOSUS indicators, shows that at the moment the water is not suitable for human consumption.

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