ANALYSIS OF ENVIRONMENTAL IMPACTS ASSOCIATED WITH WATER QUALITY OF THE BOGOTÁ RIVER

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Abstract

This investigation analyzed the impact of changes in water quality, emphasizing the importance not only to describe the causes of these changes but also the effects it has on ecosystems and the population present in the area of influence. The contamination of water sources and the ensuing changes in the physical and chemical conditions of the water are considered to be a cumulative impact because, over time, it triggers other effects on the health of ecosystems and people. The environmental impacts associated with water quality were identified and evaluated with the methodology proposed by Conesa (2010), and changes in habitat together with the impact on aquatic ecosystems and ecological flow were determined to be the major agents of change. By contrast, the least significant impacts were noise generation, emission of particulate matter, and slope instability. Extractive mining, followed by agricultural, livestock, and industrial activities generated the greatest impact on the environment. However, the difference found was only of one point on the rating scale, and all of these activities were classified as moderate. Analysis of actions that generate impact determined that the most important one, on average, is inadequate use of the soil, followed by the generation of dump sites. Estimation of the environmental impact associated with the water quality of the Bogotá River underscored that changes in water quality were classified as a critical impact. Among those areas severely impacted were alteration of landscape, wetland system, and the population's health. Among those with the lowest scores were noise generation, gas emissions, and odors. A software tool was designed to validate the

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methodology developed for analysis of said environmental impact associated with the water quality of the Bogotá River.

Keywords

Water, water management, water quality, environmental impact, Bogotá River.

Introduction

According to the Basin Management Plan (Plan de ordenamiento de cuenca or POMCA) of the Bogotá River [1], the headwaters of Bogotá River water system are at 3300 meters above sea level in the municipality of Villapinzón, and it flows into the Magdalena River at 280 meters above sea level in the municipality of Girardot. The river is made up of a natural system of ravines, rivers, lagoons, and wetlands that in most cases are tributaries of the Bogotá River and its regulation system, consisting of nine reservoirs and an irrigation district.

The Bogotá River basin is a second-order stream, which covers a total area of 589,143 ha, including 19 sub-basins, of which 547,608.21 ha correspond to 18 sub-basins (excluding the Tunjuelito River sub-basin). It provides water to the department of Cundinamarca and takes up 32% of its total surface [1].

The upper basin of the Bogotá River includes the section located between the monitoring points upstream of Villlapinzón (PM 1) and LG Puente Vargas Station (PM 32), and it receives direct or indirect discharge from the municipalities of Villapinzón, Chocontá, Suesca, Sesquilé, Guatavita, Gachancipá, Tocancipá, Cogua, Nemocón, Zipaquirá, Sopo, and part of La Calera and Cájica [1].

According to the Government of Cundinamarca [2], on the so-called La Virgen bridge, where the river is fed by important sources such as the Siecha, Aves, Neusa, and Teusacá rivers, and through the transfer of basins, it receives contributions from the Chuza, Guatiquía, and Blanco river basins. These supply the Bogotá and guarantee flow for the Chingaza and San Rafael reservoir system, characterized by a river whose headwaters are considered to be uncontaminated. However, the end of this sector presents a type 2 level, a consequence of the discharge of industrial water and some urban areas that cause deterioration to the water resource. Nevertheless, the river in this sector is used for crop irrigation given its high quality.

Although changes in water quality were analyzed by this investigation, it is important not only to describe the causes that generate it but also the effects it has on ecosystems and the population present in the area of influence. Contamination of water sources and the ensuing alteration of the physical-chemical conditions of the water have a cumulative impact by triggering other factors on the health of ecosystems and people over time.

Materials and Methods

The methodology proposed previously [3] was used to identify and evaluate the environmental impact associated with water quality.

1. Forecasts of the effects that the activities have on the environment

A brief analysis of the anthropic actions that affect the environment was conducted. A list of these and the environmental factors that may be affected by these actions was drafted, and the identification of the activities associated with water quality that affect the improvement of the quality of the Bogotá River was based on a review of the available literature on environmental problems in the upper basin of the Bogotá River, with emphasis on water quality.

The two main sources for this information included literature published in scientific databases and policy documents and reports by state entities. Thus, a context of the current state of environmental problems in the upper basin of the Bogotá River is provided, as well as their impact on water quality.

The first list of effects provides an initial perception that may be more symptomatic due to their importance to the environment. These factors and actions were organized in rows and columns to create an effect identification matrix.

Information for the development of this stage was obtained from the literature review of scientific databases and policy documents and reports from state entities, as well as from field cases observed.

2. Impact matrix

The qualitative assessment itself was carried out with this activity. [3] It describes the impact matrix as a matrix for the identification of effects with a greater degree of development. It is of the cause-effect type and consists of a double-entry table where the impacting actions appear in columns, and the environmental factors susceptible to receiving impacts are arranged in rows.

3. Qualitative assessment of impacts: Importance matrix

Once the possible changes were identified, they were then assessed. The elements of the importance matrix identified the Importance (*Iij*) of the environmental impact generated by a simple action of a single activity (*Ai*) on a considered environmental factor (*Fj*). The importance of the impact was assessed using the criteria listed in Table 1 and Equation 1.

Equation 1: Impact importance assessment.

$$\text{Importance} = \pm(3\text{IN} + 2\text{EX} + \text{MO} + \text{PE} + \text{RE} + \text{SI} + \text{AC} + \text{EF} + \text{PR} + \text{MA})$$

Source: [3]

Table 1. Impact assessment criteria

Criterion	Assessment		Criterion	Assessment	
NATURE	Beneficial Imp	1	REVERSIBILITY (Reconstruction by natural means)	Short Term	1
	Harmful Imp	−1		Medium term	2
INTENSITY (Degree of destruction)	Low or Minimum	1		Long term	3
	Medium	2		Irreversible	4
	High	4	SYNERGY (Potentiation of the manifestation)	Simple	1
	Very high	8		Moderate	2
	Total	12		Very Synergistic	4
EXTENSION (Area of influence)	Punctual	1	ACCUMULATION (Progressive increase)	Simple	1
	Partial	2		Cumulative	4
	Wide or	4	EFFECT (Cause-effect relationship)	Indirect	1
	Total	8		Direct	4
	Critical	(+4)	PERIODICITY (Regularity of the manifestation)	Irregular	1
MOMENT (Term of manifestation)	Long term	1		Periodic	2
	Medium term	2		Continuous	4
	Short term	3	RECOVERABILITY (Reconstruction by human means)	Immediately	1
	Immediate	4		Short term	2
	Critical	(+4)		Medium term	3
PERSISTENCE	Fleeting	1		Long term	4

Criterion	Assessment		Criterion	Assessment	
(Permanence of the effect)	Momentary	1		Mitigable, replaceable, compensable	4
	Temporary	2		Irrecoverable	8
	Persistent	3	IMPORTANCE (Degree of qualitative manifestation of the effect)	±(3IN+2EX+MO+PE+RE+SI+AC+EF+PR+MA)	
	Permanent	4			

Source: [3]

The impact importance was based on values between 13 and 100, and impacts with importance values under 25 were irrelevant. Moderate impacts showed importance values between 25 and 50, severe between 50 and 75, and critical when their value was over 75 (Table 2).

Table 2. Importance of the impact

Value	Importance of impact
< 25	Irrelevant
25–50	Moderate
50–75	Severe
> 75	Critical

Source Based on [3]

4. Design and development of the tool for assessment

Software was developed, called “Rio Verde,” as a tool for assessing the environmental impact on the Bogotá River basin. This facilitated assessment of the incidence of changes in water consumption habits by loading information and generating reports.

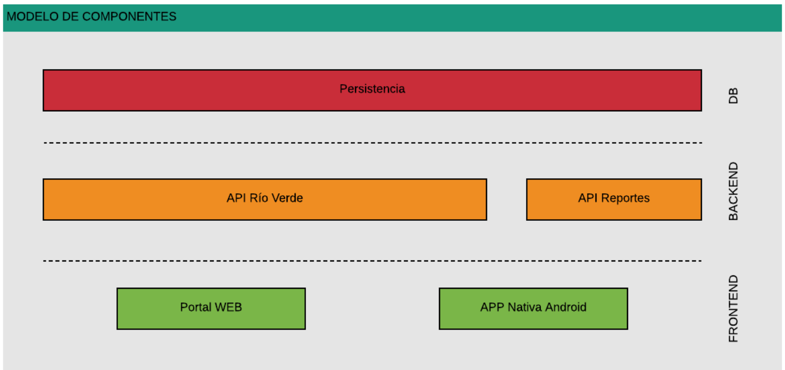
The software recorded, stored, indexed, and processed the information on physical and chemical contamination indices of the water bodies according to the Final Report to the IDEAM Ecosystems Sub-directorate related to conceptual design, logical design, and the entity-relationship model of the water quality database of the different water subsystems in Colombia. Table 3 describes the architecture of the developed system and Figure 1 shows the component design.

Table 3. System architecture

Quality attributes	Description
Usability and user experience	Usability will be validated. The current premise is to design functionalities that support simplicity.
Unique look and feel	A unique look and feel will be designed for the entire context of the application.
Use of apps must be enabled in the future	Decouple the logic of each front module through the implementation of application programming interfaces (API).
Scalability in terms of users	A monthly volume of 2,000 applications is estimated for the MPV. The SW and infrastructure design will allow gradual scaling to cover future growth of users and requests.
Processing of requests	One minute cannot be exceeded until the end of the process within the normal flow scenario, without any exception within the process.

Source: Prepared by the authors

Figure 1. Component design



Source: Prepared by the authors

MODEL OF COMPONENTS

Persistence

Rio Verde APIReports API

WEB Portal Native Android APP

Source: Prepared by the authors

FrontEnd. Own defined components are used at the FrontEnd, which are integrated into the solution by consumptions to the API (Rest/SOAP).

BackEnd. The BackEnd comprises all the components responsible for orchestration, business logic, and system validation.

Database. Persistence of the information validated by the BackEnd layer is found at this level.

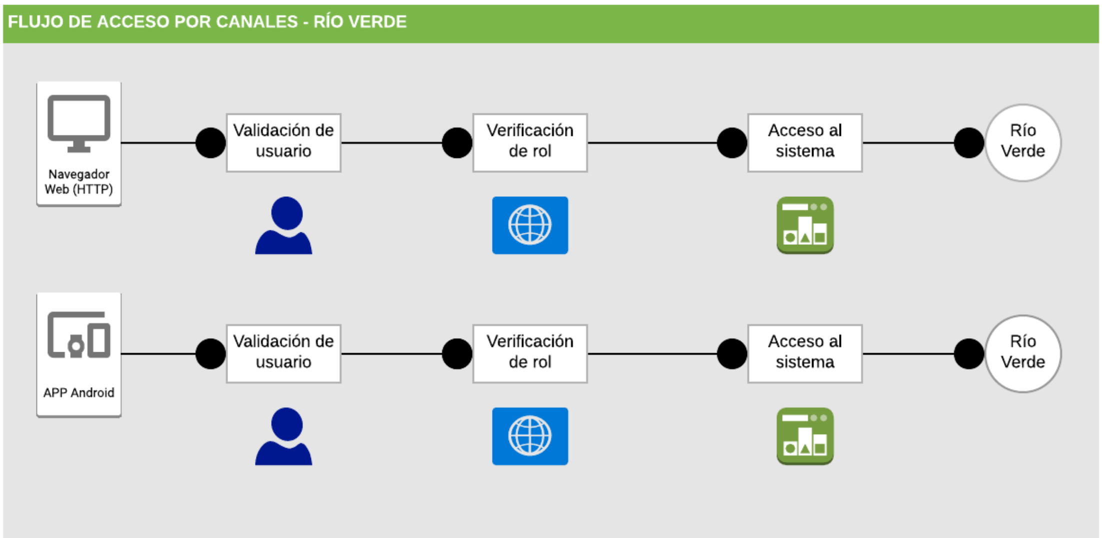
Interface Design. Requirements involved in the software development process are specified in this section. For example, what interface the user would like, the hardware interface, and the environment required by the system.

Operating Model

Two access channels were proposed within the solution: Public Web and Mobile Application.

From a technical point of view, it was intended to define a solution that could use the same functionality regardless of the channel in which it is accessed that would enable the user to perform the recording and information management in any of the channels (See Figure 2).

Figure 2. Access flow per channels: Rio Verde



FLOW ACCESS BY CHANNEL–RÍO VERDE

Web browser (HTTP) -User validation-Role Verification-System Access-Río Verde

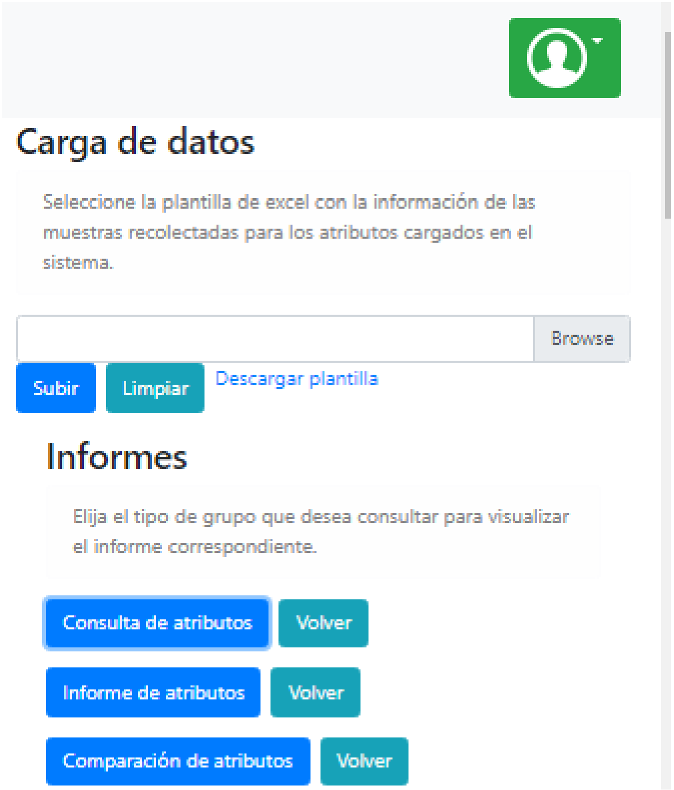
Android APP-User validation-Role Verification-System Access-Río Verde

Source: Prepared by the authors

Analyses obtained from the tool

The first process that performed involved loading the information, which can be done through an interface that allows uploading xlsx/csv-type files. Figure 3 shows this interface.

Figure 3. Loading the data



Data loading

The Excel template with information from the samples collected for the attributes loaded onto the system was selected.

Browse

Upload Clean Download template

Reports

Select the type of group you wish to query to visualize the corresponding report.

Attributes query Return

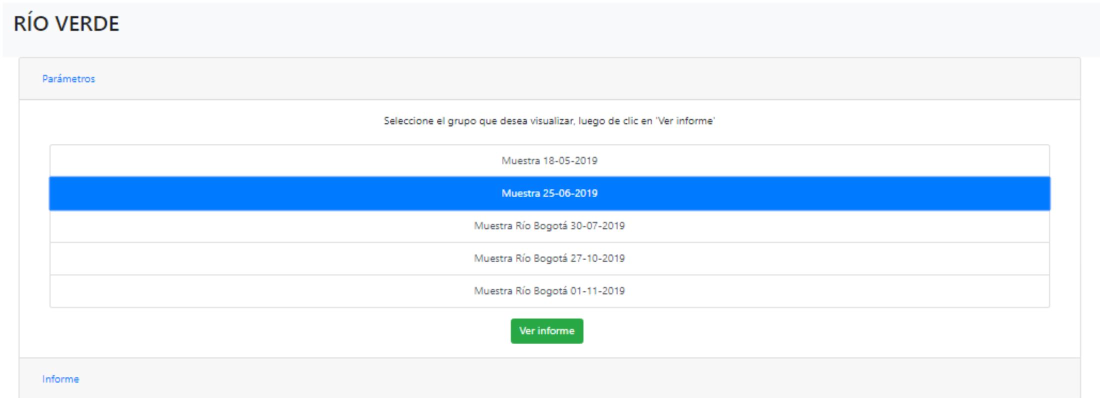
Attributes report Return

Comparison of attributes Return

Source: Taken from Rio Verde software

Attributes query. In Figure 4b and c report of results, the presence of attributes is represented for each sample taken and they show the percentage compared to the others.

Figure 4b. Selection of the queried sample



Parameters

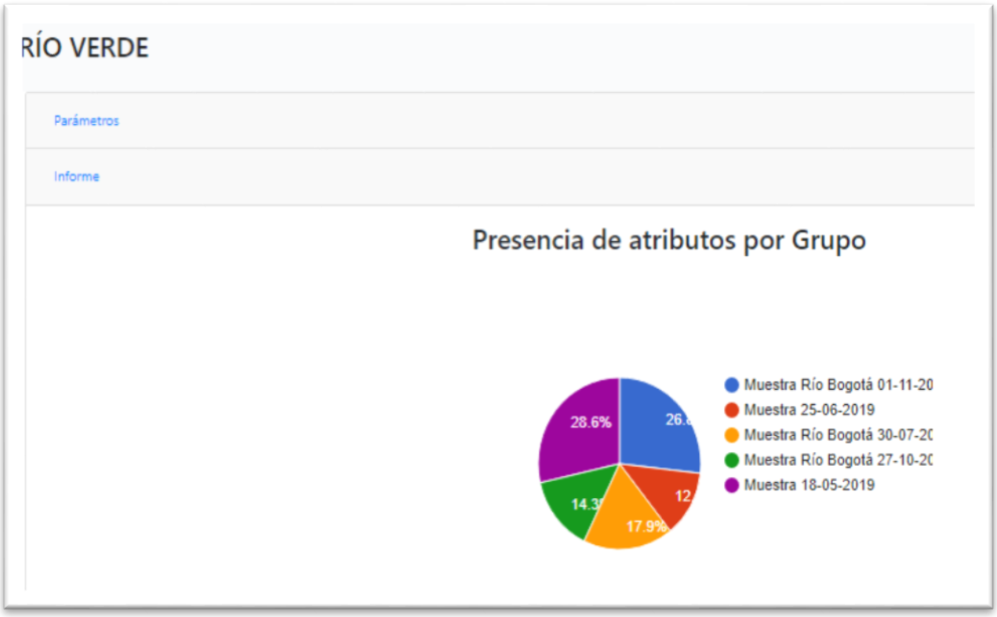
Select the group you wish to see, then click on "See Report"

Muestra = Sample

See Report

Source: Taken from Rio Verde software

Figure 4b. View of the query for presence of attributes by group



Parameters

Report

Presence of attributes by Group

Muestra = Sample

Source: Taken from Rio Verde software

Figure 4c. View of the attributes query for the selected group

Attributes for the group Sample 25-06-2019

Cumple Decreto = Meets Decree

Cumple Norma = Meets Regulation

Source: Taken from Rio Verde software

Finally, Figure 5a shows the number of attributes that comply with the current standards for water indicators, and Figure 5b shows the detail for each attribute.

Figure 5a. List of attributes per sample.

Listado de atributos

	Grupo	Atributo	Fecha	Decreto 1594	Decreto 2105	Icontec	OMS	USA
1	GR001-Muestra 18-05-2019	Virus a de la hepatitis	10/27/2019 12:00:00 AM	✓	✗	✓	✗	✗
2	GR001-Muestra 18-05-2019	Bario	10/27/2019 12:00:00 AM	✗	✗	✗	✓	✓
3	GR001-Muestra 18-05-2019	Fenoles	10/27/2019 12:00:00 AM	✓	✓	✗	✓	✗
4	GR001-Muestra 18-05-2019	Plomo	10/27/2019 12:00:00 AM	✓	✗	✗	✓	✗
5	GR001-Muestra 18-05-2019	Fenoles	10/27/2019 12:00:00 AM	✗	✓	✗	✓	✓
6	GR001-Muestra 18-05-2019	Virus a de la hepatitis	10/27/2019 12:00:00 AM	✓	✓	✓	✗	✓
7	GR001-Muestra 18-05-2019	Entamoeba Histolytica	10/27/2019 12:00:00 AM	✓	✓	✗	✗	✓
8	GR001-Muestra 18-05-2019	Plomo	10/27/2019 12:00:00 AM	✗	✗	✗	✗	✗
9	GR001-Muestra 18-05-2019	Transparencia	10/27/2019 12:00:00 AM	✗	✓	✓	✓	✗
10	GR001-Muestra 18-05-2019	Plomo	10/27/2019 12:00:00 AM	✗	✗	✓	✗	✗

1 2 10 12

List of attributes

Group Attribute Date Decreto = Decree

Muestra = Sample Hepatitis virus

Barium

Phenols

Hepatitis virus

Entamoeba hystolitica

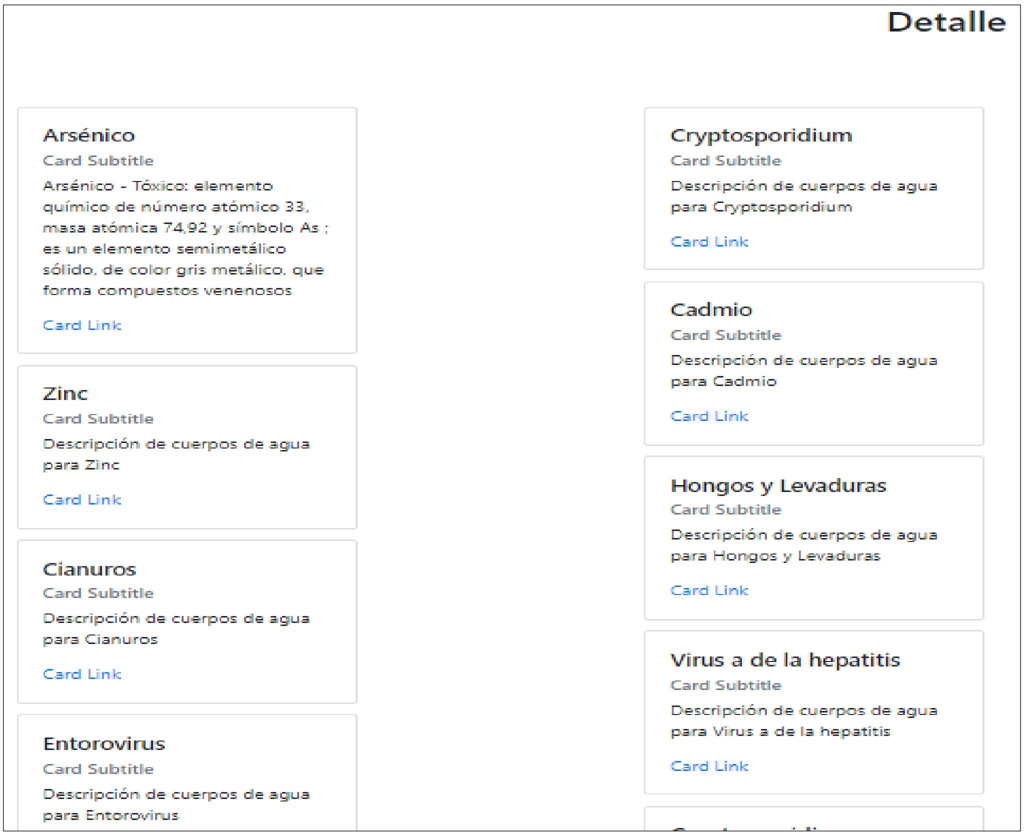
Lead

Transparency

Lead

Source: Taken from Rio Verde software

Figure 5b. Detailed view per attribute.



Details

Arsenic

Toxic: chemical element with atomic number 33, atomic mass 74.92, and symbol As; it is a gray, semi metallic solid element that forms poisonous compounds.

Zinc

Description water bodies for Zinc

Cyanides

Description water bodies for Cyanides.

Enterovirus

Description of water bodies for Enterovirus.

Cryptosporidium

Description of water bodies for Cryptosporidium.

Cadmium

Description of water bodies for Cadmium.

Fungus and Yeast

Description of water bodies for Fungus and Yeast.

Hepatitis virus

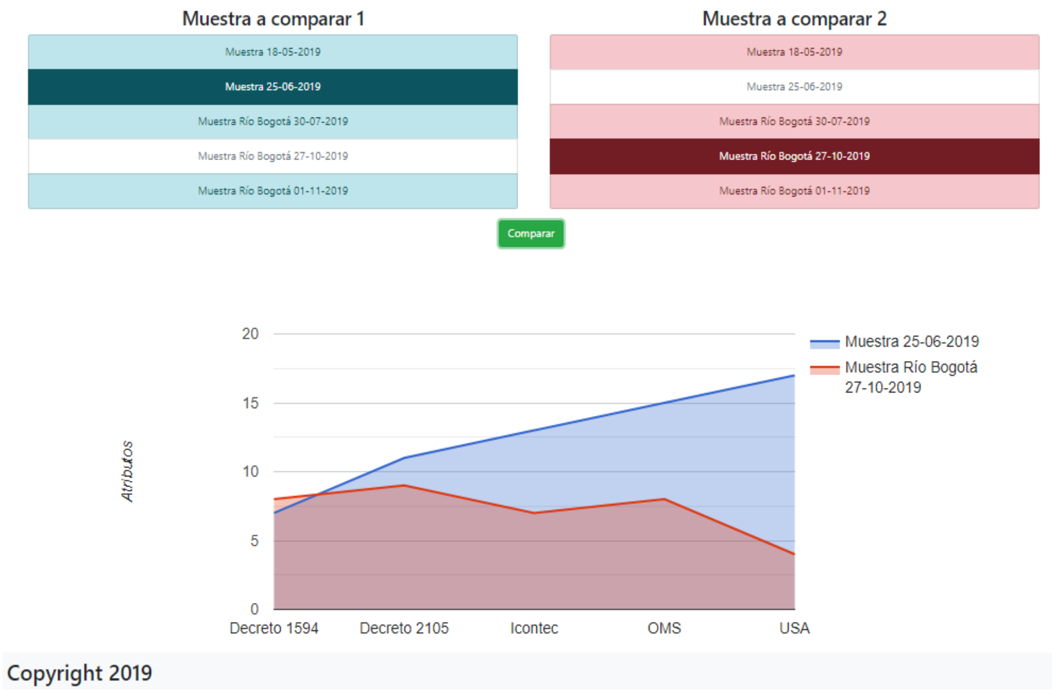
Description of water bodies for Hepatitis Virus.

Source: Taken from Rio Verde software

Finally, Figure 6 shows the report that allows for comparison of the different samples loaded in the system.

ISSN: 0004-0843

Figure 6. Sample comparison



Sample to be compared 1 Sample to be compared 2

Muestra = Sample

Comparar = Compare

Decreto = Decree

Source: Taken from Rio Verde software

Results

Anthropic activities that affect the basin

Given the characteristics and geographical location of the basin, its lands are suitable for the development of agricultural, livestock, and industrial activities; however, these have not been performed with a responsible management of the natural resources and have included highly impactful activities, mainly at the end of the process life cycles.

An identification of actions impacting the environment was made based on a literature review, and, although agricultural, industrial, and extractive activities are considered as having the greatest impact on the environment, it is also important to consider the legal and illegal urban development processes that have been carried out near the riverbanks.

The generation of discharge is one of the main activities that impacts water quality [4]. Uncontrolled discharge from Villapinzón and the tanneries located in the area considerably affect the concentration of dissolved oxygen [5]. Poor river quality was described after being contaminated by the runoff of chemicals used in potato crops, discharge from the aqueduct of the Municipality of Villapinzón, significant contamination caused by tanneries, and the discharge from the municipality of Chocontá.

The results obtained from a simple statistical regression carried out previously [6], conclude that for each increase of one million in the annual production of the tannery industry, contamination in the Bogotá River increases by 108.59 tons of solid waste per year, taking into account the marginality of pollution.

According to [7], 95 registered tanneries are in Villapinzón, of which only two hold an environmental license. This industry bears sole responsibility for the chromium contamination of the Bogotá River within the municipality. Despite the closure of several of these establishments by the Regional Autonomous Corporation of Cundinamarca (CAR), the prosecution of several workers and owners of various tanneries in 2012, and the ruling of the State Council in 2014, tanneries currently work at night and on weekends, given that these industries generate approximately 4,000 direct and indirect jobs for the inhabitants of Villapinzón. This accounts for the employment of nearly 25% of the population of the municipality.

Studies conducted on the Bogotá River [8, 9] have shown the presence of toxic elements such as Hg, Pb, Cd, Cr, and As. In some cases, the river is used for irrigation, and there is an active process of contamination of soil, plants, and animals up to unacceptable levels for humans and animals [10]. The presence of pesticides was also confirmed in river water samples, which may be caused by direct contamination of water courses by the application of pesticides, washing of containers or equipment, discharge of remnants and residues, or indirect contamination caused by lixiviation (infiltration) of products, landslides due to the unevenness of the terrain, and soil contamination [11].

During the production process of the tannery industries, the accumulation of solid waste contributed to leachate discharge with high concentrations of hazardous waste (phenols, chromium, mercury, and lead). Furthermore, [12] [13] mention that hair waste, in most cases, is discharged directly into the Bogotá River or into a sanitary landfill, generating an environmental problem with a highly negative impact on water and soil quality [14].

According to the Report from the Intersectoral and Articulated Special Audit on the Management of the Bogotá River [15], mining in the basin has generated conflicts due to contamination or land use, which has been reflected in the Land Use Planning of some municipalities. There is also water contamination and depletion of water sources, increased erosion, contamination of groundwater due to solid waste dumping from farms, land subsidence, respiratory diseases due to poor technical development in the handling of fumes from coking ovens, and conflicts over conducting activities in conservation areas or areas of mining restriction, among others [16].

These environmentally impactful actions are shown in Table 4, which groups the actions together with the activities that generate them. After identifying and assessing the environmental impact, values of greater or lesser importance were obtained based on the activity that generates the potentially impacting action. Thus, a cause-effect matrix was created where the first column represents the factor suffering the negative or positive effects of the actions (causes).

Table 4. Identification of impacting actions

Impacting actions	Legal and illegal urban development processes	Extractive mining	Livestock activities	Agricultural activities	Industrial activities
Illegal water catchments	X	X	X	X	X
Poor waste disposal	X	X	X	X	X
Inappropriate land use	X	X	X	X	X
Water use	X		X	X	X
Generation of discharges	X	X	X		X
Tree felling	X	X	X	X	
Inadequate debris removal	X	X			

Use of agrochemicals				X	
Population concentration at the riverbend	X				
Population growth	X				
WWTP discharges	X				
Total	10	6	6	6	5

Source: Prepared by the author

As expected, within the framework of the investigation, water was the most affected factor by potentially impactful actions. Another highly affected factor was soil, unlike the case of air and socioeconomic systems. Urban development processes and human settlements generated the highest impact on the environmental factors concerning the river, followed by extractive mining activities (Figure 7).

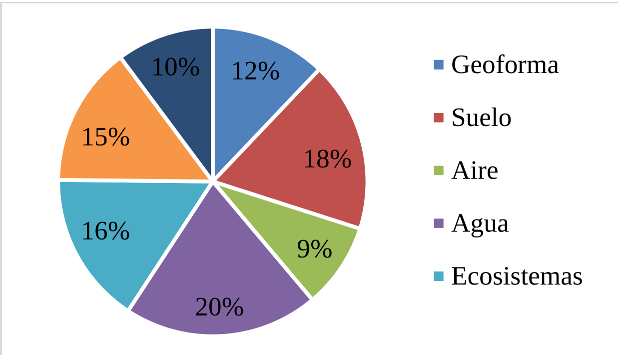


Figure 7. Proportion of impact on environmental factors

Geoform

Soil

Air

Water

Ecosystems

Source: Prepared by the author

Identification and assessment of environmental impacts

Below is a list of potential impacts related to actions associated with water quality (Table 5). These impacts were subsequently compared with previously identified actions.

Table 5. Potential impacts

FACTOR	*POTENTIAL IMPACTS*
Geoform	Slope instability
	Presence of erosive processes
	Landscape alteration
Soil	Alteration of the organic layer
	Drainage modification
	Alteration of the physicochemical properties
Air	Noise generation
	Gas emission
	Emission of particulate matter
	Odor emission
Water	Water quality changes
	Alteration of riverbeds
	Impact on ecological flow
	Alteration underground sources
Ecosystems	Impacts on the wetlands system
	Impacts on aquatic ecosystems
Fauna and Flora	Alteration of the vegetation cover
	Loss of biological diversity
	Habitat alteration
Socioeconomic	Impact on the population's health
	Property devaluation

Source: Prepared by the author

As a result of the identification of environmental impacts, it was determined that habitat alteration together with the impact on aquatic ecosystems and ecological flow are related to most of the impacting aspects identified. In turn, the less impactful aspects of these activities were noise generation, emission of particulate matter, and slope instability.

Consequently, the activity generating the greatest number of impacts is that related to the legal and illegal urban development processes, since it implies actions such as the concentration of the population]at the river bend, poor waste disposal, and inadequate debris removal and the generation of discharge, which most impact the environment (Appendix 1).

The environmental impact assessment was carried out according to the criteria shown in Table 1 defined by the methodology described previously [3] and based on the cause-effect matrix. Based on this matrix, the impacts were weighted according to the value of importance adopted: Irrelevant, Moderate, Severe, and Critical (See Appendix 2). Thus, out of the 21 impacts assessed, 1 of them was recognized as critical, another seven as severe, and 13 as moderate (

Figure 8).

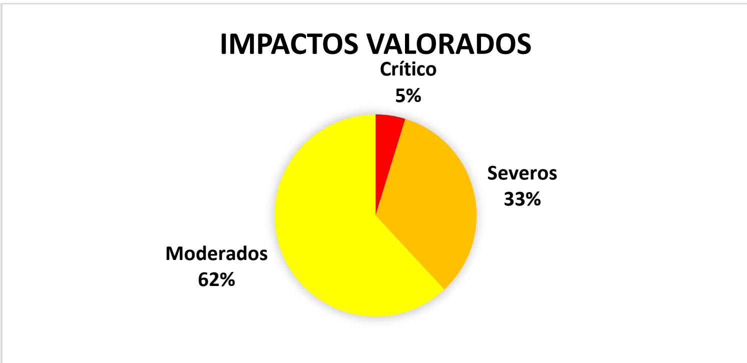


Figure 8. Percentage of impacts identified.

ASSESSED IMPACTS

Critical

Severe

Moderate

Source: Prepared by the author

The average assessment of each impact was calculated to weigh them, thus establishing the most important impacts on the basin (Table 6). Considering the scope of the investigation, changes in water quality were classified as a having a critical impact. Among the severe impacts related to water quality were alteration of the landscape and impact on the wetlands system and health of the population; and among the impacts with the lowest score were noise generation and the emission of gases and odors.

Table 6. Weighting of environmental impacts

System	*Potential impacts*	*Importance*
Water	Changes in water quality	−76
Geoform	Landscape alteration	−67
Ecosystems	Impacts on the wetland system	−65
Social	Impacts on the population's health	−56
Soil	Drainage modification	−52
Fauna and Flora	Loss of biological diversity	−52
Geoform	Slope instability	−51
Water	Impact on ecological flow	−51
Fauna and Flora	Alteration of the vegetation cover	−48
Fauna and Flora	Alteration of habitat and biodiversity	−48
Geoform	Presence of erosive processes	−47
Ecosystems	Impacts on aquatic systems	−46
Water	Alteration underground sources	−45
Soil	Alteration of physical and chemical properties	−39
Water	Disruption of riverbeds	−38
Air	Emission of particulate matter	−37
Soil	Alteration of the organic layer	−34
Social	Property devaluation	−33
Air	Noise generation	−33
Air	Gas emission	−28
Air	Emission of Odors	−28

Source: Prepared by the author

The grouped activity that generated the greatest impact on the environment was extractive mining followed by agricultural, livestock, and industrial activities. However, they differ by only one point on the assessment scale, and all of them were classified as moderate. When analyzing the impacting actions in detail, the one with the greatest average importance was inadequate use of soil, followed by the generation of discharges.

Discussion

The geographical characteristics of the upper basin of the Bogotá River have led to the development of economic activities in the primary sector in this area, primarily focused on agriculture and livestock. However, industrial parks in the southern upper sub-basin have increased in recent years, mainly in the municipalities of Tocancipá and Gachancipá, and the growth of urban centers in the municipalities of Chía and Cajicá, located around the northern edge of Bogotá, has also become evident.

According to the diagnosis made in the Cundinamarca Development Plan [17] for the municipality of Villapinzón, the process of deterioration of the Bogotá River commences as it receives pollutant discharge from the tannery industries located in this municipality and in the municipality of Chocontá. However, this situation is not new since the activities of the tannery sector in Colombia began in the 1920s in Antioquia and in the 1950s for tanneries established in the municipalities of Villapinzón and Chocontá in the department of Cundinamarca. Later, some producers in this area moved to San Benito neighborhood in Bogotá. Tanneries in this department represent the highest concentration, which represent 81.3% of the total tanneries in the country (Alzate, 2004), cited by [18].

As for the impact on the ecosystem, ecological flow is affected by the uncontrolled demand of the population and industries as well as by the anoxic conditions in some of the river basins that prevent the existence of life [19], [20].

After the identification and assessment of environmental impact activities, it has been determined that not only is the generation of discharge from economic activities the cause of the poor quality of the water in the Bogotá River, another impacting activity is the generation and poor disposal of solid waste produced not only by the production processes, but also by domestic activities [21].

Although it is necessary to meet the needs of the population, it is evident not only with the damage to the Bogotá River but also with the associated impacts, that the current extractive economic model is a factor preventing the recovery of the natural resources affected, and that it accentuates and aggravates environmental damage. In this regard, the organization of production, a better vision of the expanded market, and the respect for the environment may be the solution for a region and an economic sector that has had tradition [5] but which has remained obsolete and reluctant to change. Thus, it could be left out of economic activity, to the detriment of employment creation and to the environment in the region (specifically the leather tanning activities), which may extend to other traditional activities within the region.

Conclusions

In the estimation of the environmental impact associated with the water quality of the Bogotá River, changes in water quality are classified as having a critical impact. Severe impacts include alteration of the landscape, impact on the wetlands system, and the population's health. The impacts with lower scores include noise generation and the emission of gases and odors.

Given the close relationship between ecological, social, and economic components with water, failures in water management not only affect the quality of this resource, they generate a chain reaction that negatively impacts, although to a different extent, all environmental components.

References

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Appendix 1. Identification of environmental impacts by activity

Source: Prepared by the author

Appendix 2 Assessment of environmental impacts

FACTOR		Geoform			Soil			Air			
ACTIVITIES	POTENTIAL IMPACTS	Slope instability	Presence of erosive processes	Landscape alteration	Alteration of the organic layer	Drainage modification	Alteration of physical and chemical properties	Noise generation	Gas emission	Emission of particulate matter	Emission of Odors
Agricultural activities	Use of agrochemicals				-41		-44				
	Poor waste disposal			62	33		33		27		23
	Illegal water catchments		—32			-47					
	Use of water for irrigation										
	Tree felling	57	60	62	33	54					
	Inappropriate land use			—78	-34	-54	-29				
Livestock activities	Generation of discharges						-49				-31
	Poor waste disposal			—62	-33		-33		-27		-23
	Water use										
	Illegal water catchments		—32			-47					
	Tree felling	—57	—60	—62	-33	-54					
	Inappropriate land use			78	34	54	29				
Industrial activities	Generation of discharges						-49				-31
	Poor waste disposal			—62	—33		-33		-27		-23
	Illegal water catchments		—32			-47					
	Water use										
	Inappropriate land use			—78	—34	-54	-29				
Extractive mining	Illegal water catchments		—32			-47					
	Generation of discharges						-49				-31
	Poor waste disposal			—62	—33		-33		-27		-23
	Inadequate debris removal	—40	—60	—62	—33	-54	-47			-37	
	Tree felling	57	60	62	33	54					
	Inappropriate land use			—78	—34	-54	-29				
Legal and illegal urbanization processes	Generation of discharges						-49				-31
	Inadequate debris removal	—40	—60	—62	—33	-54	-47			-37	
	Poor waste disposal			—62	—33		-33		-27		-23
	WWTP discharges						-49				-31
	Tree felling	—57	—60	—62	—33	-54					
	Population concentration at the riverbend			62	33	54		33	31	37	33
	Population growth							-33	-31	-37	
	Water use										
	Inappropriate land use			78	34	54	29				
	Illegal water catchments		—32			-47					
Average		—55			-41			-31			
		—51	—47	—67	-34	-52	-39	-33	-28	-37	-28

FACTOR		Water				Ecosystems		Fauna and Flora			Social		Average	
ACTIVITIES	POTENTIAL IMPACTS	Water quality changes	Alteration of riverbeds	Impact on ecological flow	Alteration underground sources	Impacts on the moorlands	Impacts on aquatic systems	Alteration of the vegetal cover	Loss of biological diversity	Alteration of habitat and biodiversity	Impact on population's health	Property devaluation		
Agricultural activities	Use of agrochemicals	-79			-65		-40	—32	—28	—28	—65		—47	-48
	Poor waste disposal	79			53		33	61		45	67	23	45	
	Illegal water catchments		-47	-53	-42		-64						—48	
	Use of water for irrigation		-37	-53			-34				—67		—48	
	Tree felling			20		44		44	53	48			48	
	Inappropriate land use				-32	-81		-38	-61	-38			-32	
Livestock activities	Generation of discharges	-80	-27	-74			-51		-46	-47	-41	-48	-49	-47
	Poor waste disposal	-79			-53		-33	-61		-45	-67	-23	-45	
	Water use		-37	-52			-34						-41	
	Illegal water catchments		-47	-53	-42		-64						-48	
	Tree felling			-29		-44		-44	-53	-48			-48	
	Inappropriate land use				32	81		38	61	58			52	
Industrial activities	Generation of discharges	-80	-27	-74			-51		-46	-47	-41	-48	-49	-47
	Poor waste disposal	-79			-53		-33	-61		-45	-67	-23	-45	
	Illegal water catchments		-47	-53	-42		-64						-48	
	Water use		-37	-52			-34						-41	
	Inappropriate land use				-32	-81		-38	-61	-38			-52	
Extractive mining	Illegal water catchments		-47	-53	-42		-64						-48	49
	Generation of discharges	-80	-27	-74			-51		-46	-47	-41	-48	-49	
	Poor waste disposal	-79			-53		-33	-61		-45	-67	-23	-45	
	Inadequate debris removal	-79						-61		-45		-23	-49	
	Tree felling			20		44		44	53	48			48	
	Inappropriate land use				-32	-81		-38	-61	-38			-32	
Legal and illegal urbanization processes	Generation of discharges	-80	-27	-74			-51		-46	-47	-41	-48	-49	-46
	Inadequate debris removal	-79						-61		-45		-23	-49	
	Poor waste disposal	-79			-52		-33	-61		-45	-67	-23	-45	
	WWTP discharges	-58					-51		-46	-47	-41	-48	-46	
	Tree felling			-29		-44		-44	-53	-48			-48	
	Population concentration at the riverbend		37	38			46	44		34	51		41	
	Population growth	-38	-57	-58							-60		-42	
	Water use		-37	-53			-34						-41	
	Inappropriate land use				32	81		38	61	58			52	
	Illegal water catchments		-47	-53	-42		-64						-48	
Average		-52				-55		—49			—45			
		-76	-38	-51	-45	-65	-46	—48	—52	—48	—56	—33		

Source: Prepared by the author