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Environmental impacts associated with wastewater discharge on water sources, Norte de Santander Colombia Case Study

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ABSTRACT

Environmental impacts represent a global problem that affects all countries, causing deterioration in natural resources, especially water, altering the biotic, abiotic and socioeconomic components. In addition, they generate health problems due to the increase in solid waste, offensive odors and the proliferation of vectors and rodents. The purpose of this research is to capture the great problem that is causing the discharge of wastewater on water sources, generating environmental awareness promoting practices that reduce these alterations in the environment. The article is based on an Environmental Impact Assessment (EIA) using the Arboleda method, through the construction of a causal matrix from a representative environmental diagnosis of the affected area. Then, a physicochemical and microbiological analysis was carried out on the water body, primary information was collected from the local community to understand the socioeconomic and cultural aspects related to the anthropogenic activities that generate wastewater. In addition, a hydrological characterization of the Pamplonita River was carried out at three key points: the place where domestic wastewater is discharged, an upstream point and a downstream point. At these points, various parameters are evaluated, such as temperature, pH, dissolved oxygen, flow rate, COD, BOD5, total sedimentable solids, suspended solids, fats and oils of which the BOD5 of the discharge point does not comply with the maximum limits allowed according to Colombian legislation. Together, the components that make up the environmental baseline of the Pamplonita River are studied.

Keywords: Anthropogenic activities, Wastewater, Ecosystem, Environmental impact, Discharges.

INTRODUCTION

Human activities alter water sources and affect water quality, which can have negative consequences for public health, food security and ecosystems. Untreated domestic wastewater contains bacteria, pathogens, organic matter, and hazardous substances such as heavy metals, discharged without treatment, this wastewater causes significant alterations to the environment, deteriorating both aquatic and terrestrial ecosystems (Osorio et al., 2021).

Historically, water sources have been recipients of urban and rural waste, as well as stormwater that helps mitigate the impact of wastewater. Improper disposal of industrial waste exacerbates this

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situation. It is therefore essential to promote sustainable water use. Adopting good practices and proper management improves quality of life and conserves ecosystems (Rodríguez et al., 2022).

Untreated domestic wastewater causes pollution and degradation of water quality and quantity. In recent years, pollution has increased due to poor management of these tributaries, negatively affecting ecosystems, including natural water sources (Llashag & Juvenal, 2022).

In the municipality of Pamplonita, laboratory analyses and field sampling were carried out to understand the characteristics of the body of water that receives wastewater discharges in the urban area. This aimed to assess the impact of waste generated by human activities on local ecosystems.

BACKGROUND/STATE OF THE ART

In Nueva Cajamarca, Peru, research was conducted in 2022 titled "Evaluation of Wastewater Impacts on the Water Quality of the Galindona Canal" by Leslie Fernández Montoya. The main objective was to evaluate the water quality in the Galindona channel by analyzing physical, chemical and biological parameters. The results indicated levels of contamination above the environmental standards and limits allowed by Peruvian legislation. In addition, an environmental impact assessment was carried out which revealed a severe state of contamination in the canal due to sewage discharges.(Fernandez, 2022)

Juan Pablo Medina Rodríguez conducted research in Bogotá in 2019 on the environmental impact of discharges from the chemistry laboratory of the Sena Industrial Management Center. The study revealed the lack of a manual of standardized practices in the laboratory, resulting in increased dumping and hazardous waste. The researchers concluded that of the 184 reagents used, at least 47 have a significant negative environmental impact, and that discharges negatively affect water resources.(Medina, 2019)

In Buriticá, Antioquia, Viky González Meléndez conducted research in 2018 entitled "Environmental Impact Assessment of Gold Mining Discharges on the Bemango Creek (Remango)." The main objective was to evaluate the environmental impact of the discharges generated during the extraction of gold ore in the Bemango Stream. The results of the study showed that mining activities and their components had a negative and serious impact on the chemical properties of the water, contributing to the contamination of the stream. By applying the Water Quality Index (AQI) and the ICOS pollution indices, it was determined that water quality ranged from acceptable to very poor.(Meléndez, 2018)

In 2021, Valentina Corzo Flórez carried out research in the department of Norte de Santander called "Comprehensive Assessment of the Water Quality of the Pamplonita River in the Agua Clara sector", in support of the sub-directorate of climate change and water resources of the Regional Autonomous Corporation of the Northeastern Border. The main objective was to evaluate the water quality of the Pamplonita River, specifically in the Agua Clara area. The research included collecting data from the years 2019, 2020 and 2021, which indicated a decline in water quality over time. During the monitoring carried out in collaboration with the sub-directorate, a continuous deterioration of the river was observed due to upstream discharges and human activities in the area.(Florez, 2021)

In 2021, in Huancayo, Peru, Yony Arias Boza, Ada Jaqueline Calderón Garcilazo and Jean Pierre Orellana Cerrón conducted research on the impact of wastewater discharges into the Shullcas River during the dry season in the Bellavista Condominium section. Despite the lack of samples from the initial stretch due to zero flow, the results of the study revealed that the levels of Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD5), and Fecal Coliforms (CF) exceeded environmental quality standards (Boza et al, 2022). (Boza, Garcilazo, & Cerron, 2022)

MATERIALS AND METHOD

The results of the analysis of laboratory samples allowed for both a qualitative (based on detailed descriptions) and quantitative (through measurements and statistical analyses) approach to changes in water source. These precise data led to the formulation of conclusions and recommendations to make decisions and implement measures that reduce the negative impacts on the Pamplonita River, promoting its conservation and sustainable use. Subchapter: Statistical Methods.(Iglesias, 2021)

The collection of samples was carried out at the water source, on April 9, 2023, following the protocol for the collection of wastewater samples established by IDEAM and which were analyzed by the HidroLab laboratory.

This sample collection process began at 6:00 am, starting with the organization of the necessary equipment for sampling, which is detailed in Table 1

Table 1: *Materials used for sampling.*

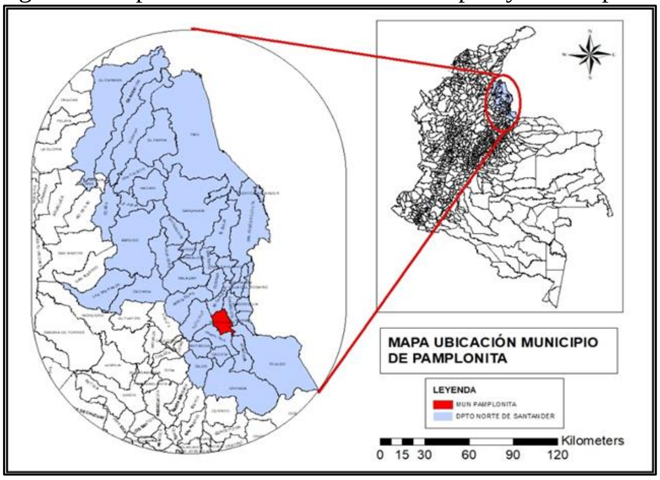
Material	Quantity	Usefulness
Cava de icopor	1	Storage and transport of samples.
1 litre plastic container	4	Sample of BOD5 and COD upstream and downstream.
1 litre plastic container	13	Aliquot taking.
3 litre plastic container	1	Composite sample.
Glass container 500ml	2	Sample of fats, oils, and total coliforms.
Acids to preserve samples.	2	Sulphuric acid and hydrochloric acid were used to preserve the samples.
Ice	10 bags	Preservation of collected samples.
Chronometer	1	It was useful to calculate the time at each interval of the samples.
Thermometer	1	It was used to measure the temperature of each of the samples.
pH Strips	13	It was used for the calculation of the pH in each of the samples.
Tape measure	1	It was used to measure the width of the river.
Ping Pong Ball	2	It was used to measure the flow by the float method.
5 litre container	1	It was used to calculate the flow rate at the discharge point.

SAMPLING

The research was carried out in the municipality of Pamplonita, located in the southwestern area of the department of Norte de Santander, Colombia.(Alcaldía municipio de pamplonita norte de santander, 2020)

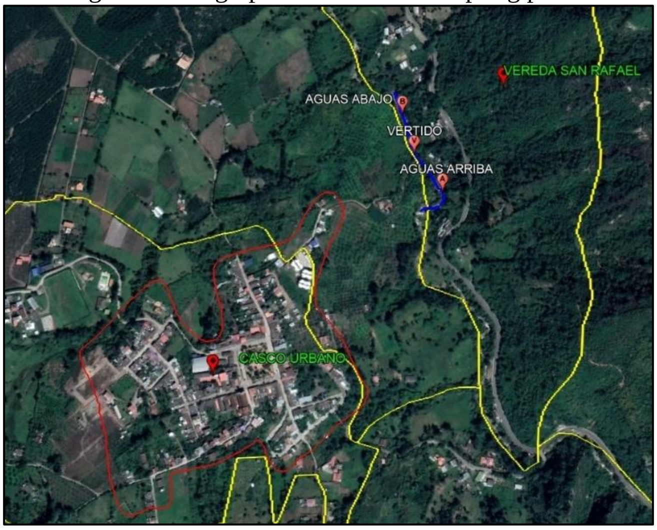
Figure 1 serves as a reference for the location of the municipality with coordinates (7°26'13.78"N; 72°38'14.47"W).

Figure 1: Map of the location of the municipality of Pamplona



The characterization of the Pamplonita River was carried out on the periphery of the urban area, in two strategic locations: one 100 meters upstream with coordinates (7°26'24.81"N; 72°38'2.39"W) and another 100 meters downstream with coordinates (7°26'30.00"N; 72°38'5.06"W) from the main discharge point located in the village of San Rafael with coordinates (7°26'27.36"N; 72°38'4.27"W) as shown below. shown in Figure 2. Following the guidelines of Resolution 0631 of 2015, analyses of parameters such as BOD5, COD, pH and temperature were carried out in both locations. At the main discharge point, BOD5, COD, total solids, fats, oils, total coliforms, temperature and flow rate were analyzed. The IDEAM instructions for composite monitoring were followed.(IDEAM, 2010)

Figure 2: Geographic location of sampling points



IDENTIFICATION AND ASSESSMENT OF ENVIRONMENTAL IMPACTS

The identification and evaluation of environmental impacts was carried out following the guidelines of the manual "Manual for the evaluation of environmental impact of projects, works and/or activities" by Jorge Arboleda. Through the analysis of data and information collected in the Municipal Development Plan and through technical visits, human activities that generate waste and direct discharges into the water source were identified and confirmed. Table 2 lists the main anthropogenic activities that have an impact on the environment.(Arboleda, Manual de Evaluación de Impacto ambiental de proyectos obra u actividad, 2008)

Table 2: Main Sources of Wastewater

No.	ASPI
1	Domestic activities
2	Agricultural activities
3	Restaurant Operation
4	Civil works activities
5	Operation of brass workshops
6	Pig farming activities
7	Tourism activities
8	Livestock activities
9	Rabbit production activities
10	Sheep production activities
11	Operation of car washes.
12	Cheese production activities
13	Confectionery production activities

Table 3 describes each of the criteria considered according to Jorge Arboleda's Impact Manual, to evaluate the negative and positive impacts that occur on the Pamplonita River in the municipality of the same name.

Table 3: Evaluation parameters of the Grove method

Presence	Duration	Evolution	Magnitude	Score
Certain	Very long or permanent	Very fast	Very high	1.0
Very likely	Long	Speedy	Loud	0.7-0.99
Probable	Stocking	Stocking	Stocking	0.4 and 0.69
Unlikely	Short	Slow	Casualty	0.2 and 0.39
Very unlikely	Very short	Very slow	Very low	0.01 and 0.19

Once the score was assigned to the evaluation parameters, the environmental rating was carried out by applying the following formula 1:

$$\boldsymbol{Ca} = \boldsymbol{C}(\boldsymbol{P}[\boldsymbol{axEM} + \boldsymbol{bxD}]) \quad (1)$$

Where:

Ca: Environmental Impact Rating.

Q: presence.

D: duration.

E: Evolution.

M: magnified.

a: Weighting constant with an absolute value of 7.0

b: Weighting constant with an absolute value of 3.0

The result of each impact was related taking into account the ranges found in Table 4.

Table 4: Importance of impact according to environmental rating.

Environmental Rating (Points)	Importance of environmental impact
≤ 2.5	Well the irrelevant
>2.5 and ≤ 5.0	Moderately significant to moderate
> 5.0 and ≤ 7.5	Significant or relevant
> 7.5	Very significant or severe
≤ 2.5	Not very positive
>2.5 and ≤ 5.0	Moderately positive
> 5.0 and ≤ 7.5	Relevant positive
> 7.5	Null

SURVEY AND EVALUATION OF THE INHABITANTS OF THE MUNICIPALITY

A survey was conducted targeting the population living in the region affected by the research. A finite sample of 100 people was used in order to understand their perception and level of awareness in relation to issues related to the preservation of the environment, especially focused on the repercussions of Wastewater (RH) discharges on aquatic ecosystems.

RESULTS

CHARACTERIZATION OF THE SPILL

By means of the volumetric method, the flow rate at the point of discharge was determined, in a period of twelve hours in which thirteen aliquots were taken; Table 5 shows the average flow rate obtained in the sampling.

Table 5: Average value of the flow rate found at the point of discharge

Point	Method	Caudal (m3/s)
Dumping	Volumetric	0.00659

The results of the samples analyzed at the discharge point were contrasted with the maximum permitted limits for Wastewater (RA) discharges as stipulated in Resolution 0631 of 2015, as detailed in Table 6.

Table 6: Comparison of the physicochemical parameters of the point of discharge with Resolution 0631 of 2015

Parameter	Results	Unit	Maximum permissible according to Resolution 0631/2015	Compliant or Non-Compliant
BOD5	94	mg/L	90 mg/L	NON-COMPLIANT
COD	146	mg/L	180 mg/L	MEETS
Total Coliforms	3300	NMP/100 ml	Analysis & Reporting	--
Oils & Fats	1,13	mg/L	20 mg/L	MEETS
Sedimentable solids	1,2	ml/L	5 ml/L	MEETS
Total Suspended Solids	83	mg/L	90 mg/L	MEETS

The COD concentration shown in Table 6 obtained a value of 146 mg/L of O2, which does NOT exceed the limits established in Resolution 0631 of 2015. However, it is important to note that the fact that this value is within the permitted limits does not guarantee that there will not be an impact on the water resource. The presence of COD can decrease the level of oxygen in the water, posing a threat to aquatic life. This increase in COD concentration is related to the use of cleaning products in households, such as detergents and solvents, as well as the use of pesticides in agriculture.

The concentration of BOD5 reflected in Table 6 resulted in 94 mg/L of O2, which exceeds the values allowed according to Resolution 0631 of 2015. This situation is due to the activity and operation of the market squares located in the vicinity of the water source, which generate discharges of wastewater with organic content.

The results in Table 6 show a significant presence of total solids, fats and oils, which is related to additional domestic and agricultural activities. These activities contribute significantly to the increased load of pollutants that are discharged into the water resource.

MONITORING OF THE RECEIVING WATER SOURCE

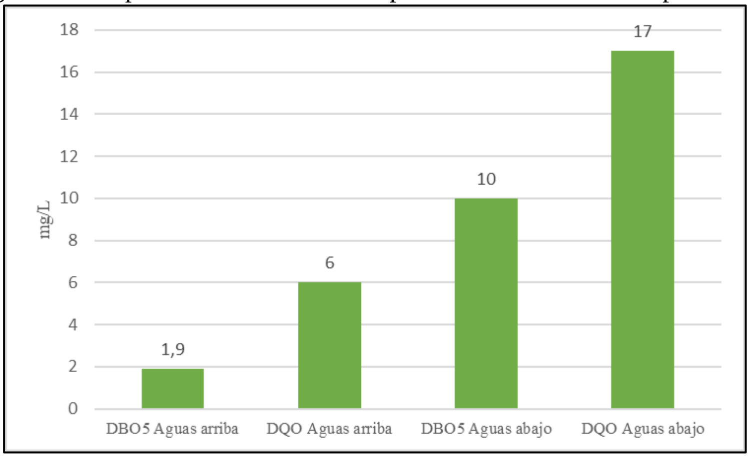
During the implementation of the project, samples were collected both 100 meters upstream and 100 meters downstream of the main dumping point that was the focus of the study. This was done in order to compare the COD and BOD5 parameters at these points and to analyze the absorption levels of the total organic load presented by the water source, as detailed in Table 7.

Table 7. Comparison and analysis of upstream and downstream parameters

Parameter	Upstream	Downstream
dBo5 (Mg/LO2)	< 2	10
COD (mg/L O2)	6	17

Figure 3 represents a comparison of COD and BOD5 levels at the points analysed in relation to discharge to the water source. The alteration caused by Wastewater (RA) in the water body is clearly observed, with a significant increase in the organic load. As a result, the ability of the stream to assimilate this organic load is limited, indicating a low degree of assimilation by the water system.

Figure 3: Comparison of the different upstream and downstream parameters



BIODEGRADABILITY INDEX

The biodegradability index (BI) is a measure that evaluates the ability of substances present in a water sample to break down into simpler components. This provides information on the assimilation of pollutants into water bodies. To calculate the IB at each of the points analyzed during monitoring, the relationship between BOD5 and COD was examined, as shown in Table 8. These values were then compared with the data in Table 9 to determine the biodegradability character of the substances in the water.

Table 8: Biodegradability Index Ranges.

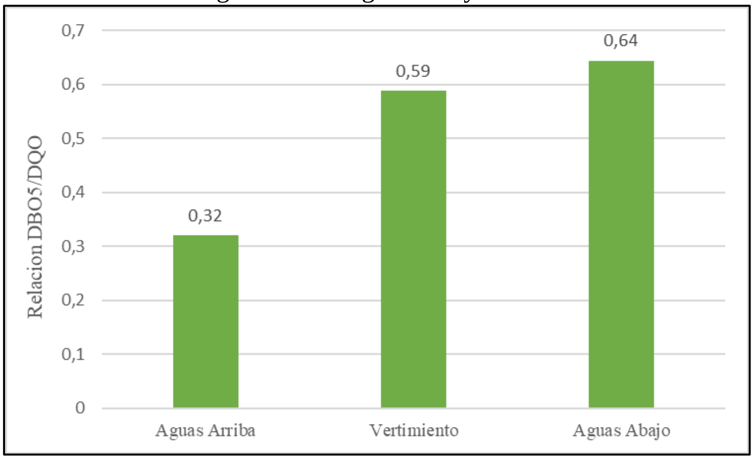
RANGOS DE LA RELACION DBO5 / DQO	GUY
Greater than 0.4	Biodegradable
0.2 to 0.4	Moderately Biodegradable
Less than 0.2	Very low biodegradable

Table 9: Biodegradability index for each point

Sampling Point	BOD5/COD ratio	Biodegradability Index
Upstream	1,9/6	0,32
Downstream	10,0/17,0	0,59
Dumping	94/146	0,64

Table 9 shows the analysis of the values of the samples collected. At 100 metres upstream, a relatively low biodegradability index is observed compared to the results of samples obtained 100 metres downstream and at the point of discharge. These last samples have a biodegradable index in each case. This highlights the urgent need for pre-discharge treatments, as shown in Figure 4.

Figure 4: Biodegradability indices



IDENTIFICATION AND ASSESSMENT OF ENVIRONMENTAL IMPACTS

The assessment of the 26 most significant impacts due to the activities carried out in the study area is presented in Table 10 and illustrated in Figure 5.

Figure 5 shows a classification of environmental impacts, where 11.54% of them are considered null, 7.69% are very significant, and 30.77% are classified as significant, while 46.15% are considered moderate and 3.85% are irrelevant. These results reflect a significant concern due to the alterations caused by human activities in the study area, with a particular emphasis on the alteration of water resources.

It is important to point out that the laboratory analyses of the physicochemical and microbiological parameters of the water samples from the discharge located in the village of San Rafael, which flows into the Pamplona River, the BOD5 does not comply with the values allowed according to the current Colombian regulations for Wastewater (RA) discharges established in Resolution 0631 of 2015 and the other parameters assessed comply, but they are close to the maximum permissible limit. This situation highlights the need to address and correct current conditions to mitigate negative impacts on the environment.

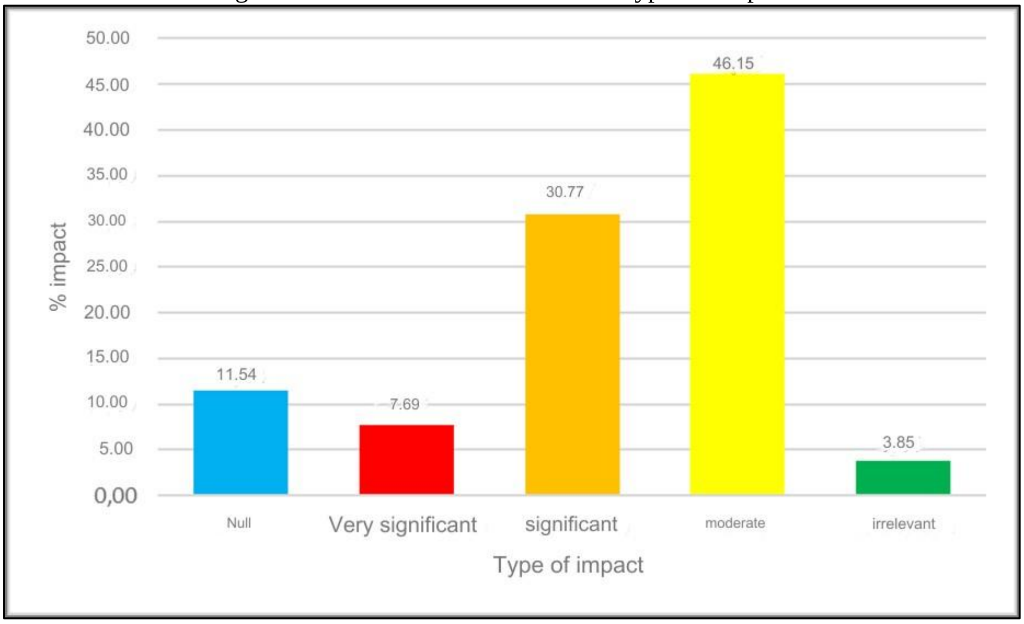
Through the development and analysis of the environmental impact assessment, it has been identified that the environmental factors most affected by human activities in the municipality, such as the discharge of domestic and non-domestic Wastewater (RA), the generation of offensive odors, increase in the levels of fats and oils, deterioration of terrestrial and aquatic fauna, Deterioration of the landscape, Deterioration of the quality of life, Impact on the flora and fauna of the place, Generation of waste and Impact on the biota. This resource is home to the aquatic ecosystem, which experiences drastic and significant changes in water quality, as well as a fragmentation in aquatic biota. This situation makes the water body vulnerable and limits its use as a source of employment and food.

Table 10: Impact assessment matrix.

Impact	**Class**	**Presence**	**Evolution**	**Duration**	**Magnitude**	**Environmental Qualification**	**Environmental impact**	
							+	-
Water Pollution	-	1,0	1,0	0,9	0,8	8,30		Very significant
Soil contamination	-	0,9	0,7	0,8	0,6	4,81		Moderate
Job creation	+	1,0	0,9	1,0	1,0	9,30	Null	
Impact on public health	-	0,9	0,5	0,6	0,6	3,51		Moderate
Soil compaction	-	0,9	0,6	0,7	0,6	4,16		Moderate
Generation of offensive odours	-	1,0	0,7	0,8	0,7	5,83		Significant
Generation of toxic substances to the soil	-	1,0	0,4	0,7	0,5	3,50		Moderate
Vector Generation	-	1,0	0,5	0,6	0,8	4,60		Moderate
Increased levels of fats and oils,	-	1,0	0,7	0,7	0,6	5,04		Significant
Nuisance in the community,	-	1,0	0,8	0,5	0,6	4,86		Moderate
Increased economic income	+	1,0	0,9	1,0	1,0	9,30	Null	
Loss of fertile soil	-	0,9	0,7	0,8	0,6	4,81		Moderate

Impact	Class	Presence	Evolution	Duration	Magnitude	Environmental Qualification	Environmental impact	
							+	-
Increase in organic and inorganic waste	-	1,0	0,7	0,7	0,5	4,55		Moderate
Improved quality of life	+	1,0	0,9	0,8	0,9	8,07	Null	
Deterioration of terrestrial and aquatic fauna	-	1,0	0,7	0,7	0,7	5,53		Significant
Deterioration of the landscape	-	1,0	0,7	0,6	0,7	5,23		Significant
Water Pollution	-	1,0	1,0	0,9	0,8	8,30		Very significant
Air Pollution	-	1,0	0,7	0,6	0,6	4,74		Moderate
Impaired quality of life	-	1,0	0,8	0,8	0,8	6,88		Significant
Erosive Processes	-	1,0	0,3	0,5	0,6	2,76		Moderate
Increase in diseases	-	1,0	0,5	0,7	0,7	4,55		Moderate
Impact on the flora and fauna of the site	-	1,0	0,7	0,7	0,7	5,53		Significant
Waste generation	-	1,0	0,7	0,8	0,7	5,83		Significant
Loss of biodiversity	-	1,0	0,4	0,4	0,4	2,32		Irrelevant
Impact on biota	-	1,0	0,7	0,8	0,8	6,32		Significant
Respiratory diseases	-	1,0	0,5	0,7	0,7	4,55		Moderate
Total, absoluto							26,67	116,50
Net impact							-89,83	

Figure 5: Result of the behavior of the types of impacts.



DISCUSSION OF RESULTS

CHARACTERIZATION OF THE SPILL

The results of the discharge characterization highlight a critical problem: BOD levels exceed the limits established by Resolution 631 of 2015. This situation underscores the urgency of implementing a wastewater treatment system to reduce the load of pollutants currently discharged directly into the receiving water body.

Although other parameters, such as COD, oils and fats, suspended solids, and total solids, are within the allowable limits under the same resolution, it is critical to note that being within these limits does not guarantee the integrity of the aquatic ecosystem. The presence of these pollutants, although within permissible limits, can have adverse effects on biota and overall water quality.

The implementation of a wastewater treatment system becomes imperative to mitigate negative impacts on water resources. In addition, the direct discharge of wastewater with high levels of BOD could have long-term consequences on water quality and the health of aquatic ecosystems.

This coincides with the research carried out by the company, which concludes that the analysis of the physicochemical parameters reveals that none of them is below the maximum permissible limits established in Resolution 0631 of 2015. Therefore, it is crucial that environmental authorities carry out continuous monitoring, in accordance with current regulations, to implement measures to comply with the established standards regarding discharges. This six-monthly monitoring is essential to ensure the protection and conservation of the quality of the water resource in the study area.(Navas & Jaimes, 2021)

IDENTIFICATION AND ASSESSMENT OF ENVIRONMENTAL IMPACTS

The environmental impact assessment carried out through the EPM method has provided a more detailed view of the negative effects that human activities are having on the natural environment of the study area. The impacts identified encompass a variety of aspects that affect both biodiversity and the quality of the environment.

One of the most notable impacts is the generation of unpleasant odors. Not only does this create a nuisance for local residents, but it can also indicate the presence of volatile chemicals and pollutants in the air, raising public health concerns.

The deterioration of terrestrial and aquatic fauna is another significant impact. Water pollution and habitat alteration due to sewage discharges can severely impact local wildlife. Terrestrial wildlife can be exposed to harmful chemicals, while aquatic wildlife are affected by changes in water quality and food availability.

Landscape degradation is evident as solid waste accumulates and the natural environment is altered. Not only does this affect the aesthetics of the area, but it can also have consequences in terms of tourism and quality of life for local residents.

The impact on local flora and fauna is an additional concern. Native plant and animal species may be displaced or harmed by human activities and water pollution.

The production of waste, both solid and liquid, places an additional burden on the environment. The improper disposal of this waste further aggravates the situation and contributes to environmental degradation.

Last but not least, water quality degradation is a critical issue. The presence of high concentrations of BOD and COD, as well as the presence of suspended solids, greases and oils, is a clear indicator of water contamination in the study area. Not only does this affect aquatic life, but it also puts the drinking water supply for the local community at risk.

This is in line with the research carried out by (Martínez et al., 2023) where they express that the analysis of environmental impacts reveals that the most significant anthropic activities, such as the discharge of wastewater, the improper disposal of waste and the construction of roads, are seriously affecting water resources, consequently, they have caused negative changes in water quality and aquatic biodiversity, which jeopardizes the sustainability of the ecosystem. In addition, this situation has an economic impact on the local community by reducing sources of employment and traditional food. It is essential to take steps to address these issues and strike a balance between human development and environmental preservation.

CONCLUSIONS

The characterization of the discharge has revealed that the BOD values exceed the limits established by Resolution 631 of 2015. As a result, it becomes absolutely necessary to implement a treatment system with the purpose of reducing the load of pollutants that are discharged directly into the water body from the wastewater.

The characterization of the spill has shown that parameters such as COD, oils and fats, suspended solids and total solids are within the limits allowed under Resolution 631 of 2015. However, it is essential to note that the fact that these values are within the established limits does not guarantee that there will not be an impact on the quality of the water resource. Therefore, it is essential to implement a treatment system with the aim of reducing pollutant loads in the water body. This is of significant relevance given that wastewater is being discharged directly, which could have long-term consequences on the quality of the water resource.

By carrying out the environmental impact assessment using the EPM method, certain impacts of greater relevance have been identified. These impacts include the generation of unpleasant odours, the deterioration of both terrestrial and aquatic fauna, the degradation of the landscape, the affectation of local flora and fauna, the production of waste and the impact on biota, as well as the degradation of water quality, among others. These findings are consistent with previous observations related to the presence of solid waste and wastewater discharge in the area.

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