

## Environmental Impacts and Health Effects in the Surroundings of the Río Hondo, Cauca

### Impactos ambientales y efectos en la salud en el entorno del Río Hondo, Cauca

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## Abstract

**Introduction:** the community of the El Salvador village lacks a sewage system, which leads to the direct discharge of untreated wastewater into the Río Hondo. The inhabitants are unaware of the environmental impacts and health risks associated with this practice.

**Objective:** the purpose of this study was to identify environmental impacts and health symptoms in the area surrounding the Río Hondo that crosses through the village.

**Methods:** two methodological phases were established for data collection. In the first phase, environmental aspects related to the water quality of the Río Hondo were identified using a checklist and a Leopold matrix. The second phase involved determining health symptoms related to environmental factors in the area, for which a survey was conducted with a sample population of 60 people.

**Results:** an 87.5% non-compliance rate was observed compared to a 12.5% compliance rate regarding environmental factors, indicating a higher percentage of environmental impact concerning water quality, land use, biodiversity, pollution sources, regulations, and human health impacts. Poor waste disposal and the lack of sewage management exacerbate the environmental and health issues faced by the inhabitants of the area. The most frequently reported symptoms in the survey were stomach pain and intestinal infections (46.7%), followed by dengue (43.3%), chikungunya (3.3%), and malaria (3.3%).

**Conclusion:** the absence of an adequate sewage system and improper waste disposal significantly contribute to environmental and health problems in the El Salvador village community. It is crucial to implement environmental management and public health measures to mitigate these adverse effects.

## How to cite?

Castro-Montaña, C.D., Gil-Pardo, D., Samboni-Valverde, M.H., Muñoz-Solarte, D.M. Environmental Impacts and Health Effects in the Surroundings of the Río Hondo, Cauca. Ingeniería y Competitividad, 2024, 26(3)e-20813680

<https://doi.org/10.25100/iyv.26i3.13680>

Recibido: 1-04-24

Evaluado: 07-06-24

Aceptado: 29-08-24

Online: 04-10 -24



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**Keywords:** : Pollution, Health impacts, Wastewater, Discharges.

## Resumen

**Introducción:** la comunidad de la vereda El Salvador no cuenta con un sistema de alcantarillado, lo que provoca el vertido de aguas residuales directamente al río Hondo sin ningún tipo de tratamiento. Los habitantes de la zona desconocen los impactos ambientales y los riesgos para la salud que esta práctica conlleva.

**Objetivo:** el propósito de este estudio fue identificar los impactos ambientales y los síntomas de salud en el entorno del río Hondo que cruza a través de la vereda.

**Métodos:** para la recolección de información, se establecieron dos fases metodológicas. En la primera fase, se identificaron los aspectos ambientales asociados a la calidad del agua del río Hondo mediante una lista de chequeo y una matriz de Leopold. La segunda fase consistió en determinar los síntomas de salud relacionados con los factores ambientales del lugar, para lo cual se aplicó una encuesta a una muestra poblacional de 60 personas.

**Resultados:** se evidenció un 87.5% de no cumplimiento versus un 12.5% de cumplimiento de los factores ambientales, lo que indica un mayor porcentaje de afectación al medio ambiente en relación con la calidad del agua, uso del suelo, biodiversidad, fuentes de contaminación, regulaciones e impactos a la salud humana. La mala disposición de residuos y la falta de gestión de un sistema de alcantarillado intensifican los problemas ambientales y de salud en los habitantes del sector. Los síntomas más frecuentes reportados en la encuesta fueron daño y dolor de estómago e infecciones intestinales (46.7%), seguidos por la enfermedad del dengue (43.3%), chikunguña (3.3%) y malaria (3.3%).

**Conclusión:** la ausencia de un sistema adecuado de alcantarillado y la disposición inadecuada de residuos contribuyen significativamente a los problemas ambientales y de salud en la comunidad de la vereda El Salvador. Es crucial implementar medidas de gestión ambiental y de salud pública para mitigar estos efectos adversos.

**Palabras clave:** contaminación, Impactos de salud, Aguas residuales, Vertimientos.

### Why was it conducted?:

This research was carried out to analyze how the environmental deterioration of the Río Hondo, caused by different sources of pollution such as the direct discharge of wastewater, due to the lack of sewerage; is presenting health risks for the inhabitants of the village of El Salvador, Popayán, Colombia.

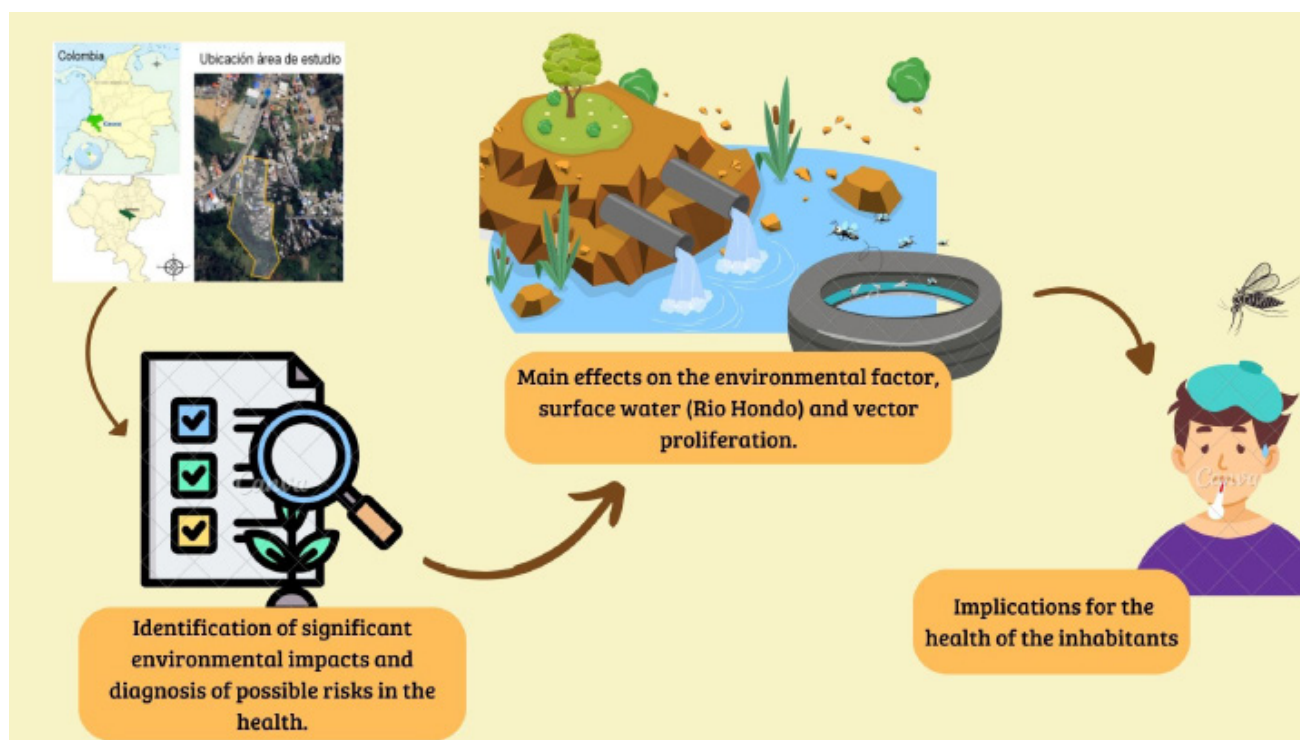
### What were the most relevant results?

In terms of environmental impacts, a high level of non-compliance with environmental factors was evidenced, indicating a significant impact on the environment in terms of water quality, land use, biodiversity, sources of pollution, and regulations. Regarding health symptoms, the most frequent among the inhabitants were stomach damage and pain, and intestinal infections, followed by dengue, chikungunya, and malaria.

### What do these results contribute?

These results provide a clear understanding of the serious environmental and health problems faced by the community due to the lack of a sewage system and poor waste disposal. This information is important to raise awareness among the community about the risks and the need to improve waste management practices; to inform the competent authorities and policymakers about the urgency of implementing adequate sanitation solutions; and finally, to promote actions to improve the quality of life and health of the inhabitants, as well as the protection of the environment in the El Salvador village.

## Graphical Abstract



## Introduction

During the last decade, we have witnessed how population growth and accelerated urbanization have generated the alteration and degradation of different ecosystems, bringing with them serious climatic consequences. Additionally, the various economic activities carried out by humans to meet basic needs contribute to the depletion of natural resources and the degradation of water basins (1). One of the causes of this latter is the discharge of wastewater into bodies of water, which is bringing with it effects on human health. In Colombia, according to 2018 reports, the national scope of public sewerage service for urban areas corresponds to 82.84% and 14.36% for rural areas, showing a significant difference in this public service and evidencing that the lack of service represents a danger to nearby water sources, since they end up being the sites of disposal of wastewater, exacerbating the problem of water pollution in many parts of the country (2). One of the concerns about this problem is that in some rural areas, people use the water from these sources for their agricultural activities, such as crop irrigation; which are then ingested by humans or by animals that are consumed by humans, generating health effects such as, for example; Acute Diarrheal Disease (ADD), Typhoid Fever, Foodborne Illness (FBI), Hepatitis A, etc.

(3) According to 2020 data, 74% of the world's population had access to a safe water supply, and it is estimated that annually, microbiologically contaminated water causes 485,000 deaths from diarrhea, although there are other chemical substances that represent a risk to health (4). Due to the above, different studies have been carried out analyzing this situation, such as, for example, a national investigation that aimed to evaluate the microbiological quality of water for consumption and wastewater in a population in Bogotá (Colombia), close to displaced housing and its relationship with the health of the population. To determine the presence of bacterial indicators, the samples were subjected to analysis using the membrane filtration technique. In their results, they found that

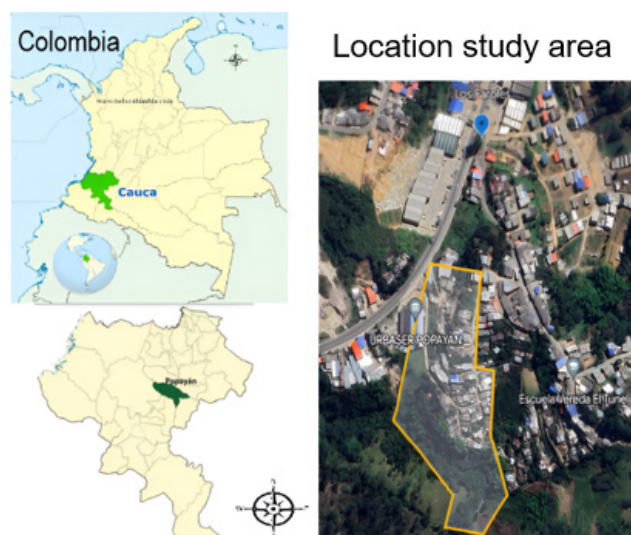
in 14 of the 36 selected houses and in 15 of the open sewer networks, contamination of fecal origin was found, and the presence of *E. coli*, *C. perfringens*, and somatic coliphages was evidenced in the potable water storage containers (5).

In the El Salvador village of the Popayan municipality, some homes are located on the protection strip or riverbanks of the Hondo River, which runs through the village. These homes, due to their location, have generated excavations and landfills, causing instability in the terrain, and there are homes built with lightweight materials like wood, creating high vulnerability and risk due to landslides that can occur during winter or heavy rainfall (6). Similarly, many of these homes, due to their location and high poverty rates, make the provision of basic services like aqueducts, sewage, and sanitation inadequate. In the first case, the village is supplied by the Río Negro Rural Aqueduct, which has a PTAP (Potable Water Treatment Plant) with multi-stage filtration technology (FIME); however, the supply of this natural resource is intermittent, forcing inhabitants to store water in different containers to have a continuous supply (7).

In the second case, the absence of this service causes homes to discharge wastewater into the main collector that flows into the river, and some homes discharge it directly into the river, causing environmental impacts in this environment. This situation has worsened in recent years, due to the population growth in this rural area, and the river now receives discharges from other nearby villages, such as the Túnel Alto village. Additionally, other activities like disposing of solid waste into the river by some villagers obstruct the river's circulation and create stagnant water, affecting the ecosystem, promoting the proliferation of vectors, and spreading diseases and infections among people. Considering the above, this study aims to identify the environmental impacts generated around the Hondo River and possible health symptoms associated with the population living in the El Salvador village (Popayan, Cauca, Colombia).

## Methodology

The research focuses on the population living near the Hondo River, which is the community of El Salvador village located south of the city of Popayan (Cauca Department) in southwestern Colombia, with coordinates: 2°25'27.2" N and 76°37'14" W, characterized by having an average temperature of 18-20°C, with an average altitude above sea level of 1,734m (Figure 1).



**Figure 1.** Geographic delineation of the study zone. **Source:** Adapted from Google Earth Pro 2024

For the development of this research, a quantitative methodology was focused on, with a bivariate correlational design in which different instruments were applied, such as: Checklist, Leopold matrix,

surveys, and narratives of the inhabitants. Additionally, variables such as: Sociodemographic aspects, environment, sanitation, and health status were taken into account. On the other hand, in the study area, a total of 150 households were determined, where for the implementation of the survey, a sample of 60 households or families was worked with, which was determined by applying equation 1 of finite population in order to establish the number of households to visit.

Determination of sample size according to the population of the area, which gave 59.

$$n = \frac{Nz^2pq}{(N-1)e^2 + z^2pq} \text{ (Equation 1)}$$

Where:

n: Sample size

N: Population

e: Margin of error (10% → 0.10)

z: Confidence level of 95% → 1.96

p: Probability of the studied event occurring (50%)

q: Probability of the studied event not occurring (50%)

Note: In statistical analysis, "p" and "q" are used to denote the probability of an event happening (p) and not happening (q), respectively. These probabilities are complementary, meaning that  $p + q = 1$ .

$$n = \frac{150 * 1.96^2 * 0.5 * 0.5}{(150 - 1) * 0.10^2 + 1.96^2 * 0.5 * 0.5} = 59$$

The methodology consisted of two phases, in which the aforementioned instruments were utilized, and the details of which are outlined below:

Identification of environmental aspects associated with the water quality of the Hondo River

Activity 1: To identify the environmental aspects that may affect the inhabitants of the village, a technical visit was made to the study site, guided by community leaders and through direct observation, a checklist (Appendix 1) was applied, which verified the level of compliance in different aspects such as water quality, land use, biodiversity, sources of pollution, regulations, and impacts on human health (8). For the elaboration and graphic analysis of the checklist, some office tools such as Word and Excel were used.

Activity 2: Leopold Matrix Application for Environmental Impact Evaluation A Leopold matrix (Appendix 2) was applied as a tool to evaluate the environmental impacts in the village. The matrix was completed through direct observation and detailed information gathered during the visit to the study site. The matrix established relationships between different environmental factors, including: water, air, soil, processes, flora, fauna, ecological relationships,

And the activities carried out in the community, such as solid waste disposal, wastewater discharge, etc. (9). Consequently, the columns listed the environmental components and factors, and the rows listed the activities carried out in the community. Additionally, the matrix was completed and analyzed using the Excel office tool, and for the evaluation and assessment of the impacts, a study by Ortiz and Peralta was taken into account, which established requirements such as: a) (-7 to -10) highly significant impacts, which are those that have significant effects on the environmental factor, difficult to correct, widespread, irreversible, and permanent; b) (-4 to -6) significant impacts, which are feasible to correct, localized, and temporary; c) (-1 to -3) negligible impacts, which are correctable, reversible, sporadic, and with punctual influence; and d) (1 to 10) beneficial impacts, which are positive impacts.



## Identification of Health Symptoms Linked to Environmental Aspects in the El Salvador Village Community

Based on a study conducted in the municipality of La Garita, North of Cucuta (Colombia), a survey called "Factors influencing the generation of diseases due to inadequate wastewater disposal in El Salvador village, Popayan" (Figure 2) was applied. The survey consisted of variables: a) sociodemographic factors such as gender, age, educational level, and occupation; b) environment, which addressed aspects such as the number of inhabitants per household, floor material, roof, and walls of each house; c) sanitation, which evaluated the final disposal of waste and the use of rainwater; and d) health, which explored the diseases affecting the community, their affiliation to a health system, frequency of attendance, and habits that allowed understanding the sanitary conditions and health status of the community (10). The survey was conducted online using Google Forms with each of the village inhabitants and was graphically analyzed using the Excel office tool.

## Results and Discussion

### Environmental Aspects Affecting the Water Quality of the Hondo River

#### Activity 1: Environmental Conditions Assessment Related to the Water Quality of the Hondo River

In Figure 2, the results obtained from the checklist are revealed, which allowed identifying the different environmental aspects. These were categorized into water quality, sources of pollution, land use, biodiversity, regulation, and impacts on human health. The checklist was divided into six factors, each with different activities, each equivalent to 6.25%. The percentages for each aspect were obtained, and the following was determined: water quality 19%, land use 19%, biodiversity 6%, and sources of pollution 6%, regulations 13%, and impacts on human health 25%, as observed during the visit to El Salvador village.

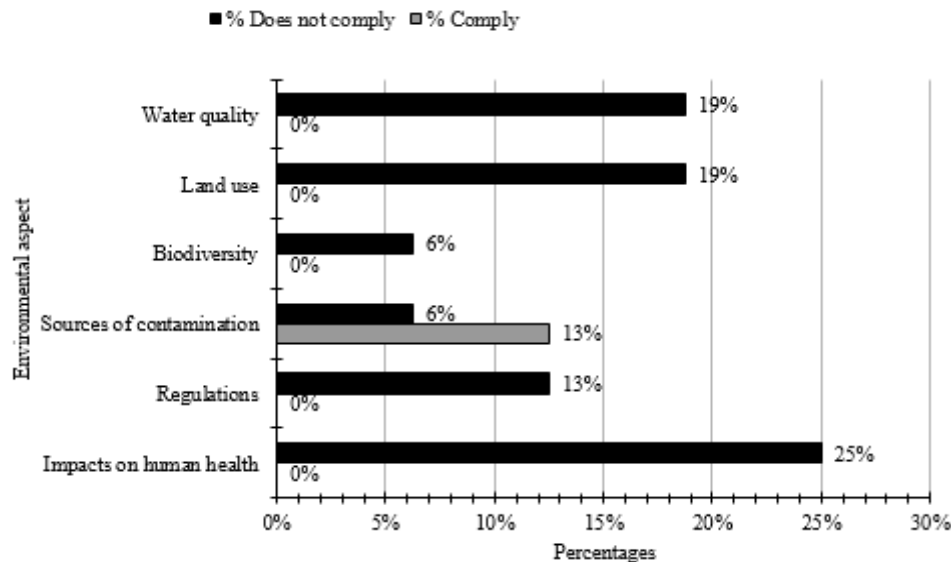


Figure 2. Compliance with the aspects related to the applied checklist

Consequently, the results reveal a substantial shortfall in compliance in El Salvador village, with a non-compliance rate of 87.5% and a compliance rate of merely 12.5% regarding environmental aspects, indicating a more severe adverse impact. In the environment, affecting factors such as soil, air, water, fauna, and flora, as well as related socioeconomic components. In comparison, a study conducted at a company producing and marketing artisanal sweets in the province of Manabí (Ecuador) showed a compliance percentage of 58%. Although both studies reveal deficiencies in compliance with environmental aspects in the checklist, El Salvador village presents a higher degree of non-compliance, evidencing greater impacts on the environment (8).

According to the results obtained, a study by Rafael D’Almeida Martins and Leila Ferreira supports that human activities generate impacts on the environment that cause a disruption of its balance, mainly due to air, water, and soil pollution, and degradation of flora and fauna (11). According to the MAPFRE Foundation, these effects can have a negative impact on human health, causing diseases, disability, or death, and it has been shown that the well-being of populations directly depends on the state of ecosystems. Therefore, it is essential to measure, plan, and minimize any activity that can alter the ecological balance, considering that as the human population grows, natural resources are depleted, and it is urgent to improve the sustainability of human development (12). Different human activities affect water quality through deforestation, waste generation, wastewater disposal, and soil erosion, which evidences the contamination of the main water source of the Río Hondo

Activity 2: Categorization of Environmental Impacts

The following (Table 1) presents the quantification of environmental impacts identified through the Leopold Matrix.

Table 1. Final Environmental Impact Assessment

Environmental Factor	Impacts			
	Highly Significant	Significant	Negligible	Benefits
Air	3	6	3	0
Water	7	4	2	3
Soil	4	3	5	1
Processes	4	0	3	0
Flora	2	2	1	0
Fauna	2	2	7	2
Ecological Relationships	3	0	3	2
Basic Services	4	4	7	9
Economy	0	0	0	7
Total	29	21	31	24
	105			

Reference: Authors

In the matrix, a total of 105 interactions were identified, of which, according to each evaluated activity in the categorization of environmental impacts, 28% belong to highly significant impacts, 20% significant, 30% negligible, and 23% beneficial, presented in the Salvador area. Furthermore, it is evident that the greatest negative environmental impact caused by the different activities is found in the human and physical components, corresponding to the environmental factor of basic services and water with 14.3% and 12.4%, respectively. Similarly, it can be seen that the surface water quality factor is the one with the highest highly significant impact (5), followed by the health factor with a total of 4 highly significant impacts, considered to be of great incidence and complex to correct; and it is also added that the activities that generate the most impact on these factors are the discharge of wastewater and stagnant water.

Consistent with the findings of the research article “Sun and Beach Tourism: Tourist Impact on the Ecosystems of Ayangué Commune, to Improve the Management of Tourist Activity in Santa Elena

Province”, the water environmental factor emerges as a critical concern, owing to its susceptibility to a higher number of adverse impacts that can directly affect the health and quality of life of local residents (9).

Some of the environmental modifications caused by human activities can be observed in this village, as they are a result of economic processes, social inequality, and a lack of basic services such as water supply and sanitation, which in turn lead to health complications due to the proliferation of vectors, insects, and bad odors that worsen over time due to population growth. Therefore, there is a direct connection between poverty and environmental degradation, according to the prevailing school of thought (13). In a study conducted by Miguel Bustamante and Roberto Campos, it is described how humans, in their quest for productivity and fulfillment of their needs, transform their environment, deplete natural resources, and generate inequalities, making it necessary to adopt a new paradigm in consumption and production patterns that connects poverty, human life, and society, since without equity, equal opportunities, and addressing poverty, environmental destruction will increase (14). Thus, the importance of a healthy environment is reflected in the Report on the Sustainable Development Goals (2023 Edition), which highlights that it is vital to “ensure a healthy life and promote well-being for all at all ages” (15), where public environmental health plays a crucial role, referring to the intersection between the environment and public health, and addressing environmental factors that influence health, such as physical, chemical, and biological factors, as changes in these determinants cause adverse effects on health and well-being, and according to the Pan American Health Organization, addressing these environmental determinants suggests a direct improvement in people’s health, indirectly also improving productivity and socioeconomic aspects (16).

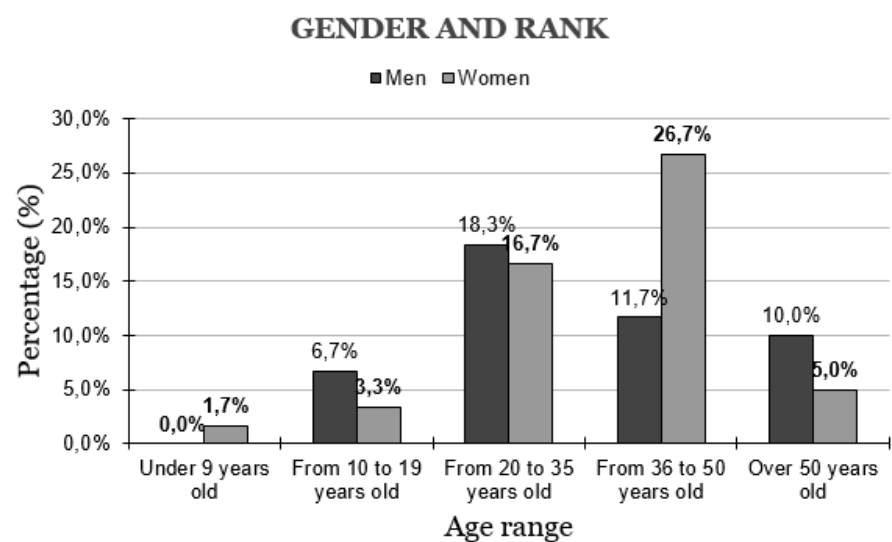
Non-potable and residual water constitutes the main source of pathogenic microorganisms that spread in the environment and affect the population through contaminated water intended for consumption. In the third report Water in a Changing World (2009), the main causes of death related to environmental factors, mainly due to sanitation and water management, are presented by UNESCO. The table mentions various diseases, highlighting Diarrhea, indicating that there are 1,523,000 annual deaths attributable to problems related to water, sanitation, and hygiene, and 94% of the total disease burden is due to environmental factors. Similarly, the table shows how the lack of adequate water supply and sanitation significantly contributes to deaths from Dengue, with a total attributable burden of 95% (17).

### Identification of health effects associated with environmental factors in the El Salvador village population

#### Sociodemographic characteristics

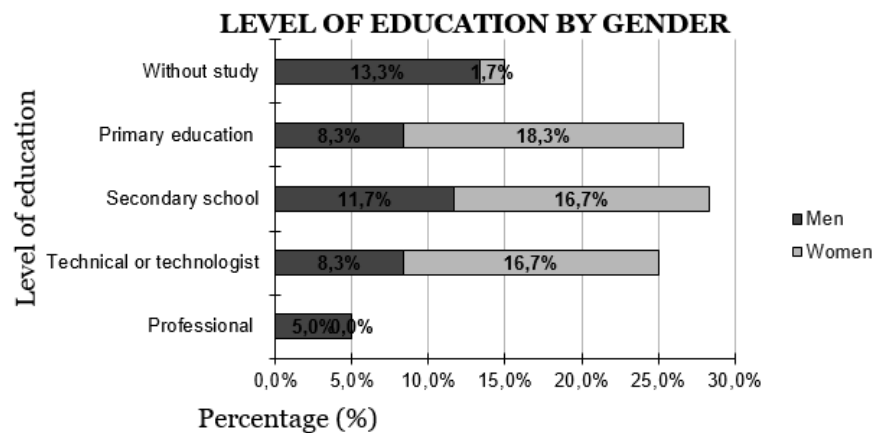
In Figure 3, it can be seen that the highest percentage corresponds to the female gender, with 26.7% in the age range of 36 to 50 years. This is because families are often headed by single mothers who are forced to take on roles that require them to be the breadwinners of their households. As a result, in order to meet their economic needs and ensure a steady income, it is common for them to live in areas where housing costs are lower (13). The 16.7% are in the age range of 20 to 35 years, 3.3% are between 10 and 19 years old, 1.7% are under 9 years old, and the remaining 5.0% are over 50 years old.





**Figure 3.** Distribution of surveyed inhabitants by gender and age group

Regarding the level of education achieved by the study population, Figure 4 shows that over 80% of the surveyed individuals have officially completed primary education, while less than 16% have no formal education. Additionally, in this category, it stands out that 13.3% of those with no formal education are men, and the remaining 1.7% are women. Similarly, it is evident that only 5% of the surveyed individuals are professionals, and they are men. This may be due to the fact that women often have to interrupt their studies, either in school or in their professional life, because of pregnancy, which makes it difficult for them to continue their education, or because some decide to devote themselves fully to family life, indicating a low level of professional education in the population (18). This could be due to the distance from educational institutions, given that the area lacks public transportation and the nearest schools only offer basic primary education (13).



**Figure 4.** Level of education by gender of the surveyed inhabitants.

Regarding occupation, Figure 5 shows some of the main occupations of the surveyed individuals in order to understand the labor situation of the households in the study area and how it affects their social situation.

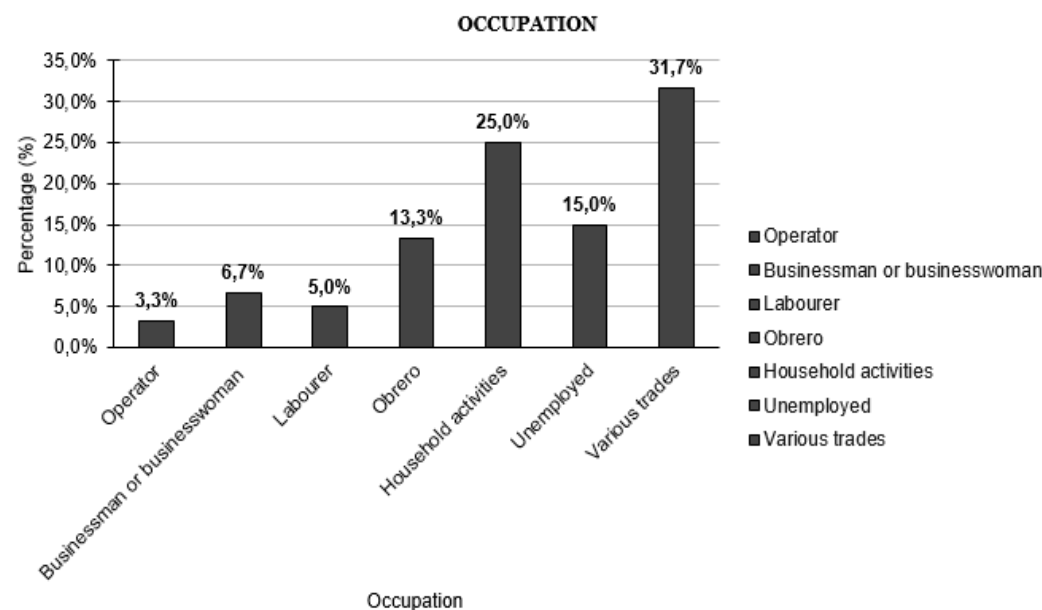


Figure 5. Occupation of the surveyed inhabitants

Therefore, it was found that the majority of the surveyed individuals, 31.7%, are engaged in various trades, 25.0% are related to household activities, and 15.0% are unemployed, indicating a possible low income in the surveyed households. Thus, it can be inferred that most jobs are informal occupations or labor due to the complex economic situation and the high demands of finding formal employment. Therefore, People opt for the quickest and most accessible option to have income for their household. According to data from the National Statistics Department (DANE) at the national level, Popayan has a high rate of informality, represented by 61.86%, which confirms the limited job opportunities in the city (19).

Environment

In Table 2, it is indicated that a good percentage of the surveyed households (71.7%) are composed of 2 to 5 people, and 18.3% are composed of 6 to 10 people, with a smaller percentage of 3.3% for more than 10 people and 6.7% for one person out of the total surveyed. In a study on the composition of households in the department of Cauca, it is indicated that the rural area is represented by 54% of the total population, and the average number of people per household is 3.89, along with a maximum of 14 people per dwelling, and for the urban sector, an average of 3.37 people is found, which reflects that the main influencing factor is the poverty conditions in the department of Cauca, with indices of 62.1% and 34% of extreme poverty (20).

Table 2. Household structure

Household Integration	Percentage (%)	(%) Quantity
1 person	6.7	4
2 to 5 people	71.7	43
6 to 10 people	18.3	11
More than 10 people	3.3	2
Total	100	60

Reference: Authors

Table 3 presents data on the characteristics of healthy housing, including the materials used for walls, roofs, and floors.

Table 3. Building materials used in homes

	Material	Quantity	Percentage (%)
Wall	Wood	16	26.7
	Brick	40	66.7
	Plastic	2	3.3
	Adobe	2	3.3
	Total	60	100.0
Roof	Zinc	28	46.7
	Sheeting	13	21.7
	Eternit	19	31.7
	Total	60	100.0
Floor	Cement	9	15.0
	Ceramic	16	26.7
	Concrete	17	28.3
	Wood	1	1.7
	Not applicable	17	28.3
	Total	60	100.0

Reference: Authors

According to the previous results: Regarding the walls of the housing; 66.7% are made of brick and 26.7% are built with wood; it was also evident that there were houses built in combination with other materials such as plastic and adobe. On the other hand, 46.7% of the houses had zinc tile roofs, 31.7% of Eternit, and 21.1% with sheet metal. Finally, regarding the material of the floor of the housing, 28.3% indicated that the material is concrete, followed by 26.7% of ceramics, 15% of concrete, 1.7% of wood, and the remaining 28.3% do not have floor material. Now, poverty can increase people’s vulnerability to environmental impacts, people with low resources often live in areas with high levels of pollution, as they do not have the economic resources to live in cleaner areas, these populations have little coverage of basic services and do not have easy access to health services, which can make it difficult for them to treat diseases caused by pollution [\(21\)](#).

The El Salvador village, being a community with multiple economic hardships, is considered to have a higher environmental impact due to its activities, which is why the population becomes more vulnerable and exposed to effects, without access to efficient healthcare systems, job opportunities or assurance of a dignified life [\(22\)](#).

Figure 6 refers to the public services available in the homes of El Salvador village, where 70% have access to water, energy, and gas services, 26.7% have access to water and energy, and 3.3% have only water service. This last percentage is low compared to the others because the company responsible for installing these services did not connect them to the homes in the lower part of the village due to the risk it poses to the residents, therefore, in some homes, it is common to see old wood-burning kitchens. However, according to data from the National Administrative Department of Statistics (DANE), the coverage of public services in the city of Popayan, including the rural area, is high in terms of energy with 98.7% and aqueduct with 96.1%, but the coverage of sewage services is lower, represented by 84.9%, and gas service with 63.5% [\(23\)](#).

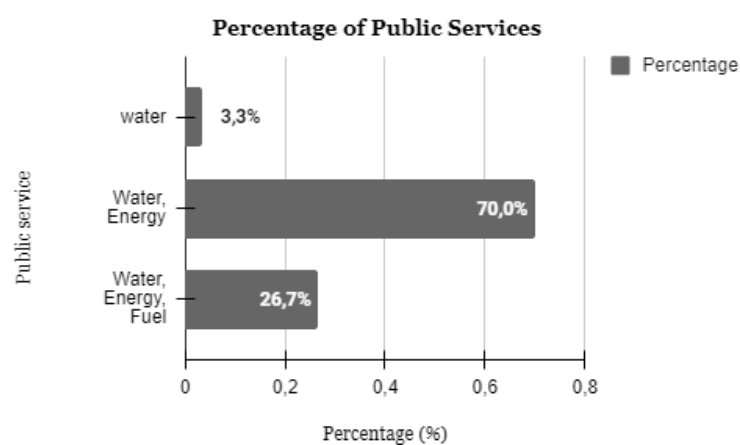


Figure 6. Access to public utilities in households

Table 4 shows data on the primary source of water supply for homes, the quality of the water consumed, and the regularity of the water service.

As a result, the survey respondents reported that 93.3% rely on the municipal water supply as their primary source of water, while 3.3% have a self-built well that is replenished by a natural spring located near the river.

Table 4. Source of water supply for the households of the surveyed residents

Question	OPCIONES	NUMBER OF RESPONSES	PERCENTAGE (%)
What is the primary source of water supply for the home?	Municipal water supply	56	93.3
	Private well	2	3.3
	River	2	3.3
How do you typically use water in your home??	Directly from the tap	38	63.3
	After boiling	20	33.3
	Bottled water	1	1.7
What is the water service like in your household?	Very regular	5	8.3
	Irregular	55	91.7
	Never	0	0.00

Reference: Authors

In Table 4, the results corresponding to the main source of supply in each household, 93.3% stated that the water is supplied from the aqueduct, 3.3% from a nearby well, and 3.3% from the river. Regarding the state in which the water is consumed, 63.3% drink water directly from the tap, 33.3% boil it before consumption, while the remaining 1.7% consume bottled water. This has an influence on the diagnosis that is sought to be made according to the diseases present in the inhabitants of the area, highlighting that the Río Negro aqueduct, of which they are subscribers, does not have a complete and safe potabilization process, since having water service can be seen that it comes with particles of earth making it not totally reliable for direct consumption (24). As mentioned in similar studies to the investigation, the odor and appearance are related to the quality of the water and the lack of potabilization of it in rural aqueducts (25). However, some communities opt to boil the water as an alternative action to reduce the level of contamination.

However, some families think that drinking tap water directly is safe and does not pose any health risks. Additionally, the survey reveals that the water service is intermittent, with 91.7% of respondents stating that it is only available 3 days a week, while 8.3% consider the service to be quite frequent.

Wastewater Management

In Table 5, it is shown how the final disposal of waste is carried out in each household, where 86.7% of the surveyed residents claim to deposit it in the garbage truck, 8.3% burn it, 3.3% recycle it, especially making use of organic waste, which is used as fertilizer for the land where they have their crops, and 1.7% deposit it in the river. An example of this is a study conducted to analyze the management of solid waste in municipal management from a systemic review in Peru, which states that training and awareness-raising on good waste management practices should be promoted, accompanied by the use that can be given to them to improve the quality of life of the population and also reduce the volume of solid waste destined for the landfill [\(26\)](#).

Table 5. Final disposal of waste in each household

How do you dispose of household waste?	NUMBER OF RESPONSES	PERCENTAGE (%)
Garbage truck	52	86.7
Burning	5	8.3
River	1	1.7
Recycling and using organic waste as compost	2	3.3
TOTAL	60	100.0

Reference: Authors

The following (Table 6) shows some of the responses from the residents of El Salvador village, where it is evident that 71.7% of the surveyed residents collect rainwater for later use; on the other hand, the majority of the surveyed residents, exactly 91.7%, wash the food they consume with the water that supplies the household.

Understanding these habits is crucial, as it provides valuable insights that can be connected to the underlying causes of specific health issues affecting the residents, which will be explored in more detail later [\(25\)](#).

Table 6. Habits and hygiene practices evaluation

Question	Number of Responses		Weighting (%)		
	Yes	No	Yes	No	Total
A- Is rainwater harvesting practiced in your household for future use?	43	17	71.7	28.3	100
B- Do you use containers with stored water for several days?	45	15	75	25	100
C- Do you wash the food you consume with the water supplied in the household?	55	5	91.7	8.3	100

Reference: Authors

Health status

Table 7 shows the results of the questions asked to understand the perception of the residents of “El Salvador” village about the diseases they frequently suffer from, the healthcare system they are affiliated with, the possible habits they have that may harm their health, and the frequency with which they visit the doctor.



Table 7. Results on health habits of the surveyed residents

Question	Options	Number of Responses	Percentage (%)
Do you have the habit of smoking cigarettes?	Yes	6	10.0
	No	44	73.3
	Occasionally	10	16.7
Are you currently enrolled in a healthcare program?	Yes	51	85.0
	No	9	15.0
What is your frequency of attending medical check-ups?	Very regular	17	28,3
	Rarely	28	46.7
	Never attends	15	25.0

Reference: Authors

Regarding the question “What is your smoking habit?” to determine if this affects their health, 73.3% of respondents do not smoke, and the remaining 26.7% are divided between those who do smoke and those who smoke occasionally. Similarly, the survey reveals the status of the healthcare system for the respondents, with 85% affiliated with a Health Promotion Entity (EPS), all of whom belong to the subsidized regime, and 15% without affiliation. Furthermore, 46.7% of those affiliated rarely attend medical check-ups, 28.3% attend very frequently, and 6.7% do not attend at all. Given the above, it is essential to highlight that the residents in this area have limited financial resources, making it difficult for them to attend medical check-ups. They are also beneficiaries of the System for Identifying Potential Beneficiaries of Social Programs (SISBEN) and receive government-funded healthcare services, as they are considered a vulnerable population. However, despite having a free healthcare system, people believe that the poor quality and attention of this system can worsen their health conditions. Therefore, they opt to recover at home or not attend medical check-ups frequently. A report by The Lancet Global Health supports the above, showing that in middle- and low-income countries, such as Colombia and many in Latin America, more than 8 million people die from treatable diseases, and 60% of these deaths are due to poor quality care [\(27\)](#).

Regarding the frequency of illnesses among residents (Table 8), it was found that 46.7% frequently suffer from illnesses, 45% rarely experience conditions, and 8.3% have not experienced any. In the El Salvador village, the poor quality of the water from the aqueduct system stands out, primarily due to contamination from organic matter. This contamination comes from nearby residences and contains various pathogens that pose a risk to health. The situation is concerning since people exposed to this water absorb these substances directly or indirectly, which is why the frequency of acquiring gastrointestinal infections is significant, particularly in a population vulnerable to consuming this water [\(24\)](#). This issue occurs in many low-resource areas that are vulnerable, as seen in a study conducted in Timbio, where cases of gastroenteritis, diarrhea, and intestinal ( parasitosis) were identified, associating the cause with the possible role of water as a natural reservoir for emerging pathogens like *Helicobacter pylori* [\(28\)](#).

Table 8. Frequency of illnesses among surveyed residents

	Never	Ocassional	Frequent	Total
How often do family members experience stomach-related health issues, such as stomach pain or intestinal infections?	5	27	28	60
Percentage (%)	8.3	45.0	46.7	100.0

Reference: Authors

Figure 7 shows the diseases that have occurred over the years and the symptoms that can be related to the bad odors to which they are exposed. It can be observed that 43.3% of the residents have suffered from Dengue, making it the most common disease in the area, while the remaining 56.7% have suffered from other diseases. The surveyed residents also reported that stomach damage and vomiting are frequent symptoms, but they do not attend a medical center due to the costs of transportation, which is not easily accessible, and instead opt to recover using homemade remedies prepared by themselves.

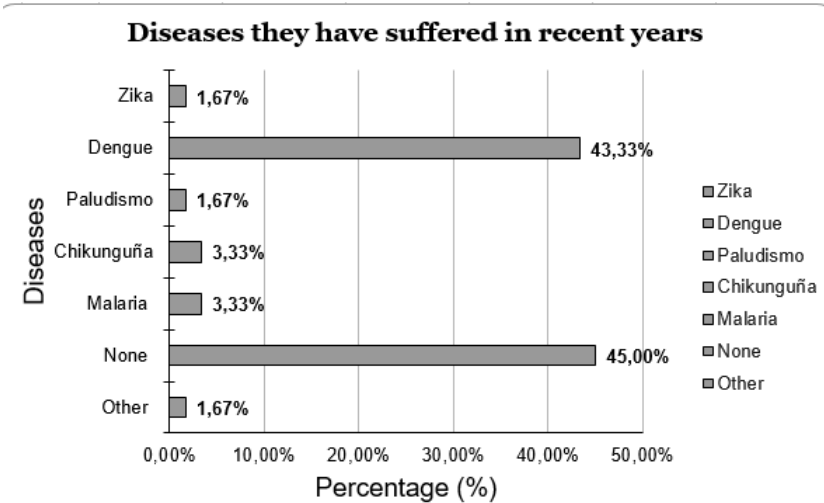


Figure 7. Percentage compliance with the applied checklist

The main component determined through the survey was the health diagnosis of the target population due to the water conditions they have access to and are affected by inadequate waste disposal, as they lack a sewage system. Consequently, factors such as the bad odors emitted by the waste cause the proliferation of vectors like mosquitoes and midges, which expose people to diseases like Dengue. According to the Pan American Health Organization (PAHO), this disease is transmitted by the bite of an infected mosquito and affects people of all ages, with symptoms ranging from mild to incapacitating fever, as well as severe headaches, pain behind the eyes, muscle and joint pain. This disease can progress to severe forms, characterized by shock and respiratory difficulties, which mainly affect children and the elderly (29). These insects breed in stagnant water, such as puddles, trash cans, and old tires, which is exacerbated by water contamination, creating favorable conditions for the proliferation of this mosquito, increasing the risk of dengue transmission (30). In the case of El Salvador village, the contamination of the Hondo River is creating favorable conditions for the reproduction of these vectors, as the contamination can cause the river water to stagnate, considering that the levels of organic contaminant load are high and ideal for vector proliferation due to the disposal of wastewater.

This supports a report released in the city of Popayán, which revealed a high prevalence of new Dengue cases. Specifically, a significant increase in the number of affected individuals was observed in Commune 9, where El Salvador village is located, making it the commune with the most reported

cases. The age range of the infected citizens corresponds to people between 27 and 59 years old. Considering the above, the Health Secretary, through the Government of Cauca, declared a red alert for Dengue in the department in March 2024, as it has been experiencing an outbreak since 2023 (31). Table 9.

Table 9. Recent illnesses among surveyed residents.

Other types of illnesses recently suffered:	Percentage (%)
flu	10.0
Ovarian cysts and heart problems	1.7
Chronic rhinitis	1.7
Malaria	1.7
Indigestion	5.0
Tonsillitis	1.7
Intestinal infection	5.0
Headache	1.7
Indigestion and vomiting	3.3
Indigestion, vomiting, and flu	1.7
Flu and stomach pain	1.7
Flu and vomiting	1.7
Intestinal infection and fever	3.3
Multiple symptoms	1.7
N/A	58.3
Total	100.0

Reference: Authors

In Table 9, the most relevant results are flu with 10.0%, intestinal infection with 5.0%, and indigestion also with 5.0%. It is considered that, being a population with limited economic resources, they face various challenges related to sanitation. This is linked to the consumption of water directly from the aqueduct, which does not safely purify its water, and the storage of stagnant water for several days due to intermittent service. This is a direct factor in the transmission of gastrointestinal diseases, frequently caused by viruses, bacteria and protozoa present in contaminated water (32). On the other hand, the most common disease in the community is Dengue, and residents report experiencing symptoms such as fever, rash, vomiting, and headache. These findings are supported by a study conducted in Colombia by a group of students in 2008, which demonstrates the relationship between environmental pollution, poverty, and transmitted diseases. It was found that children living in areas with high water contamination have a higher risk of developing respiratory diseases (33). Additionally, diagnoses have been made in the country that relate environmental factors to the impact on public health, as various environmental characteristics can affect human health, and it is understood that there is a direct relationship between exposure to environmental agents and health outcomes (34). Table 10.

Table 10. Spearman’s rank correlation analysis of variable relationships.

Variables	$\rho$	P	N
Gender - Associated disease	0,26	0,85	60
Age - Associated disease	-0,30	<b>0,02*</b>	60
Educational level - Associated disease	0,31	<b>0,02*</b>	60
Health regimen - Associated disease	-0,34	<b>0,01*</b>	60
Rainwater collection - Associated disease	0,15	0,26	60
Water storage - Associated disease	0,19	0,16	60
Food washing - Associated disease	0,13	0,33	60
Digestive disorders - Associated disease	0,39	<b>0,002*</b>	60
Frequency of potable water service - Associated disease	0,08	0,56	60

\* p < 0,05, **Bilateral significance.** Reference: Authors

variables, water use and management, and associated diseases, finding a statistically significant, low, and directly proportional linear relationship between associated disease and age, educational level, health regimen, and digestive disorders with  $p < 0.05$ . This indicates that these associated variables are determinants for generating diseases originated by vector transmission such as *Aedes aegypti*, with younger age and subsidized health regimen (SISBEN) showing a higher disease index. A positive relationship is observed between associated diseases like dengue, zika, and chikungunya, viral diseases transmitted by *Aedes* mosquitoes, and digestive disorders, which not only cause typical symptoms like fever, skin rashes and joint pain, but also significant and complex gastrointestinal manifestations. Notably, dengue is often accompanied by gastrointestinal complications, including abdominal pain, nausea, vomiting, and even hepatomegaly, which have been consistently reported in various clinical studies (35). Although less frequently, zika and chikungunya may also cause digestive symptoms, suggesting a potential interplay between these viral infections and the digestive system (36, 37). These findings emphasize the importance of considering gastrointestinal symptoms in the diagnosis and management of these diseases. Moreover, they highlight the need for educational initiatives aimed at preventing vector-borne diseases and improving the quality of life of affected communities, as well as ongoing research and monitoring of the water quality of the Hondo River (38).

## Conclusions

Through the environmental impact assessment using the checklist, we can verify what was observed during the technical visit to the site, highlighting that 87.5% of the environmental conditions are not met. There is a presence of natural and anthropogenic activities affecting environmental factors such as soil, air, water, and others. Human activities are considered to impact the environment in various ways, potentially having a negative effect on human health. Additionally, socioeconomic factors like poverty increase people's vulnerability. Therefore, it is crucial to take measures to reduce the contamination of the Hondo River and protect the health of the people in the village. Access to potable water is essential for people's health and well-being. In this case, the intermittence and irregularities in water treatment can have severe consequences for public health in vulnerable communities. Furthermore, physical factors like public services, habits, and management affect and exacerbate people's health. There is also evidence of gastrointestinal symptoms, flu, and diseases that have occurred with higher incidence, such as Dengue at 43.3%, due to people's exposure to contaminated water sources, which produce the proliferation of disease-transmitting insects, although they are unable to recognize their symptoms, they experience them consistently when the water has not undergone complete treatment. One of the key findings of this research was the community's perception of living on the riverbanks; the population that is more distant is unaware of the full implications of the river's contamination, including the distress caused by foul odors, health issues resulting from the proliferation of disease-carrying vectors, landslides due to soil instability, and the river's impact during rainy seasons.

To effectively address this issue, it is crucial to promote a shift in behavior and raise awareness within the community regarding the significance of water management and the responsibility for environmental and health impacts in the area. Recognizing the correlation between water quality and human health is a vital factor in encouraging the conservation of natural resources. To tackle this problem, it is essential to raise awareness about the importance of preserving water resources and promote sustainable practices, which may include implementing water conservation measures and responsible practices that minimize water pollution in their surroundings. Nevertheless, it is vital to have public bodies intervene beyond these practices, as there are measures that exceed the community's capabilities, such as constructing sanitary facilities, which fall under the responsibility of the city administration or other local authorities. Moreover, implementing water treatment systems will mitigate pollution in the Hondo River, as municipal wastewater has a detrimental impact on the environment and, due to inadequate sewerage, is discharged into the Hondo River. Consequently, improving the environment will lead to a reduction in health risks.

## Acknowledgments

We extend our sincere appreciation to the members of the El Salvador community for their willingness to share their time and insights during our visits. Additionally, we are grateful to the Autonomous University Corporation of Cauca and Professor Diana Milena Muñoz for their invaluable guidance, expertise, and support, which played a crucial role in the successful completion of this research project.

## CRediT authorship contribution statement

María Helena Samboni Valverde: conceptualization, Data curation, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing, Resources. Carmen Daniela Castro Montaño: conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Validation, Visualization, Writing – review & editing, Writing – original draft. Daniela Gil Pardo: Data curation, conceptualization, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. Diana Milena Muñoz: conceptualization, Data curation, Formal analysis, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing.

## Financing

The authors declare that they did not receive resources for the writing or publication of this article.

## Conflict of Interest

The authors declare that they have no conflict of interest in the writing or publication of this article.

## Ethical implications

The authors do not have any type of ethical involvement that should be declared in the writing and publication of this article.

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**APPENDIX 1.** Checklist el salvador rural settlement, popayan, cauca.

CHECKLIST, VERIFICATION OF ENVIRONMENTAL CONDITIONS ASSOCIATED WITH THE WATER QUALITY OF THE RIO HONDO				
DATE OF APPLICATION	09-09-2023	NAME OF PERSON IN CHARGE		Carmen Castro
N°	Description	Compliant		Observations
		YES	NO	
WATER QUALITY				
1	Is there any treatment of wastewater before discharge into the river?		X	No wastewater treatment systems are evident
2	Does the water have the characteristic color and odor of the river?		X	The water appears cloudy and has a strong odor
3	Is the river free of solid waste and clean?		X	Some solid waste is evident in the river
LAND USE				
4	Is there an absence of nearby deforested areas?		X	Deforested areas are observed.
5	Do the riverbanks have stability and show no significant erosion?		X	Significant erosion is evident, posing a risk to the community during heavy rainfall.
6	Do land use activities and engineering works help stabilize the soil?		X	The construction of houses due to population growth in this area has made the terrain highly unstable.
BIODIVERSITY				
7	Is there a presence of living organisms (fish, algae, etc.)?		X	No living organisms are evident.
SOURCES OF CONTAMINATION				
8	Is the area free from nearby industries that discharge effluents into the river?	X		No nearby industries are evident.
9	Do nearby agricultural activities practice sustainability?		X	No sustainable practices are evident in nearby agricultural activities.
10	Is the area free from specific sources of contamination?	X		Specific sources, such as household waste, are apparent.

REGULATIONS

11	Are there environmental education programs available to the community?		X	There is no evidence or record of such programs.
12	Are there local policies and regulations in place to protect the river?		X	There is no knowledge of such policies or regulations.
IMPACTS ON HUMAN HEALTH				
13	Are there no reported cases of illnesses related to the river water in the community?		X	There are known cases of illnesses related to the river water, such as gastrointestinal issues.
14	Is the community content with the state and quality of the river water?		X	The community is dissatisfied with the state of the river and has been requesting assistance to address the issue.
15	Have any epidemiological studies been carried out to link water quality to health problems?		X	No such studies are known to have been carried out.
16	Are there any reported cases of vector-borne diseases caused by river contamination?		X	There are reported cases of vector-borne diseases, including dengue fever.
	PERCENTAGE (%)	12.5	87.5	

**APPENDIX 2. LEOPOLD MATRIX**

[https://docs.google.com/spreadsheets/d/1gMNHbEitQDmY-NyfQzjmBBNjOTQrTUU6sxSd\\_rUiIMw/edit?gid=735556695#gid=735556695](https://docs.google.com/spreadsheets/d/1gMNHbEitQDmY-NyfQzjmBBNjOTQrTUU6sxSd_rUiIMw/edit?gid=735556695#gid=735556695)



**APPENDIX 3.** SURVEY "Factors influencing the generation of diseases due to inadequate wastewater disposal in El Salvador hamlet, Popayan"

[https://docs.google.com/forms/d/e/1FAIpQLSdGzH8950DdW7otGxngEQSx91pXTxcIrm1m-5L366gD5q6uZg/viewform?usp=sf\\_link](https://docs.google.com/forms/d/e/1FAIpQLSdGzH8950DdW7otGxngEQSx91pXTxcIrm1m-5L366gD5q6uZg/viewform?usp=sf_link)