

Analysis of Water Quality in the Chiquito River in Tegucigalpa, Francisco Morazán.

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Abstract– *The main objective of this study is to evaluate the quality of the water in the Chiquito River of Tegucigalpa, Honduras, to determine the levels of contamination that may endanger public health and the environment. The investigation involved an extension of around 9.93 kilometers of the river, with sampling stations located in key locations such as El Chimbo, Colonia El Sitio, Colonia Bolívar and Mercado La Isla. To achieve this objective, a methodology that included systematic collection of water samples in sterile containers, direct observation of visible contamination and analysis in a specialized laboratory of physical, chemical and microbiological parameters.*

The results showed significant changes in water quality, with some critical contamination points requiring immediate action. Parameters were found to be outside the permitted limits when comparing with local and international standards. This demonstrates the importance of implementing sustainable management and pollution control strategies. Improvements in sanitation infrastructure and constant monitoring are proposed to safeguard the public health and environment of the Chiquito River.

Sources of pollution such as untreated residual discharges, industrial waste and illegal dumping were discovered in the vicinity of the river, in addition to the findings. The gradual deterioration of water quality has been caused by human activity, which has affected aquatic biodiversity and communities that depend on water for their domestic and recreational needs. It is essential that the local population receives environmental education and that more rigorous policies for waste regulation are promoted. The implementation of ecological restoration programs is also recommended to reduce damage and restore the health of the river ecosystem.

Keywords: *Water quality, River, Pollution levels, environment, parameters, industrial waste, river ecosystem, aquatic biodiversity.*

I. INTRODUCTION

Water pollution is a critical environmental problem that affects public health, biodiversity and the sustainable development of communities. In the Honduran capital, Tegucigalpa, the Chiquito River is an important source of water for various human activities but has faced increasing pressure due to urbanization and industrial activity. Water pollution not only impacts aquatic ecosystems, but also poses significant risks to communities that depend on the river for drinking water supply, agriculture and the broader economy.

The La Soledad River micro-basin, in Valle de Ángeles, Honduras, faces significant problems related to the degradation of natural resources. At a global level, natural resources have suffered accelerated degradation, with

cultivated soils being the most affected. The decrease in forested areas reduces the recycling capacity of chemical elements, increasing the pollution of water bodies. The excessive use of agrochemicals and untreated wastewater discharges are main causes of this pollution. In dry times, pollution reaches critical levels, affecting aquatic life and reducing the supply of fresh water. These problems have environmental, social and economic impacts, which the inhabitants of the micro-basin have identified as priorities. [1]

The release of wastewater from both the domestic environment and the industrial sector, when carried out without adequate and necessary treatments, is considered one of the most significant causes of pollution of our rivers in Tegucigalpa, including the Chiquito River. Industrial development and accelerated urbanization have exceeded the capacity of existing infrastructure to treat these waters, resulting in the release of biological and chemical contaminants into the aquatic environment. [2]

The Choluteca River is crucial to the country's progress efforts. The fourth largest basin in the country, with 7,976 km², is the one that empties its waters into the Pacific Ocean. More than 1.5 million Hondurans reside in the basin, particularly in the urban areas of the cities of Tegucigalpa, which is the capital of Honduras, and Choluteca, known for its warmth and proximity to the border with Nicaragua. The population density in that specific area is also related to the presence of a high number of factories and companies dedicated to production. In fact, the city of Tegucigalpa, in particular, is home to more than 500 industrial facilities alone. The contamination of the Choluteca River, with a pollutant load (BOD) of 74 tons/day, has been caused by urbanization and industrial development. [3]

II. METHODOLOGY

A. Focus and Scope

The approach used in this research was quantitative, oriented to the measurement and analysis of numerical data related to water pollution in the Chiquito River. This approach allows for accurate assessment of contamination levels, identification of sources, and understanding of patterns of variability in water quality. Additionally, this approach uses data collection and analysis to answer one or more research questions and verify previously formulated hypotheses. [4]

The scope of this research is experimental, since it involves the collection of data in the field through sampling and its subsequent analysis in the laboratory. The aim was to identify and quantify various contaminants present in the water of the

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Chiquito River, as well as to evaluate changes in water quality at different points of the river. Furthermore, this scope determined the limits of the study and the variables that were analyzed, as well as the extension in terms of time, space and resources. [5]

B. Research variables

i. Dependent variable

For this research, the level of pollution caused by all human activities, types of pollution such as Industrial, agricultural and residential, has been determined as an independent variable, taking into account the surroundings of the Chiquito River.

ii. Independent variable

In the case of the dependent variable, all the evaluated parameters will be taken into account, which will allow us to know the result of the water quality index (ICA

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C. Techniques and Instruments

i. Tools

- Plastic Containers of 2 Liter capacity
- Beaker: container that will be used for sample mixtures.
- Turbidimeter: To measure the turbidity of water directly.
- Labels: To identify samples by sampling points.
- Sterile bottles for microbiological analysis: special for collecting samples for the analysis of fecal coliforms and other microorganisms.
- Funnel: it is an instrument that will be used to channel liquids.
- Disposable gloves and personal protection
- Multiparameter probes: for measuring parameters such as pH, temperature, dissolved oxygen and conductivity.

ii. Techniques

- In situ tests: tests that are carried out at the time of taking samples with the field equipment.
- Perform analysis in a specialized laboratory using standardized procedures.
- Minitab: software for statistical analysis of water quality data.
- Analysis of Variance: statistical technique to compare the means of the samples and find significant differences in water quality.
- MS Excel: to calculate the water quality index and analyze.

D. Population and Sample

i. Population

The study focused on a population distributed in the following 4 river stations:

- Station 1: It is located in the Village of El Chimbo, the road that leads to Santa Lucia with coordinates: 14°08'00.4"N 87°07'15.9"W. This station was chosen since it is a high part where the Chiquito River begins.
- Station 2: It is located in the Colony on the Highway Site that leads to Santa Lucia with coordinates: 14°06'46.2"N 87°09'09.8"W. This area was chosen because it is the entrance to a populated neighborhood, with a daily flow of people.
- Station 3: Located in Colonia Bolívar Tegucigalpa with coordinates: 14°06'27.7"N 87°10'55.6"W. This station was selected because it is evident that it is an area highly contaminated by the residents of the neighborhood.
- Station 4: It is located on the Mallol Comayagüela Bridge with coordinates: 14°06'11.4"N 87°12'20.4"W. This station was selected because it is the closest area to the mouth of the Chiquito River into the Choluteca River.

ii. Sampling

Convenience sampling will be carried out to select accessible and representative points along the Chiquito River during the research period. This method optimizes efficiency in data collection, considering contextual factors such as logistics and resource limitations. Sampling points will be located near potential pollution sources, including industrial and agricultural discharges, as well as residential and natural areas. This strategy will allow obtaining a comprehensive view of water quality from various perspectives, guaranteeing an exhaustive and representative analysis. [6] Additionally, this research aims to feed a longitudinal study for which it had already been defined that four seasons would be analyzed.

iii. Sample

Samples in relation to the seasons

It was decided to take samples at different points of the river in this way:

- Station 1 Aldea el Chimbo Highway that leads to Santa Lucia

At this station, 4 samples will be collected, with points located one at point A, two central points and one point B. These will be analyzed according to the 9 water quality parameters: PH,

turbidity, temperature, dissolved oxygen, fecal coliforms, nitrates, total phosphorus, BOD, total solids.

- Station 2: Colonia el Sitio Road that leads to Santa Lucia

At this station, 4 samples will be collected, with points located one at point A, two central points and one point B. These will be analyzed according to the 9 water quality parameters: PH, turbidity, temperature, dissolved oxygen, fecal coliforms, nitrates, total phosphorus, BOD, total solids.

- Station 3: Colonia Bolívar Tegucigalpa

At this station, 4 samples will be collected, with points located one at point A, two central points and one point B. These will be analyzed according to the 9 water quality parameters: PH, turbidity, temperature, dissolved oxygen, fecal coliforms, nitrates, total phosphorus, BOD, total solids.

- Station 4: Mallol Comayagüela Bridge

At this station, 4 samples will be collected, with points located one at point A, two central points and one point B. These will be analyzed according to the 9 water quality parameters: PH, turbidity, temperature, dissolved oxygen, fecal coliforms, nitrates, total phosphorus, BOD, total solids.

Estaciones	Análisis Externo (1 Galón)	Análisis en UNITEC (1 Galón)	Muestra en Frasco Estéril para análisis en UNITEC
1	4	4	4
2	4	4	4
3	4	4	4
4	4	4	4

Illustration 1

Source: Own elaboration

Samples of 2 liters will be sent to an external laboratory for analysis of BOD, Total Phosphorus, Nitrates, Total Solids while the others will be evaluated in the UNITEC laboratory. Temperature and pH will be measured directly on site. Additionally, 16 additional samples will be collected for analysis of fecal coliforms in an external laboratory. All samples will be stored and transported under strict protocols to ensure their integrity. The results obtained will be used to evaluate the quality of the water in the selected stations.

E. Study Methodology

The study methodology for research on water pollution in the Chiquito River of Tegucigalpa, Francisco Morazán, was designed to address the central problem and test the proposed hypotheses. Field visits were conducted to identify critical sampling points along the river. Water samples were obtained in sterile containers, which were transported to an accredited

laboratory for analysis. The parameters analyzed included pH, turbidity, temperature, dissolved oxygen, total solids, dissolved oxygen, BOD and fecal coliforms.

To evaluate visible contamination, such as inorganic waste and changes in the physical properties of water, field observations, laboratory analyzes and sample collection were carried out. Personal protection, measuring equipment and sterile containers were used. Data analysis was performed using specialized software to detect correlations and patterns. This method ensured the reproducibility of the study and demonstrated that the findings regarding water contamination in the Chiquito River were clear and valid.

By using MS Excel to calculate the water quality index, the data were interpreted according to the standards established by the NSF. This analysis allowed us to determine the water quality index of the Chiquito River. To ensure the accuracy of the procedures used and the reliability of the results on water quality in the Chiquito River, validation was carried out through triangulation with experts.

F. Validation Methodology

In our research project, the engineering tools were validated through a triangulation method by experts, ensuring their reliability and validity. To determine the statistical significance of the results, experts in microbiology and statistics consulted and examined a variety of opinions. To do so, they used tools such as analysis of variance (ANOVA) and the test of means. Enabling effective communication and real-time information sharing, these consultations were conducted both in person and online.

At each sampling point, pilot tests were carried out with n=4 in order to evaluate the performance of the tools in real conditions and adjust their implementation. To ensure that samples were representative of areas with high human interaction, sampling points were strategically chosen based on population density and proximity to the river. To ensure the validity and reliability of the engineering tools, this rigorous approach provides a solid foundation for the study's analyzes and results.

III. ANALYSIS AND RESULTS

A. Laboratory test results

Once all the corresponding samples were collected at the 4 stations of the river, the next thing was to carry out the corresponding laboratory tests, with which it was expected to obtain the results of the selected parameters and in addition to answer the questions posed, taking carried out the PH and Temperature analysis in situ in the river, on the day of sampling, the following parameters in the UNITEC Laboratory: dissolved oxygen, total solids, fecal coliforms, Turbidity. And the BOD, Nitrate and Total Phosphorus tests carried out in an external laboratory.

TABLE 1

LABORATORY RESULTS FOR PH

Parámetro y Unidad de Medida	N. De Estación	Toma 1	Toma 2	Toma 3	Toma 4
PH	Estación 1 (El Chimbo)	6.60	6.71	6.57	6.66
	Estación 2 (Col. El Sitio)	6.91	6.94	6.97	6.96
	Estación 3 (Col. Bolívar)	6.68	6.76	6.78	6.80
	Estación 4 (Mercado La Isla)	6.52	6.66	6.69	6.68

Source: Own elaboration

TABLE 2

LABORATORY RESULTS FOR TEMPERATURE

Parámetro y Unidad de Medida	N. De Estación	Toma 1	Toma 2	Toma 3	Toma 4
TEMPERATURA (°C)	Estación 1 (El Chimbo)	18.50	18.80	18.60	18.50
	Estación 2 (Col. El Sitio)	19.60	19.70	19.60	19.90
	Estación 3 (Col. Bolívar)	21.80	21.40	21.50	21.90
	Estación 4 (Mercado La Isla)	22.20	21.80	21.60	21.90

Source: Own elaboration

TABLE 3

LABORATORY RESULTS FOR TURBIDITY

Parámetro y Unidad de Medida	N. De Estación	Toma 1	Toma 2	Toma 3	Toma 4
TURBIDEZ(UNT)	Estación 1 (El Chimbo)	36.00	28.00	27.00	31.00
	Estación 2 (Col. El Sitio)	140.00	240.00	190.00	240.00
	Estación 3 (Col. Bolívar)	130.00	160.00	110.00	130.00
	Estación 4 (Mercado La Isla)	95.00	75.00	70.00	70.00

Source: Own elaboration

TABLE 4

LABORATORY RESULTS FOR DISSOLVED OXYGEN

Parámetro y Unidad de Medida	N. De Estación	Toma 1	Toma 2	Toma 3	Toma 4
OXÍGENO DISUELTO (mg/l)	Estación 1 (El Chimbo)	2.47	3.25	1.82	2.73
	Estación 2 (Col. El Sitio)	3.97	3.45	3.90	2.93
	Estación 3 (Col. Bolívar)	1.63	2.86	4.23	2.60
	Estación 4 (Mercado La Isla)	1.37	1.50	1.43	1.04

TABLE 5

LABORATORY RESULTS FOR TOTAL SOLIDS

Parámetro y Unidad de Medida	N. De Estación	Toma 1	Toma 2	Toma 3	Toma 4
SÓLIDOS TOTALES	Estación 1 (El Chimbo)	NR	NR	NR	NR
	Estación 2 (Col. El Sitio)	0.10	0.10	0.10	0.10
	Estación 3 (Col. Bolívar)	1.00	1.10	1.00	0.50
	Estación 4 (Mercado La Isla)	0.50	0.50	0.50	0.10

Source: Own elaboration

TABLE 6

LABORATORY RESULTS FOR DBO

Parámetro y Unidad de Medida	N. De Estación	Toma 1	Toma 2	Toma 3	Toma 4
DBO (mg/l)	Estación 1 (El Chimbo)	4.00	2.00	2.00	1.00
	Estación 2 (Col. El Sitio)	1.00	1.00	1.00	2.00
	Estación 3 (Col. Bolívar)	44.00	39.00	39.00	41.00
	Estación 4 (Mercado La Isla)	39.00	29.00	34.00	39.00

Source: Own elaboration

TABLE 7

LABORATORY RESULTS FOR TOTAL PHOSPHORUS

Parámetro y Unidad de Medida	N. De Estación	Toma 1	Toma 2	Toma 3	Toma 4
FOSFORO TOTAL (mg/l)	Estación 1 (El Chimbo)	0.04	0.08	0.04	0.04
	Estación 2 (Col. El Sitio)	0.25	0.21	0.45	0.12
	Estación 3 (Col. Bolívar)	1.90	1.43	2.72	1.97
	Estación 4 (Mercado La Isla)	1.09	1.02	1.08	1.06

Source: Own elaboration

TABLE 8

LABORATORY RESULTS FOR NITRATES

Parámetro y Unidad de Medida	N. De Estación	Toma 1	Toma 2	Toma 3	Toma 4
NITRATOS (mg/l)	Estación 1 (El Chimbo)	NR	NR	NR	NR
	Estación 2 (Col. El Sitio)	NR	NR	NR	NR
	Estación 3 (Col. Bolívar)	NR	NR	NR	NR
	Estación 4 (Mercado La Isla)	NR	NR	NR	NR

TABLE 9

LABORATORY RESULTS FOR FECAL COLIFORMS

Parámetro y Unidad de Medida	N. De Estación	Toma 1	Toma 2	Toma 3	Toma 4
COLIFORMES FECALES (ufc/100ml)	Estación 1 (El Chimbo)	800.00	900.00	1600.00	400.00
	Estación 2 (Col. El Sitio)	20000.00	18000.00	21000.00	17000.00
	Estación 3 (Col. Bolívar)	30000.00	32600.00	37000.00	36500.00
	Estación 4 (Mercado La Isla)	51000.00	47000.00	55300.00	50500.00

IV. CONCLUSIONS

A. Specific Conclusions

i. The quality of the water in the Chiquito River varies significantly between the different seasons according to the analysis carried out. The pH was between 6.5 and 6.9, indicating conditions close to neutral and suitable for aquatic life. However, turbidity was concerning at Station 2 (Col. El Sitio) with 202.50 NTU, which could affect photosynthesis and aquatic life. Dissolved oxygen levels of less than 1.04 mg/L are insufficient to maintain healthy biodiversity. Additionally, there is a significant risk of eutrophication due to high phosphorus concentrations in stations 3 and 4, which reach up to 2.72 mg/L.

ii. Using a one-way ANOVA analysis, statistically significant differences ($p < 0.05$) are identified in the levels of total phosphorus, BOD and turbidity between the different sampling points. Tukey's multiple comparisons test revealed that station 3 is the most affected since it has a significantly higher concentration of total phosphorus (mean = 2 mg/L, 95% CI (2.0, 2.5)) compared to the other stations. In addition, the confidence interval graphs for pH and dissolved oxygen show greater variability in stations 1 and 4, with pH ranges between 6.6 and 7.0 (95% CI) and dissolved oxygen between 1.4 and 3.6 mg/L (95% CI) respectively.

iii. Triangulation with experts, which included 10 consultancies during the quarter, was essential for the comprehensive validation of the research on water quality in the Chiquito River. Having an industrial engineering advisor, a CESCO advisor and a microbiologist allowed each area of the project to be supported by a specialist. The meetings held facilitate the validation of the study, significantly reducing the margin of errors. This approach ensured a more accurate and reliable analysis, strengthening the quality and credibility of the results obtained.

B. General Conclusion

i. The analysis of the Water Quality Index (WQI) for the Chiquito River, the general condition of the water is of medium to low quality. The AQI values of stations 1 and 2 were 54.8 and 55.0, respectively, which classifies the water in a medium condition. However, stations 3 and 4 are classified as low quality with AQI values of 35.6 and 39.7, respectively. This variability in results shows that there are major problems with pollution and the state of the river's aquatic ecosystem.

The ICA app has provided a clear view of water quality, identifying important areas that need attention. These diagnoses not only help to better understand the state of the river, but also serve as a basis for conservation and corrective policies. To protect the aquatic ecosystem and improve the water quality of the Chiquito River, authorities and resource managers must use the information collected.

V. RECOMMENDATIONS

A. Research Recommendations

i. Given that the precision in the measurement of physicochemical and microbiological parameters is fundamental for the validity of the research results, it is recommended to establish a careful protocol for collecting samples, receiving correct advice, in addition to carefully carrying out calibration and regular maintenance. . of the laboratory equipment used in taking samples from the Chiquito River. This protocol may include the calibration of equipment such as pH meters, turbidimeters, and dissolved oxygen and total solids analysis equipment, following the necessary specifications.

ii. Perform a statistical analysis focused on evaluating water quality through the use of ANOVA and design of experiments with Minitab. It will allow the study to analyze parameters such as BOD, pH, turbidity and total phosphorus, comparing different sampling points and collection times. Using ANOVA, it is more feasible to observe significant variability in the results, helping to understand the sources of contamination and their impacts. In this way, the research will allow us to obtain robust results to have a fundamental basis and improve the water quality conditions of the river.

iii. The incorporation of triangulation with experts, focusing on collaboration to capture the results. Having a microbiologist advisor can be key to interpreting results of microbiological analyzes and validating data from the study carried out. These consultancies guarantee a rigorous focus on the direct analysis and interpretation of data, complementing the physicochemical analyzes carried out throughout the research. Triangulation with specialists will strengthen the credibility of the findings and allow informed decisions to be made about water quality management.

C. RECOMMENDATIONS FOR THE RUBR

i. The Municipal Mayor's Office of Tegucigalpa and Santa Lucía can develop and promote environmental education programs that promote awareness about the importance of caring for the Chiquito River. These programs should be aimed at students, families and local communities and include workshops, talks and awareness campaigns about the impact of daily activities on water quality. Educational activities should address topics such as proper waste disposal, reducing the use of chemicals, and participating in river cleanup activities.

ii. The Center for Studies and Control of Contaminants (CESCCO), to guarantee the integrity of water samples during collection and transportation, can develop and implement advice that leads to a rigorous protocol that covers all aspects of the handling and transportation of the samples. . Technical advice that includes clear instructions on sample preparation, appropriate labeling, and storage and transportation conditions necessary to preserve sample quality. Appropriate sampling containers should be used and samples kept at recommended temperatures to avoid alterations in results.

It is recommended that future researchers expand the sampling points along the Chiquito River to obtain a more accurate representation of water quality in different sections. The use of statistical analysis with Minitab, together with the implementation of ANOVA, is essential, since it allows identifying significant differences between the sampled areas and obtaining a more complete and robust analysis of the data. This methodology can provide key information for the management and improvement of water quality in the river.

VI. APPLICABILITY/IMPLEMENTATION

The results obtained in this research have direct applicability in the management and improvement of the water quality of the Chiquito River. By using the Water Quality Index (WQI) and experimental design techniques, it was possible to identify the critical parameters that affect water quality, such as pH, turbidity and dissolved oxygen levels. These results can serve as a basis for local authorities, such as CESCCO, to make informed decisions on the measures necessary to improve water quality in the region.

Furthermore, the methodology used can be implemented by other institutions, both academic and governmental, to evaluate water quality in other water bodies in the country. This would allow the analysis to be replicated in different rivers and lakes in Honduras, establishing a scientific standard in the monitoring of water resources and providing technical support in the planning of interventions for environmental improvement and the protection of public health.

VII. EVOLUTION OF CURRENT WORK/ FUTURE WORK

The work carried out so far has allowed us to establish a baseline on the water quality of the Chiquito River, but it is evident that there is still room for the evolution and expansion of this research. In the future, it would be beneficial to expand the number of sampling points along the river to obtain a more complete view of its condition over time and under different climatic conditions. In addition, it will incorporate analysis of other contaminants, such as heavy metals or industrial waste, which would allow a more complete diagnosis of the potential risks for the inhabitants of the area.

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