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Water Quality Analysis in a Micro-Watershed for the Community of Loma Alta Norte

Andrea Nicolle Amador Mendoza[1], Jean Emerson Castro Nuñez[2], Nereyda Lainez[3], Paola Michelle Pascua Cantarero[4], Víctor Alvarado [5]
[1] Facultad de Ingeniería, Universidad Tecnológica Centroamericana (Unitec)
Boulevard Kennedy, Tegucigalpa, Francisco Morazán,
andrea.mendoza01@unitec.edu; jcastro0801@unitec.edu
[2] Facultad de Ingeniería, Universidad Tecnológica Centroamericana (Unitec)
Boulevard Kennedy, Tegucigalpa, Francisco Morazán,
nereyda.lainez@unitec.edu.hn; paola.pascua@unitec.edu.hn; vpineda@serna.gob.hn

Abstract **-** The study in the micro-basin of Santa Lucía, in the community of Loma Alta Norte, has aimed to determine whether the water has met the appropriate conditions to guarantee the health of the inhabitants. The research has focused on analyzing the water quality at different points, by non-probabilistic sampling, and on validating the results of the parameters in the National Technical Standard for the Quality of Drinking Water and the Technical Standards for Wastewater Discharges. The methodology has included physicochemical and microbiological analyses, using statistical tools such as t tests and ANOVA to compare the data obtained, employing experimental design. The results of the physicochemical and microbiological tests carried out in the laboratory, together with the ANOVA analysis, have indicated that the water quality parameters, such as temperature, turbidity and TDS, show significant differences between the stations. However, these differences are not alarming and do not suggest threatening contamination in the water. Furthermore, parameters such as pH, nitrates and phosphates have been kept within the permissible ranges, all evaluated in accordance with the "National Technical Standard for Drinking Water Quality" and the "Technical Standards for Wastewater Discharges". The calculation of the water quality index has indicated that all the stations analyzed in the micro-basin are within an acceptable range, with a use criterion classified as "Excellent Quality". This shows that the water in the Santa Lucía micro-basin, in the community of Loma Alta Norte, meets optimal quality according to the standards established by the NSF. Consequently, it has been reflected that water is suitable for human consumption and does not present significant risks of contamination that may affect the environment.
Keywords**:** Water quality, ANOVA, Physicochemical tests, Standards No. 084 and 058, Micro-basin.

1. Introduction

Water quality is a global challenge influenced by both natural and anthropogenic factors, with direct repercussions on human health, biodiversity and ecosystems. Several studies highlight the problems associated with water quality analysis.

In Tegucigalpa, Honduras, a study on bottled water identified significant variations in total dissolved solids levels between different local brands, along with an inverse relationship between pH and the presence of coliforms and aerobic bacteria. These findings showed disparities in treatment processes, emphasizing the need for regular monitoring to ensure water quality and safety [1]. On the other hand, in an analysis carried out in Guaimaca, a rural area of Honduras, problems such as high turbidity, contamination by fecal coliforms and high levels of biochemical oxygen demand (BOD) were detected, attributed to deficiencies in infrastructure and maintenance. These results highlight the urgency of optimizing water treatment and supply systems to ensure its safe use [2]. Additionally, a recent study in communities in the Central District addressed water scarcity by implementing linear programming to optimize its distribution among Water Boards. This approach reduced losses and ensured a more efficient supply, demonstrating the potential of mathematical tools to support sustainable water management and improve the quality of life in vulnerable communities [3]. These previous studies were used as a basis for the present research report, which proposes to study water quality by evaluating both the physicochemical and microbiological water parameters of the micro-basin located in the Santa Lucía region, in the department of Francisco Morazán, Honduras, which supplies the community of Loma Alta Norte. The approach will include the measurement of microbiological and physicochemical parameters in this way it will be possible to observe whether they meet the requirements to be water for human consumption and that there is no possibility of health risks. As the tests carried out in

the laboratory, statistical tests will be applied and evaluated to observe and identify the differences that exist with the water samples collected at key points in the micro-basin. In this way, it will be known whether the parameters established in the "National Technical Standard for Drinking Water Quality" and the "Technical Standards for Wastewater Discharges" are met, noting whether there is a negative or positive behavior for making use of it.

2. Methodology

A quantitative approach was applied, using engineering tools and techniques, which allowed for precise analysis and obtaining measurable data. This approach, as noted in one study, facilitates the relationship between measurable variables and their interpretation through statistical methods, allowing for identifying patterns in the data and determining their compliance with established standards. [4].

In this research, an experimental scope was considered. In which the use of statistics is made, through which the effects and differences that these are found in the research are evaluated. [5]. This scope was taken since the data collection was taken in the field work by the sampling technique. In addition to this, for this research the scope helps to decide the limits of the study.

2.1. Population

For this research, the universe was delimited to 3 stations in the micro-basin located in the Loma Alta Norte community, as shown below:

- Station #1: It is located 7 km from the community of Loma Alta Norte, with the geographic coordinates 14°9’48’’N 87°6’8’’O. This station was selected due to its proximity to the water intake.
- Station #2: It is located 300 meters from Station #1 with the following coordinates: 14°9’48’’N 87°6’8’’O. This station is located at the waterfall; it was selected as an intermediate point.
- Station #3: It is located 600 meters from Station #1, with the coordinates 14°9’51’’N 87°6’7’’O. This station was selected due to the presence of agricultural activities in its vicinity.

2.2. Sampling

In this present study, non-probabilistic sampling was used, specifically convenience sampling. Convenience sampling is what allows for choosing those samples in a simpler way, specifically it gives the researcher the freedom to be able to choose their samples according to what is best for their research. [6].

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2.3. Sample

3 samples were taken for each station, for a total of 9 samples, of which 8 parameters were taken and evaluated. These captures were 3 for Nitrates, 3 for Phosphates, 3 for Turbidity, 3 for Total Dissolved Solids, and 1 for Dissolved Oxygen and Fecal Coliforms, except for the Temperature and pH parameters, which were taken on-site, and BOD, which was taken in an external laboratory. All samples were captured in similar flasks with the same quantity of 1.5L for each, except for fecal coliforms, for which sterile flasks were used.

2.4. Sample in relation to the stations

Station #1: 14°9’48’’N 87°6’8’’W, 203° SW at 1790 m altitude. It is the last section downstream where the intake is located Station #2: 14°9’48’’N 87°6’8’’O, 15° N 1760 m altitude. It is the section located between the source of the spring and the intake or station #1

Station #3: 14°9’51’’N 87°6’7’’O, 321° NW at 1770 m altitude. It is the section closest to the spring.

2.5. Samples in relation to Intakes

18 samples will be taken in 1.5L containers, corresponding to the number of 3 stations and 3 samples for each sampling station. Therefore, the total number of samples collected will be 27 in total, 18 in 1.5L bottles and 9 in sterile bottles respectively.

2.6. Analyzed Variables

For this study, the ICA-NSF water quality index was determined as the dependent variable from the already analyzed result of the micro-basin of the Loma Alta Norte community. The dependent variables study the alteration of the causes and the tests to be measured, evaluating the object to be studied in the research. [7].

The independent variables were determined as the possible contamination of the micro-basin due to the agricultural activity that is present in the place. This type of variable is what generates the explanation or the purpose of another event, since they are the factors with which it is certain to be able to explain the dependent variables. [8].

2.7. Instruments and applied techniques

For data collection and analysis, several instruments were used, including a telephone to record coordinates, a camera to capture images of the sampling points, sterile jars to store the water samples and laboratory equipment such as the pH meter and the turbidimeter.

In addition, statistical analysis tools such as ANOVA and t tests were applied, in addition to which Microsoft Excel software was used for ICA calculations and Minitab to organize and graphically represent the results of the comparisons between them of the tests obtained in the laboratory.

3. Results and Analysis

3.1. Dissolved Oxygen (DO)

Table 1: DO (Dissolved Oxygen) Results

Parameter	No. Sample	Station 1	Station 2	Station 3
DO (mg/L)	**Sample 1**	7.1	6.6	7.1

In table #1, the DO levels of all stations comply with the ranges of the “United States Environmental Protection Agency”, exceeding the minimum of DO>5 mg/L. [9]. This range is considered optimal for biological processes, survival, reproduction, development and mobility of aquatic species.

3.2. pH

Table 2: pH Results

Parameter	No. Sample	Station 1	Station 2	Station 3
pH	**Sample 1**	6.97	6.68	6.91
	Sample 2	6.96	6.87	6.78
	Sample 3	6.87	6.98	6.95

In table #2, it shows that the stations comply with the pH range allowed by the "Technical Standard for wastewater discharges to receiving bodies and sanitary sewers" which indicates that the range is from 6 to 9. [10]. Concluding that the water does not present extreme acidity or alkalinity.

3.3. Nitrates

Table 3: Nitrate Results

Parameter	No. Sample	Station 1	Station 2	Station 3
Nitrates (mg/L)	**Sample 1**	3.2	5.9	3.9
	Sample 2	4.7	4.0	6.2
	Sample 3	6.4	4.3	7.81

In Table #3, it shows that the nitrate levels in all samples are within the limit recommended by the “National Technical Standard for Drinking Water Quality”, with a range of (25 mg/L-50 mg/L). [10]. Which indicates that the water is in good condition and does not present eutrophication in the micro-basin.

3.4. Fecal Coliforms

Table 4: Fecal Coliform Results

Parameter	Station 1	Station 2	Station 3
Fecal Coliform	2	4	3

In table #4, the results show that the values are within the admissible value according to the "Standard for the safe use of water in agriculture", which establishes that the minimum value in this case for its use must be less than 1000 CFU. [10]. Which gives access for its use in irrigation in agriculture, however, for human consumption a chlorination process must be carried out for its adequate consumption.

3.5. Temperature

Table 5: Temperature Results

Parameter	No. Sample	Station 1	Station 2	Station 3
Temperature (Celsius Degrees)	**Sample 1**	28.1	22.2	24.5
	Sample 2	27.8	22.4	24.9
	Sample 3	28.4	22.1	24.5

In table #5, it can be observed that station 2 does not comply with the maximum permissible temperature value according to the “National Technical Standard for Drinking Water Quality”, which establishes that it must be <25.00 degrees Celsius. [10]. The results, for the most part, indicate a cool temperature, which favors the growth of microorganisms and solubility, making it suitable for human consumption and agricultural activities, except for station.

3.6. Turbidity

Table 5: Turbidity Results

Parameter	No. Sample	Station 1	Station 2	Station 3
Turbidity	**Sample 1**	2.8	5.0	2.1
	Sample 2	1.7	7.0	2.3
	Sample 3	1.8	4.1	3.2

In table #6, sample 2 from station 2 presents a turbidity of 7 NTU, exceeding the maximum limit of 5 NTU. This high value could be due to the use of pesticides or other chemicals in agricultural activities located upstream of the micro-basin. In contrast, the other stations are within the acceptable range of the "National Technical Standard for Drinking Water Quality" (1 to 5 NTU) [10], indicating optimal conditions with crystal-clear water and no evidence of contamination.

3.7. Total Dissolved Solids (TDS)

Table 7: Total Dissolved Solids (TDS) Results

Parameter	No. Sample	Station 1	Station 2	Station 3
TDS (mg/L)	**Sample 1**	45	47	48
	Sample 2	44	47	47
	Sample 3	45	46	47

In table #7, the values of the samples at each of the stations are within the permissible value of 1000 mg/L, as established in the “National Technical Standard for the Quality of Drinking Water”.[10] The results indicate low TDS values, indicating that there is little existence of heavy metals or other derivatives contaminating the water.

3.8. Phosphate

Table 8: Phosphate Results

Parameter	No. Sample	Station 1	Station 2	Station 3
Phosphate (mg/L)	**Sample 1**	0.28	0.31	0.24
	Sample 2	0.25	0.32	0.26
	Sample 3	0.12	0.34	0.19

In table #8, the phosphate concentrations in the collected samples are within the maximum permissible value of 15.21 mg/L as established in the "Technical Standard for wastewater discharges to receiving bodies and sanitary sewers". [10]. After obtaining the results, it can be known with certainty that the water has not gone through a eutrophication process.

3.9. Biochemical Oxygen Demand

Table 9: Biochemical Oxygen Demand (BOD) results

Parameter	No. Sample	Station 1	Station 2	Station 3
BOD (mg/L)	**Sample 1**	1	<1	<1

In table #9, the BOD concentrations in the collected samples are within the maximum permissible value of <=3 mg/L, as established by the "Secretariat of Environment and Natural Resources" which indicates excellent quality. [13]. The results show that there is a very low organic load, indicating that there is no eutrophication process or hypoxic conditions.

4. Comparison of Results with Permissible Values Using Statistical Tools

A statistical analysis was performed using the one-sample t-test to compare water quality parameters with the values established by national technical standards. T-tests are used to compare means and detect significant differences between samples.[11]. The confidence level was 95%, with the following hypotheses:

- Null hypothesis (Ho): The results meet the established parameters.
- Alternative hypothesis (Ha): The results do not meet the established parameters.

Table 10: T-Test Results

Parameter	Station 1 (p-valor)	Station 2 (p-valor)	Station 3 (p-valor)	Analysis
pH	0.999	0.995	0.998	Meets established parameters.
Nitrates	1.000	1.000	1.000	Meets established parameters due to limited information collected.
Temperature	0.670	0.055	0.001	Stations 1 and 3 meet, Station 2 does not meet.
Turbidity	0.993	0.355	0.991	Meets established parameters.
Total Dissolved Solids	1.000	1.000	1.000	Meets established parameters.
Phosphate	1.00	1.00	1.00	Meets established parameters.

4.1. pH results

The results at the three stations showed a p-value greater than 0.05, which implies that they comply with the permissible ranges of 6 to 10 according to the "Technical Standards for discharges of wastewater to receiving bodies and sewers and sanitary facilities".[10].

4.2. Nitrate Results

The results at the three stations showed a p-value greater than 0.05, which implies that they comply with the permissible ranges (25 mg/L-50 mg/L) established in the “National Technical Standard for the quality of Drinking Water”.[10].

4.3. Temperature Results

For Station 1 and 2 they obtained a p-value greater than 0.05, which implies that it complies, while at Station 2, the p-value was 0.001 (does not comply), Station 2 does not comply with the regulatory parameters, according to the "National Technical Standard for the Quality of Drinking Water" which establishes that it must be <25.00 degrees Celsius [10].

4.4. Turbidity Results

The three stations showed p-values greater than 0.05, indicating that the results comply with the values established in the “National Technical Standard for the Quality of Drinking Water” where it mentions that the acceptable range is (1 NTU- 5 NTU). [10].

4.5. Total Dissolved Solids Results

The p-values were 1.000 at the three stations, indicating that the TDS meet the permissible ranges established in the “National Technical Standard for Drinking Water Quality” where it mentions that the permissible value is 1000 mg/L. [10].

4.6. Phosphate Results

The p-values were 1.000 at the three stations, concluding that the results comply with the permissible value of 15.21 mg/L as established in the “Technical Standards for Wastewater Discharges to Receiving Bodies and Sanitary Sewers.” [10].

A statistical analysis was performed using one-sample ANOVA to evaluate the conformity of the water quality parameters with the values established by the national technical standards. ANOVA compares group means to identify significant differences. [12]. The confidence level was 95%, with the following hypotheses:

- **Null hypothesis (Ho):** No significant difference is observed in the values of the parameters A between the different stations.
- **Alternative hypothesis (Ha):** A significant difference is observed in the values of the parameters A between the different stations.

Table 11: Results of the analysis using ANOVA (Tukey Method)

Parameter	Analysis	Tukey Method
pH	The null hypothesis (Ho) was accepted, there are no differences in the values between the stations.	They do not present differences. They are statistically similar.
Nitrates	Nitrates The null hypothesis (Ho) was accepted, there are no differences in the values between the stations.	They do not present differences. They are statistically similar.
Temperature	The null hypothesis (Ho) was rejected, and the alternative was accepted, there are differences in the temperature between the stations.	They present variations, possibly due to climatic or altitudinal factors
Turbidity	The null hypothesis (Ho) was rejected, and the alternative was accepted, there are significant differences between the stations.	Station 1 and 3 are statistically similar, while station 2 differs from the others
TDS	The null hypothesis (Ho) was rejected, and the alternative was accepted, there are significant differences between the stations.	Station 1 differs from the other stations.
Phosphates	The null hypothesis (Ho) was accepted, there are no differences in the values between the stations.	They do not present differences. They are statistically similar.

5. ICA-NSF (National Sanitation Foundation) Water Quality Index

Table 12: ICA-NSF Water Quality Index Results

Stations	Final ICA (Quality Rank)	Usage Criteria
Station 1	92.848	Excellent quality
Station 2	91.235	Excellent quality
Station 3	90.25	Excellent quality

It is observed in table #11 that the results of the water quality index calculation of all the analysed stations present high values, where it is shown that the water quality range as established by the ICA-NSF, [13], indicates that values that are in the range of 90-100 are a criterion for the use of excellent quality. [14]. According to this criterion, the water of the Santa Lucía micro-basin, in the community of Loma Alta Norte, is classified as high quality. This indicates that the water does not represent significant risks for human supply, nor does it threaten aquatic life or the environment. [15]. Therefore, it is concluded that the water resource meets the standards necessary for its safe use.

6. Conclusions

6.1 The results of the samples from the 3 stations in the micro-basin indicated that most of the parameters complied with the ranges established by the Technical Standards for Wastewater Discharges and the National Standard for Drinking Water. Although 100% of the stations complied with BOD, DO, pH, nitrates, fecal coliforms, phosphates and TDS, stations 2 and 3 presented high values in turbidity and temperature in one sample, reaching 90% compliance. Turbidity could be linked to agricultural activities and temperature to altitudinal factors. Despite these minor alterations, the water in the micro-basin maintains a quality suitable for aquatic life and human consumption in the Loma Alta Norte community.

6.2 The parameters were analysed using the t test at each station, obtaining acceptable results, except for temperature at station 2, which showed variations attributed to factors such as altitude. This analysis confirms that the results meet the regulatory standards at 95%. Through the analysis of variance and the Tukey method, significant differences were identified in 3 of the 6 parameters studied statistically (temperature, turbidity and TDS), while pH, nitrates and phosphates showed statistical similarities between stations. These differences could indicate minor alterations in water quality, possibly influenced by agricultural activity, although without evidencing a serious impact.

6.3 Using Excel, the Water Quality Index was calculated, obtaining optimal results in the three stations analyzed, with indices higher than 89%. Station 1 registered an ICA of 92.848, while station 2 obtained 91.235, and station 3 obtained 90.25, the latter being the lowest (but not bad) due to its proximity to agricultural activities in the upper part of the micro-basin. Despite this variation, all stations remain within the "Excellent Quality" range according to the criteria. These results indicate that the water in the Santa Lucía micro-basin, in the Loma Alta Norte community, does not present significant contamination, making it suitable for community supply and does not represent risks to the environment.

6.4 In general, the water quality of the Santa Lucia micro-basin, in the community of Loma Alta Norte, was evaluated as “Excellent” according to the results of the Water Quality Index (ICA-NSF), with values above 89% in the three stations analysed. These results confirm that the water is suitable for both human consumption and the preservation of aquatic biodiversity. To ensure its sustainability, it is recommended to implement regular monitoring with physicochemical and microbiological analyses, which will allow the detection and mitigation of possible external alterations. In conclusion, the micro-basin presents optimal conditions for the safe and sustainable supply of the community.

7. Applicability

This work was developed in the field of water quality analysis, with the implementation of experimental design tools and the application of the Water Quality Index (ICA – NSF). The results obtained represent a significant contribution to understanding the water conditions of the Santa Lucía micro-basin, providing evidence to support decisions aimed at the protection and sustainable management of this water resource and the use of water as a source of supply for the community of Loma Alta Norte. The techniques, protocols and tools implemented in the statistics and analysis of water quality can be replicated by other studies by other researchers for the analysis of studies in similar water bodies in other geographic contexts of Honduras.

References

[1] Granados, F. Y. R., & Cantarero, P. M. P. (2024). Quality evaluation of Honduran bottled water for human consumption through experimental design. *World Congress on Mechanical, Chemical, and Material Engineering*.

[2] Zamorano, A. E. L. (n.d.). *Caracterización de calidad de agua en el ciclo de consumo del municipio de Guaimaca, Francisco Morazán, Honduras*. Zamorano.edu. Retrieved December 2, 2024, from https://bdigital.zamorano.edu/server/api/core/bitstreams/adff91ec-de5f-4c84-9eaa-4df1651b4cbe/content

[3] Robles Zúniga, E. W. (2024). Reduction of water scarcity in water management boards of the central district with linear programming. Proceedings of the 22nd LACCEI International Multi-Conference for Engineering, Education and Technology (LACCEI 2024) : "Sustainable Engineering for a Diverse, Equitable, and Inclusive Future at the Service of Education, Research, and Industry for a Society 5.0."

[4] Sánchez Flores, F. A. (2019). Fundamentos Epistémicos de la Investigación Cualitativa y Cuantitativa: Consensos y Disensos. Revista Digital de Investigación En Docencia Universitaria, 13(1), 101–122. https://doi.org/10.19083/ridu.2019.644

[5] Diseño experimental o de experimentos (DoE). (2022, octubre 26). SafetyCulture. https://safetyculture.com/es/temas/diseno-de-experimentos/

[6] Hernández González, O. (2021). Aproximación a los distintos tipos de muestreo no probabilístico que existen. Revista Cubana de Medicina General Integral, 37(3). http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-21252021000300002

[7] Variables dependientes: ¿qué son y cuál es su uso? (n.d.). Programas. Retrieved December 2, 2024, from https://programas.uniandes.edu.co/blog/variables-dependientes

[8] Amiel Pérez, J. (2007). Las variables en el método científico. Revista de La Sociedad Química Del Perú, 73(3), 171–177. http://www.scielo.org.pe/scielo.php?script=sci_arttext&pid=S1810-634X2007000300007

[9] 5.2 Dissolved Oxygen and biochemical oxygen demand. (2009). https://archive.epa.gov/water/archive/web/html/vms52.html

[10] FAOLEX. (n.d.). Fao.org. Retrieved November 27, 2024, from https://www.fao.org/faolex/results/details/es/c/LEX-FAOC175672/

[11] Perdomo Carrillo, D. A., Corredor, Z., & Ramírez-Iglesia, L. (2012). Características fisicoquímicas y morfométricas en la crianza por fases de la tilapia roja (Oreochromis spp.) en una zona cálida tropical. Zootecnia tropical, 30(1), 099–108. https://ve.scielo.org/scielo.php?script=sci_arttext&pid=S0798-72692012000100011

[12] Gutiérrez, G., & Amairani, K. (2023). Macroinvertebrados como bioindicadores de la calidad del agua del Río Grijalva, Chiapa de Corzo, Chiapas. https://repositorio.unicach.mx/handle/20.500.12753/4987

[13] (N.d.-f). Amelica.org. Retrieved December 2, 2024, from https://portal.amelica.org/ameli/journal/334/3341965005/html/

[14] SEMARNAT. (N.d.). Gob.Mx:8443. Retrieved November 15, 2024, from https://apps1.semarnat.gob.mx:8443/dgeia/compendio_2013/dgeiawf.semarnat.gob.mx_8080/ibi_apps/WFServlet28b9.html

[15] De aguas, E. P. de L. Í. de C., & De agua, es S. en U. E. N. las C. P. o. N. de C. F. (n.d.). *El Índice de calidad de agua propuesto por Brown es una versión modificada del "WQI" (Water Quality Index) que fue desarrollada por La Fundación de Sanidad Nacional de EE. UU. (NSF)* Wordpress.com. Retrieved November 27, 2024, from https://limnologiauniquindio.wordpress.com/wp-content/uploads/2013/03/c3adndices-de-calidad-de-agua.pdf