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Rosas López Esperanza[1], Bárcena Vicuña Guadalupe Gabriela [2], Alonso Calpeño Mariela Juana[3], Ramírez Hernández Johana[4]

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[1]Chemical Engineer, Tecnológico Nacional de México, Instituto Tecnológico Superior de Atlixco, Electromechanical Engineering,esperanza.rosas@itsatlixco.edu.mx , cell: 244 107 2486. Calle Prolongación Heliotropo 1201 Col. Vista Hermosa, C.P. 74218. https://orcid.org/0009-0006-2311-4176.

[2]Master's Degree in Advanced Technology, Tecnológico Nacional de México, Instituto Tecnológico Superior de Atlixco, Biochemical Engineering,guadalupe.barcena@itsatlixco.edu.mx , cell: 244 447 3054. Calle Prolongación Heliotropo 1201 Col. Vista Hermosa, C.P. 74218. https://orcid.org/ 0009-0000-0244-8421.

[3]Ph.D. in Strategic Planning and Technology Management, Tecnológico Nacional de México, Instituto Tecnológico Superior de Atlixco, Ingeniería Sistemas Computacionales,mariela.alonso@itsatlixco.edu.mx , cell: 2441190652. Calle Prolongación Heliotropo 1201 Col. Vista Hermosa, C.P. 74218. https://orcid.org/ .0000-0001-7276-1923

[4]Ph.D. in Chemical Sciences, Tecnológico Nacional de México, Instituto Tecnológico Superior de Atlixco, Ingeniería Bioquímica, johana.ramirez@itsatlixco.edu.mx , cell: 2222004243. Calle Prolongación Heliotropo 1201 Col. Vista Hermosa, C.P. 74218. https://orcid.org/ .0009-0004-177 6-0863

***Summary** --The* United Nations (UN) approved the 2030 Agenda, which is made up of 17 Sustainable Development Goals (SDGs), for this work, SDG 6 is considered, which consists of ensuring the availability and sustainable management of water and sanitation for all (1). Water is a fundamental resource for socioeconomic development and people's health.

In the state of Puebla, the municipality of Atlixco is located in the community of San Jerónimo Coyula with 7,750 inhabitants; however, due to the lack of drinking water, the population uses water from the Ahuitzoc River for various domestic activities (2). This river begins at a spring where some residents drink the water directly.

In order to identify the quality of the river water, physicochemical and microbiological tests were applied to five sites where the Ahuitzoc River flows during the dry season in April and May, one sampling per month.

It is important to evaluate water quality by means of physicochemical tests such as: hardness, temperature and pH (3). In addition, it is important to identify the results within the permissible limits for human consumption established by national regulations (4).

The work consisted of the following stages: 1. Identifying the sampling points; 2. Total dissolved solids *in situ*; 4. Conduct microbiological and hardness tests in the laboratory.

The environmental impact to the Ahuitzoc River, was evident with the microbiological results with CFU/mL> 250 obtained in the last sampling site (M5), therefore, that local authorities should implement and benefit the community and the environment.

Key words: physicochemical, microbiological, water body, hardness.

Abstract -- The United Nations (UN) approved the 2030 Agenda for Sustainable Development, which consists of 17 Sustainable Development Goals (SDGs). For this study, SDG 6, which focuses on ensuring the availability and sustainable management of water and sanitation for all, is considered (1). Water is a fundamental resource for socioeconomic development and human health.

In the state of Puebla, there is the municipality of Atlixco, where the community of San Jerónimo Coyula, with a population of 7,750 inhabitants, is located. However, due to the lack of potable water, the population uses water from the Ahuitzoc River for various domestic activities.
(2). This river originates from a spring where some residents drink the water directly.

With the aim of assessing the water quality of the river, physicochemical and microbiological tests were conducted at five sites along the Ahuitzoc River during the dry season in April and May, with one sample taken each month.

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The assessment of water quality through physicochemical tests such as hardness, temperature, and pH is essential to determine the quality of a water body (3). Additionally, it is necessary to compare the results with the permissible limits for human consumption as established by national regulations (4).

The study followed these steps: 1. Identifying sampling points; 2. Collecting samples; 3. Measuring pH, temperature, and total dissolved solids in situ; 4. Conducting the hardness test; and 5.

The environmental impact on the Ahuitzoc River was evident in the microbiological results, with colony-forming units (CFU/mL) > 250 obtained at the final sampling site (M5). Therefore, actions need to be taken by local authorities to benefit both the community and the environment.

Key words **-** hardnes, microbiological, physicochemical, water body.

INTRODUCTION

Global needs indicate a growing demand for freshwater, energy and food, therefore, the scientific community is developing a new approach to analyze, evaluate and implement mitigation measures in the face of this great crisis. This is how the concept of the water-energy-food nexus (WEF) (5) arises, and the interactions that occur between these three resources, with all the synergies and trade-offs that result from this relationship.

In addition to the global need for access, the code of the human right to water, which consists of incorporating as a central regulatory idea the fact of guaranteeing that the entire population has access to drinking water as a fundamental requirement for the quality of life of people, is integrated into the global need for access. This right was recognized by the United Nations General Assembly in its resolution 64/292 of July 28, 2010 (6) and Latin America and the Caribbean do not have access to sanitation services, a situation that is aggravated in rural areas (7).

A clear example of water needs are the bodies of water, in the state of Puebla is located the Atoyac, one of the two most polluted rivers in Mexico. Water quality in the Upper Atoyac River Basin

(CAA) has been deteriorated by industrial and municipal discharges, as well as by the effluents of local inhabitants, all of which have little or no treatment, causing health, production, and ecosystem damage (8).

Rivers are bodies of water that are continuously polluted and their flows are used by people living in the vicinity of the river, and it is important to determine and analyze the quality of the water.

A tributary of the Atoyac River is the Nexapa River, which is located in the Balsas hydrological region. Within its basin are the municipalities of Atlixco and Izúcar de Matamoros, with an ecological condition that was evaluated in a study carried out by measuring physicochemical parameters and total and fecal coliforms in 20 sites, from which it was concluded that the river has a deteriorated ecological condition (9).

Another body of water that has been investigated to determine water quality is the Prieto River, where the efficiency of phytoextraction of heavy metals and the spring of the Church of Santa Barbara Almoloya, Puebla, was evaluated. Looking for a socially feasible method to contribute to the reduction of its contamination (10).

It is worth mentioning that the rivers of the state of Puebla are identified in the hydrological system as follows: The Epatlán river runs parallel to the Nexapa river and pours its waters into it at the town of Puctla, 4 km south of Izúcar de Matamoros and a little further on at 10 km it flows into the Atila river in the town of Atzala, This last river rises on the southeastern slope of the Popocatepetl volcano, about 12 km NW of Tochimilco, and flows southeast until it reaches the town of Huaquechula, where it changes course to head south; On its way, it receives contributions from the Ahuitzoc, César Matadero and Ahuehueyo rivers, which flow down from the slopes of this same volcano (11).

In the city of Atlixco, a Wastewater Treatment Plant (WWTP) was installed, the treated discharge is discharged into the Cantarranas river to irrigate crops in Santa Ana Coatepec, Huaquechula. The objective of this work (12) was to evaluate the quality of the treated water and assess its use in agriculture. Samples were taken at three points: the influent and effluent of the treatment plant and at the floodgate. Sampling was carried out during the rainy and dry seasons.

Most of the water used in the country is destined for human use and consumption (13). However, the quality of this resource in rural areas is not considered, and it is essential to identify the quality of the water bodies.

Currently, river pollution is mainly due to untreated domestic wastewater discharges by households near water bodies. In particular, the Ahuitzoc River is affected by the direct discharge of domestic wastewater.

It is essential to evaluate the water quality of the Ahuitzoc river through the application of parameters physicochemical and microbiological tests to determine if they comply with the permissible limits established by regulations (14) for human consumption.

The risks and health impacts to the inhabitants of San Jerónimo Coyula may occur due to the consumption of contaminated water. This body of water is of great importance to the community, and it is necessary that it meet the characteristics of its composition, both for consumption, drinking and food preparation, as well as for daily needs.

In this sense, the authorities of the municipality of Atlixco and the community of San Jerónimo Coyula recognize the urgency of evaluating the water quality of the Ahuitzoc River. Because the population uses this resource for their daily activities and even consumes it directly, it has been decided to carry out physicochemical tests, such as hardness, temperature, pH and total dissolved solids (TDS) and microbiological analyses to detect the presence of Escherichia *coli*. In this way, the quality of this body of water was determined in accordance with the regulations.

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DEVELOPMENT

Methodology.

The stages applied to this work consist of five.

Step 1. Identify sampling points

Sampling points according to the geographical area.

Stage 2. Sampling

Adequate sampling depends on environmental and human factors. It is important to apply Mexican regulation NMX-AA-014-1980. Receiving bodies - sampling, which consists of extracting a representative portion of a body of water for the purpose of examining various characteristics.

Laboratory work began with water samples to determine physicochemical and microbiological parameters.

Stage 3 Physicochemical Parameters

The following physicochemical parameters were analyzed according to the regulations applicable to each one.

This Mexican Standard NMX-AA-007-SCFI-2013 (15). Water analysis - determination of temperature in natural, waste and treated waste waters - test method, establishes the test method for temperature measurement, when using direct measuring instruments or instruments that indicate proportional expansions or forces in temperature changes, in raw non-saline natural waters (epicontinental, subway and pluvial), in saline waters (marine, coastal, estuarine, estuarine, marsh and subway), raw municipal and industrial waste waters and treated municipal and industrial waste waters, and treated municipal and industrial waste waters. industrial applications in the range from 0 °C to 45 °C. °C.

The objective of NMX-AA-008-SCFI-2016 [16], Water analysis. - pH measurement in natural, waste and treated wastewater. Test method, is the national application and establishes the test method for the measurement of pH in natural, waste and treated wastewater, in the pH range 0 to pH 14 and in a temperature range from 0 °C to 50 °C.

NMX-AA-072-SCFI-2001 (17). Water analysis - determination of total hardness in natural water, wastewater and treated wastewater, indicates that the conductivity value is a parameter regulated by maximum permissible limits in wastewater discharges to sewage or receiving bodies, it is also a water quality parameter for agricultural uses and activities, for primary contact and for human consumption.

Stage 4. Hardness

The term hardness has traditionally been used to refer to alkaline earth cations dissolved in water. When it is referred to as total hardness, it refers to the total concentration of calcium and magnesium ions (18).

The physicochemical tests were performed with Conductronic PC16 equipment, a portable pH, Total Dissolved Solids (TDS) and Temperature meter, as well as distilled water, a pintle, and pH 4, 7 and 10 calibration solution.

The Conductronic PC16 was used to determine the pH, TDS and temperature parameters *in situ, as* shown in Figure 1.

Figure 1. Measurement of TDS, g/L Temperature °C and pH. Source: Own elaboration.

The determination of the hardness parameter was carried out at the Sistema Operador de los Servicios de Agua Potable y Alcantarillado del Municipio de Atlixco (SOAPAMA), in the laboratory located at the Treatment Plant. The following material was used in the laboratory: a Fisher Scientific thermos flask, two 25 mL burettes, three 100 mL beakers, three 250 mL Erlenmeyer flasks, a pint glass with distilled water and the reagents

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buffer solution, eriochrome black T and EDTA
0.01 M.

Figure 2 shows the hardness analysis of sample 5. 50 mL of sample are placed in the 250 mL Erlenmeyer flask and 2 mL of buffer solution are added to obtain a pH of 10.0 to 10.1.
Subsequently, an appropriate amount of eriochrome black indicator T was added and the sample showed a reddish wine color.

Figure 2. Sample with black eriochrome indicator T. Source: Own elaboration.

Microbiological tests

The method applied to the samples taken from the water body is established in NOM-092-SSA1-1994, method for counting aerobic bacteria on a plate, which establishes the method for estimating the number of viable microorganisms present in the water body.

in a food, drinking water and purified water, by colony count in a solid medium, incubated aerobically.

The following equipment was used to start these tests: OHAUS Pioneer analytical balance, EVAR vertical autoclave, CFL.101 SEVE vertical laminar flow chamber, Felisa colony counter and LAB LINE incubator.

The materials were: beaker, Erlenmeyer flask each with the capacity of 1000 mL CIVEQ brand, stirring rod, disposable Petri dishes, Accumax PRO automatic pipette 20-200 µL with tips for 100 µL volume.

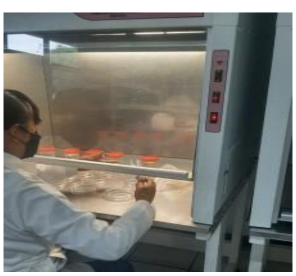

Figure 3. Preparation of inoculum for microbiological testing
Source: Own elaboration.

After completion of the inoculation in the Petri dishes, they were placed in the incubator to be checked after 24-48 hr at a temperature of 35°C. The plates are incubated at the appropriate temperature (always in inverted position and with nomenclature). In figures 4, the plates to be placed in the incubator are shown.

Figure 4. Inoculation in Petri dishes Source: Own elaboration.

DISCUSSION AND ANALYSIS OF RESULTS

1. **Identification of sampling points.** To select the sampling points, a survey was carried out in which five suitable locations were identified for sampling during the dry season. They were identified as follows:

- M1, Spring
- M2, Barranca
- M3, Aquiles Serdán Street Canal
- M4, Álvaro Obregón Street Canal
- M5, Domingo Arenas Street Canal.

Figure 5 and 6. Sample 1. Spring and Sample 5 Domingo Arenas Street channel.
Source: Own elaboration.

Sampling to the water body.

Sampling at the sites of interest was carried out in a simple and timely manner, using appropriate sample bottles, which are directly immersed in the water.

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in the river current. Samples are labeled indicating the date and place of sampling.

Samples for storage are placed in a refrigerator with temperatures from 2° to 5°C.

Figures 7 and 8 show the sample collection from the points of the ravine (M2) and the Álvaro Obregón street canal (M4), cylindrical bottles with standard 946 mL caps were filled and samples for microbiological tests were taken in sterile 150 mL containers for analysis.

Figure 7 and 8. Sample 2. Barranca and Sample 4 channel Calle Álvaro Obregón.
Source: Own elaboration.

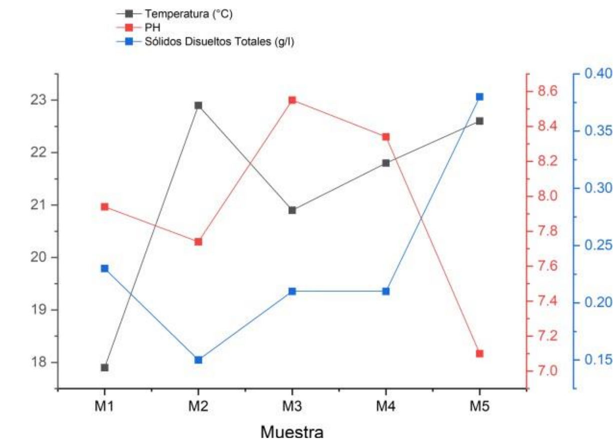
Analysis of physicochemical tests.

Table 1 shows the results obtained at the sampling sites, in stage 1, the parameter that indicates the permissible limit of 6.5 - 8.5 according to regulations.
For this stage, samples 3 and 4 are results that indicate the effect of residual discharges into the channel. Graph 1 shows the behavior of the physicochemical parameters in this stage 1.

Table 1. Results of stage I measurements.

Sample	Temperature (°C)	PH	Dissolved Solids Total (g/L)
M1	17.9	7.94	0.23
M2	22.9	7.74	0.15
M3	20.9	8.55	0.21
M4	21.8	8.34	0.21
M5	22.6	7.1	0.38

Source: Own elaboration



Graph 1. Physicochemical results of stage 1.

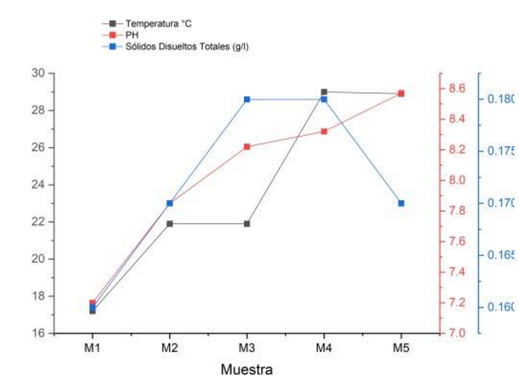
Table 2 shows the results obtained from the Conductronic PC16 measurements, in stage 2, the relationship of data is in samples 3 and 4, both are from community streets and domestic activities contribute to the alteration of the watercourse.

Table 2. Results of measurements in stage 2.

Sample	Temperature °C	pH	Dissolved Solids Total (g/L)
M1	17.2	7.2	0.16
M2	21.9	7.85	0.17
M3	21.9	8.22	0.18
M4	29	8.32	0.18
M5	28.9	8.57	0.17

Source: Own elaboration

According to the data in Table 2, the following graph 2 shows the relationship between the data in sample 1 remains stable; however, in samples 3, 4 and 5, variations in the parameters of temperature, pH and total dissolved solids are observed.



Graph 2. Measurement results of stage 2.

The following equation was used to determine the total hardness:

$$DUREZATOTAL(\frac{CaCO3mg}{L}) = \frac{A*B*1000.}{mlde\ muestra}$$

A= ml of titrated EDTA used

B= mg $_{CaCO3}$ equivalent to 1 ml EDTA= 1 $_{mgCaCO3/mL}$

EDTA

ml of sample= Volume of sample taken

The hardness results obtained from stage 1 are identified in Table 3.

Table 3. Stage 1 Hardness Results

Samples	mL of EDTA		Volume in L	CaCO3 mg/L
M1	3.1	3.2	0.00315	63
M2	3.7	3	0.00335	67
M3	4.1	4.2	0.00415	83
M4	3.2	3.2	0.0032	64
M5	5.3	5.1	0.0052	104

Source: Own elaboration

Table 4 shows the results of stage 2, the samples are considered to be within the permissible limit shown in Table 5.

Table 4. Stage 2 hardness results.

Samples	mL of EDTA		Volume in L	CaCO3 mg/L
M1	3.2	3	0.0031	62
M2	3.5	3.2	0.00335	67
M3	3.3	3.1	0.0032	64
M4	3.5	3.4	0.00345	69
M5	3.3	3.6	0.00345	69

Source: Own elaboration.

Table 5 indicates the classification of hardness to determine water quality, and the maximum desirable concentration limit according to the WHO.

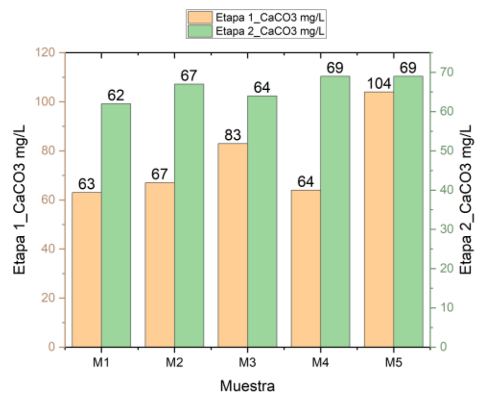
Table 5. Hardness classification

WATER QUALITY	
Hardness	CaCO3 mg/L
Adding quality	up to 150
Medium quality	up to 300
Acceptable quality	up to 500
Very poor quality	more than 600

Source: The World Health Organization, WHO, has adopted 100 mg/L $_{CaCO3}$ as the maximum desirable concentration and 500 mg/L as the maximum allowable concentration.

Graph 3 shows the hardness results obtained in stages 1 and 2. According to the information in Table 5, the hardness results are as follows

a desirable maximum concentration.



Graph 3. Hardness results of stages 1 and 2.

Microbiological tests.

Samples taken from the sampling sites were analyzed in the Special Analysis Laboratory of the Biochemical Engineering program at the Instituto Tecnológico Superior de Atlixco.

The Petri dishes were then removed from the LAB LINE incubator. The Colony Forming Units (CFU) of each of the Petri dishes were counted. Figure 9 shows sample M4-3 (sample 4 from Álvaro Obregón street).

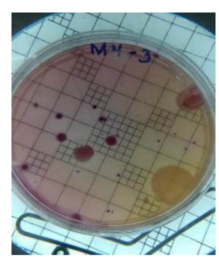


Figure 9. The Petri dish is divided into four quadrants Source: Own elaboration.

For CFU counting, the Felisa colony counter was used, as shown in Figure 10, each box was analyzed in this equipment for counting the CFU of each sample.

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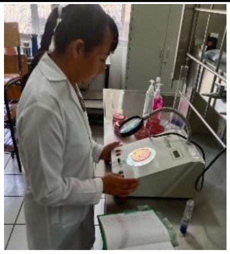


Figure 10. CFU count with the colony counter, Felisa. Source: Own elaboration.

Figure 11 below shows the growth of enterobacteria from the microbiological tests of the five sampling sites.

Figure 11. Growth of enterobacteria in Petri dishes. Source: Own elaboration.

The results obtained from the microbiological test, performed for stage 1, are shown in Table 6, where samples 2, 3 and 5 have CFU >.

Table 6. Microbiological results of stage 1

Sample	Test 1	Test 2	Test 3	CFU/mL
M1	2	3	3	8
M2	52	33	500	**585**
M3	133	132	133	**398**
M4	83	70	36	189
M5	uncountable	uncountable	uncountable	—

Source: Own elaboration.

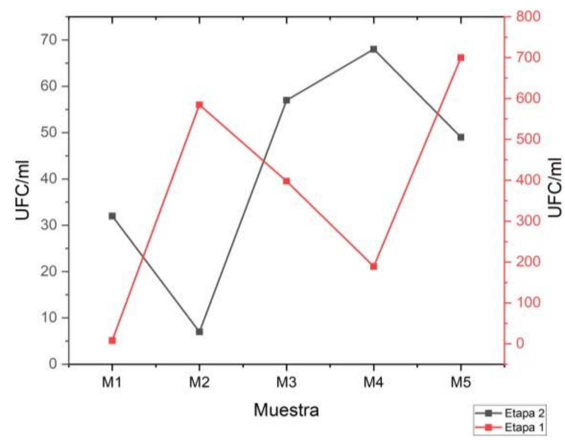
The microbiological results of stage 2 are shown in Table 7, where CFU <.

Table 7. Microbiological results of stage 2.

Sample	Test 1	Test 2	Test 3	CFU/mL
M1	14	10	8	32
M2	2	0	5	7
M3	19	20	18	57
M4	20	25	23	68
M5	15	16	18	49

Source: Own elaboration.

Graph 4 below shows both stages and the significant changes in CFU in each sample during the low water period. It indicates that contamination is more prevalent on Saturdays, when people carry out domestic activities and use the canal channel.



Microbiological results of stages 1 and 2.

Therefore, five sampling points were assigned, starting at the spring and continuing along the ravine and the streets Aquiles Serdán, Álvaro Obregón and Domingo Arenas. Two sampling stages were carried out in April and May, both during the dry season.

The results obtained allow us to present an overview of the quality of the Ahuitzoc River, in physicochemical and microbiological terms. The pH levels of the samples were found to be within the limits established by NOM-127-SSA1-2021, Water for human use and consumption, which means that the river water is within the recommended acidity ranges; however, variations towards alkaline values (8.55) were detected, which would be related to the domestic activities carried out by the people of the community during the dry season.

The finding in the microbiological analysis determined that sample five (Domingo Arenas street), has a high concentration UFC/mL greater than 250, which implies that it is water contaminated by fecal pathogens can result in diseases and infections, as indicated in the NOM- 127-SSA1-2021.

Contamination can occur according to the use of water, specifically in the springs, in the case of Ahuitzoc river is contaminated by the presence of people who wash clothes and use detergents, a similar case was the diagnosis made to the spring "El Paraíso" located in Santiago de Cuba, the results reflected the contamination of the spring, because the parameter of total coliforms were found above the maximum allowable concentration established by the NC 1021:2014.(19).

The results obtained in this work are similar to the physicochemical and microbiological evaluation of water for human consumption in six communities in Peru. The microbiological parameters (*Echericha* Coli, thermotolerant and fecal coliforms), 4/17 monitoring points exceeded the limit value allowed by the regulations for water for human consumption (20).

The spring where the Ahuitzoc riverbed originates, the results of the physicochemical parameters are within the permissible limits for human consumption and the microbiological analyses carried out at points along the river 4/5 show that the water is contaminated by coliforms.

These results are similar to the research conducted in Jiscullaya springs, El Collao, Puno, Peru, where the quality of water for human consumption was determined and total coliforms could be linked to diarrheal and infectious diseases due to poor biological water quality (21).

CONCLUSIONS

It is concluded that monitoring and analysis of the quality of water bodies is of vital importance. Therefore, the results presented are evidence of the need to continue with more physicochemical and microbiological tests during the seasons of the year and variations in community activities along the Ahuitzoc River.

The importance of the infrastructure for wastewater treatment is highlighted, benefiting the care of the environment and the use of water resources.

This is an important challenge for the community of San Jerónimo Coyula to mitigate the contamination of the Ahuitzoc River and its environmental impact, thus improving the community's quality of life and contributing to long-term environmental sustainability.

As a result of this work, we propose the construction of an artificial wetland with surface flow, applicable in low population communities for the treatment of domestic wastewater that is discharged into bodies of water, benefiting the care of the environment and the use of water resources.

In addition to a second future research, we have the link with the Organismo Operador de los Servicios de Agua Potable y Alcantarillado del Municipio de Atlixco (SOAPAMA) to perform the physicochemical and microbiological analysis of the water quality in the wells located in the communities of the Municipality of Atlixco.

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Contribution role table

Role	Author
Conceptualization	Rosas López Esperanza
Methodology	Rosas López Esperanza, Bárcena Vicuña Guadalupe Gabriela.
Project Management	Rosas López Esperanza, Bárcena Vicuña Guadalupe Gabriela,
Resources	Rosas López Esperanza, Bárcena Vicuña Guadalupe Gabriela
Supervision	Bárcena Vicuña Guadalupe Gabriela,
Validation	Rosas López Esperanza, Bárcena Vicuña Guadalupe Gabriela.
Software	Alonso Calpeño Mariela Juana,
Visualization	Rosas López Esperanza
Drafting Proofreading and editing.	Rosas López Esperanza, Bárcena Vicuña Guadalupe Gabriela.