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Estudio de la calidad del agua en la presa El Volantín, Jalisco, México (2014-2015)

Water Quality Study of El Volantín Dam, Jalisco, Mexico (2014-2015)

Estudo da qualidade da água na barragem de El Volantín, Jalisco, México (2014-2015)

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Resumen

En este trabajo se presenta la caracterización de los contaminantes en las aguas de la presa El Volantín, municipio Tizapán el Alto (Jalisco), con el objetivo de determinar la calidad del agua. Para ello, se han tomado como base de referencia los índices establecidos por los valores de la escala ICA (índice de calidad del agua). En tal sentido, se realizaron cinco muestreos en la mencionada presa: tres en el año 2014 (marzo, junio y septiembre) y dos en 2015 (enero y abril). Estos muestreos se tomaron en 4 puntos (El Casco, El Volantín, Las Canoas y Villa Madero) para analizar los contaminantes inmersos en el agua, ya que existen descargas de drenajes que se realizan de manera directa en la presa, específicamente en la comunidad El Volantín. Las muestras se evaluaron según las normas NOM-001-SEMARNAT-1996 y NOM-127-SSA1-1994 en dos laboratorios (Microbiología y Análisis Fisicoquímicos) del Centro Universitario de Ciencias Exactas e Ingenierías de la Universidad de Guadalajara. Los resultados muestran que el grado de contaminación en la presa es regular. En concreto, los parámetros de la demanda bioquímica de oxígeno, la demanda química de oxígeno, los sólidos suspendidos totales y el color se encuentran fuera de los límites permisibles señalados en las mencionadas normas.

Palabras clave: calidad, contaminantes, indicadores, presa El Volantín.

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Abstract

In this work, the characterization of pollutants in the waters of the El Volantín dam, Municipality of Tizapán el Alto Jalisco, with the objective of making an analysis to determine the quality of water, taking as a reference base the indexes established by the values of the ICA (Water Quality Index) and being able to determine if water quality is viable for agricultural and livestock use and livestock.

The results obtained show that the degree of contamination of El Valentine dam is "Regular", where the parameters of the biochemical oxygen demand, the chemical oxygen demand, the total suspended solids and the color are found outside the permissible limit mentioned on NOM 001-SEMARNAT-1996 and NOM-127-SSA1-1994 and parameters as sulphates, nitrates, cyanides, cadmium, chromium, copper, nickel, lead, zinc, are within allowable limits mentions NOM 001-SEMARNAT-1996 and NOM-127-SSA1-1994. Five samples were taken at El Volantín dam, three in 2014 in the months of March, June and September. In 2015, two samples were taken, one in January and the other in April. These samplings were carried out in 4 points (El Casco, El Volantín, Las Canoas and Villa Madero) to analyze the pollutants immersed in the water, since there are discharges of drains that are made directly in the dam, specifically in the community of The Volantin.

The samples were evaluated according to standards NOM 001-SEMARNAT-1996 and NOM 127-SSA1-1994, in two laboratories of the University Center of Exact Sciences and Engineering of the University of Guadalajara; the one of Microbiology and the other one of Physical-chemical Analysis.

Keywords: quality, contaminants, indicators, El Volantín Dam.

Resumo

Este artigo apresenta a caracterização dos poluentes nas águas da barragem de El Volantín, município de Tizapán el Alto (Jalisco), com o objetivo de determinar a qualidade da água. Para isso, os índices estabelecidos pelos valores da escala ICA (índice de qualidade da água) foram tomados como base de referência. Nesse sentido, foram realizadas cinco amostragens na referida hidrelétrica: três no ano de 2014 (março, junho e setembro) e duas em 2015 (janeiro e abril). Estas amostras foram tomadas em quatro pontos (capacete, Volantin, canoas e Villa log) para analisar contaminantes imersos em água, como há descargas de esgotos que são feitas directamente na barragem, especificamente na comunidade

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O Volantín. As amostras foram avaliadas de acordo com as normas NOM-001-SEMARNAT-1996 e NOM-127-SSA1-1994 em dois laboratórios (microbiologia e análises físico-químicas) do Centro Universitário de Ciências Exactas e da Engenharia na Universidade de Ciências Guadalajara. Os resultados mostram que o grau de contaminação na barragem é regular. Especificamente, os parâmetros de demanda bioquímica de oxigênio, demanda química de oxigênio, sólidos suspensos totais e cor estão fora dos limites permitidos indicados nos padrões acima mencionados.

Palavras-chave: qualidade, contaminantes, indicadores, barragem de El Volantín.

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Introduction

El Volantín is municipality of Tizapán el Alto, and is located southeast of the state of Jalisco, at a height of 1881 m. n. m. (Figure 1). According to the 2010 Population and Housing Census (National Institute of Statistics and Geography [Inegi], 2010), the community has 565 inhabitants (239 men and 263 women). This municipal delegation has as a source of work the small-scale dairy industry, but its production is considered of high quality. For more than 70 years the inhabitants of El Volantín have used the water of the dam for livestock consumption, fishing and recreational activities, while those of Tizapán el Alto have used it to irrigate the crops, especially vegetables. that are marketed in the region.

However, in recent years, due to the drainage discharges that nearby communities make directly to the dam, it has been observed that the water is no longer completely clean. Characteristics such as the color and smell of water in some points of the dam generate distrust among the inhabitants about its cleanliness and the consequences of its use. This has caused a reduction in the entry of economic resources for families.

The construction of the curtain of the dam was carried out under the direction of the engineer Antonio Coria, with the collaboration of the head of the Small Irrigation Department, the engineer Eduardo Rojas. The construction was in charge of the engineers Luis Murguía and Carlos Aldrete; The dam was created as a project of the National Irrigation Commission. The purpose of this work was to supply irrigation to

the sown fields of the municipal capital (Tizapán el Alto) in times of no rain. This location was chosen due to its unevenness, since that way the water could flow naturally through the channels. The first years of the construction of the dam offered great benefits to the surrounding communities, especially those of El Volantín, Villa Madero and Las Canoas. Prior to this construction, the main economic activities of the region were livestock and agriculture. However, with the dam, some villagers went fishing for carp, catfish and whitefish. In addition, it became a recreation center for the residents, either for the boat ride or as a spa.

Figura 1. Cortina de la presa El Volantín

Fuente: Elaboración propia

For a long time the inhabitants downloaded the drainage of their houses in their pens or plots. However, in 2001, the sewage network was introduced, which caused the drainage waters to be discharged to the dam, including those generated in pig hogs. Over the years the quality of the water has not been optimal, as it has changed its color and smell. Even so, at present the dam continues to supply water for irrigation in the municipal capital of Tizapán el Alto, since it has been assumed that its quality can improve with the route it does for several kilometers through streams and canals.

In this regard, the purpose of this paper is to present the results of the analysis performed on water samples taken at four points of the El Volantín dam to determine its quality based on standards NOM

001-SEMARNAT-1996 and NOM-127- SSA1-1994. In this way, we try to offer elements to characterize and quantify the existing pollutants in the dam, as well as to determine strategies for its reduction and adequate treatment. For this, the following are the water quality indices (ICA) by characterizing pollutants in different sites of the dam.

Materials and methods

Indicators for water quality (ICA)

The ICA defines the aptitude of the water body in relation to the priority uses it may have. These indices are called specific uses. The ICA proposed by Brown and McCleland (1973) is a modified version of the WQI (Water Quality Index) developed by the National Health Foundation of the United States (NSF) to compare rivers in several places in that country.

The ICA was designed in 1970, and can be used to measure, over time, changes in water quality in different stretches of rivers, which allows to establish whether it is healthy or not. In order to know the ICA, 9 parameters are involved: fecal coliforms (in NMP / 100 ml), pH (in pH units), biochemical oxygen demand in 5 days (BOD5 in mg / L), nitrates (NO3 in mg / L), phosphates (PO4 in mg / L), change in temperature (in ° C), turbidity (in FAU), total dissolved solids (in mg / l) and dissolved oxygen (OD in% saturation).

The ICA adopts, for optimal conditions, a maximum value of 100, which decreases with the increase in water pollution. Water quality is classified according to the data in table 1.

Tabla 1. Clasificación del ICA propuesto por Brown y McCleland (1973)

CALIDAD DEL AGUA	COLOR	VALOR
Excelente		91 a 100
Buena		71 a 90
Regular		51 a 70
Mala		26 a 50
Pésima		0 a 25

Fuente: Brown y McCleland (1973)

Waters with ICA greater than 90 are capable of having good diversity in aquatic life. Waters with regular category ICA generally have less diversity of aquatic organisms and often encourage the growth of algae. Waters with bad category ICA may have only a low diversity of aquatic life and are probably experiencing problems with contamination. ICA-rated waters can have a limited number of aquatic life forms, present abundant problems and are usually not acceptable for activities that involve direct contact with it, such as swimming.

To determine the ICA value at any point it is necessary to have the measurements of the 9 parameters mentioned above, the calculation of the index, the numerical evaluation of the ICA, with multiplicative techniques and weighted with the allocation of the specific weights contributed in the research of Brown and McCleland (1973). To calculate the Brown and McCleland index, we can use a weighted linear sum of the subscripts $(ICAa)$ or a multiplicative weighted function $(ICAm)$. These aggregations are expressed mathematically as follows:

$$ICAa = \sum_{i=1}^{9}(sub_{\mathrm{i}} * w_{\mathrm{i}}); \qquad ICAm = \prod_{i=1}^{9}(sub_{\mathrm{i}}{}^{w_{\mathrm{i}}})$$

Where

- $w_{\mathrm{i}} =$ relative weights assigned to each parameter (sub_{i}) and weighted between 0 and 1, in such a way that the sum is equal to one.
- $sub_{\mathrm{i}} =$ parameter subscript i, awarded by graphics or interpolation to perform the summation.

Other authors (Landwehr and Denninger, 1976) showed that the calculation of the ICA by multiplicative techniques is more sensitive to the variation of the parameters, since they reflect more accurately a change in quality. The technique applied in this study is multiplicative. The relative weights of the various parameters are presented in Table 2.

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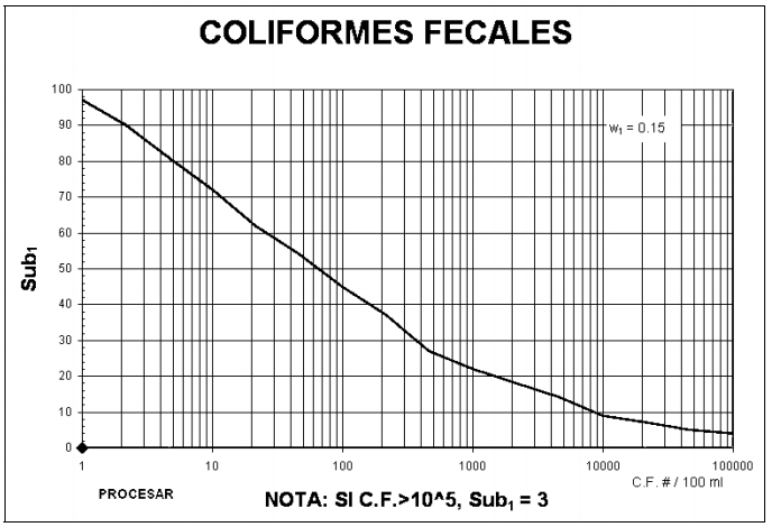
Tabla 2. Pesos relativos de los 9 parámetros

I	sub_i	w_i
1	Coliformes fecales	0.15
2	pH	0.12
3	DBO5	0.1
4	Nitratos	0.1
5	Fosfatos	0.1
6	Cambio de temperatura	0.1
7	Turbidez	0.08
8	Sólidos disueltos totales	0.08
9	Oxígeno disuelto	0.17

Fuente: Landwehr y Denninger (1976)

To determine the value of the ICA, it is necessary to replace the data in the equation ($ICAm$), from where you get the sub_{i} of different graphics. It can be seen that for a $w_1 = 0.15$ (which is for the first relative weight of fecal coliforms presented in table 3) has different values for the first value sub_1, Depending on whether the fecal coliforms are greater than 100 000 bact / 100 ml, the value of $sub_{\text{i}} = 3$. If the value of fecal coliforms is less than 100 000 bact / 100 ml, you should look for the corresponding value in the graph of figure 2.

Figura 2. Valoración de la calidad de agua en función de coliformes fecales



Fuente: Landwehr y Denninger (1976)

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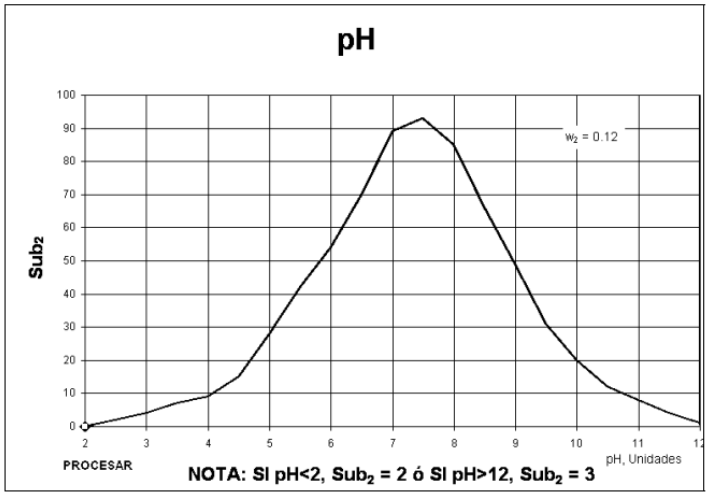
To determine the sub_i value for pH, the graph in figure 3 is taken into account, in which it can be seen that for $w_2 = 0.12$ the sub_i value is determined depending on the pH units. If pH≤2 units, the value that is taken for $sub_2 = 2$; and if the pH value> 2 units, the value of $sub_2 = 3$. In the case that the pH value is different from these values, the value corresponding to the graph is taken.

Figura 3. Valoración de la calidad de agua en función de *pH*



Fuente: Landwehr y Denninger (1976)

The biochemical oxygen demand in 5 days (BOD5) is based on the graph of Figure 4, so for the case of $w_3 = 0.10$ the value for the sub_3 is taken depending on the value that corresponds to the graph.

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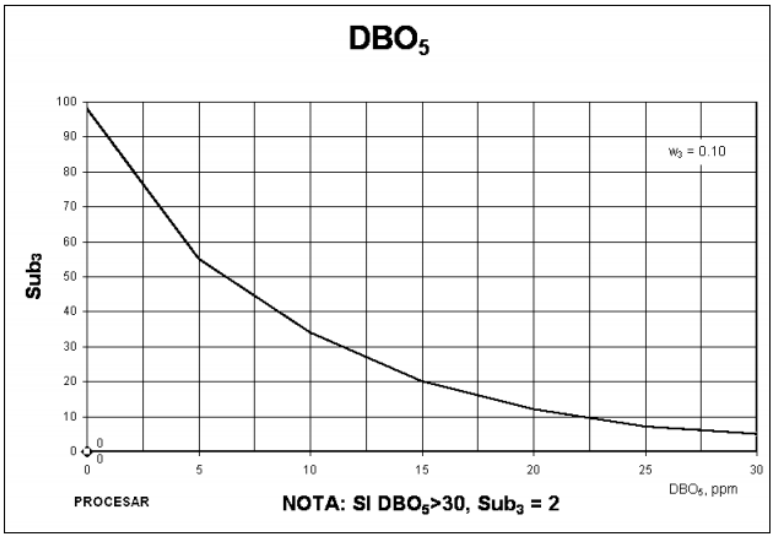
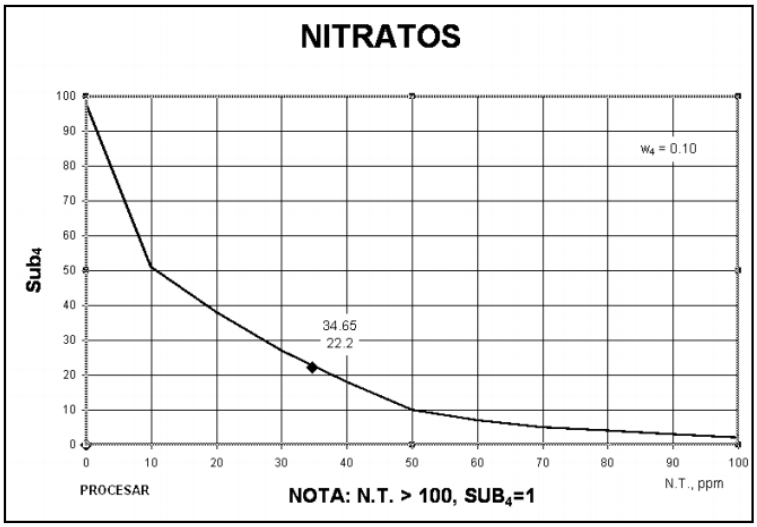
Figura 4. Para demanda bioquímica de oxígeno



Fuente: Landwehr y Denninger (1976)

For nitrates, the graph of Figure 5 is taken into account, so for the case of $w_4 = 0.1$, the value for the sub_4 is taken depending on the value that corresponds to it in the graph.

Figura 5. Valoración de la calidad de agua en función de nitrógeno



Fuente: Landwehr y Denninger (1976)

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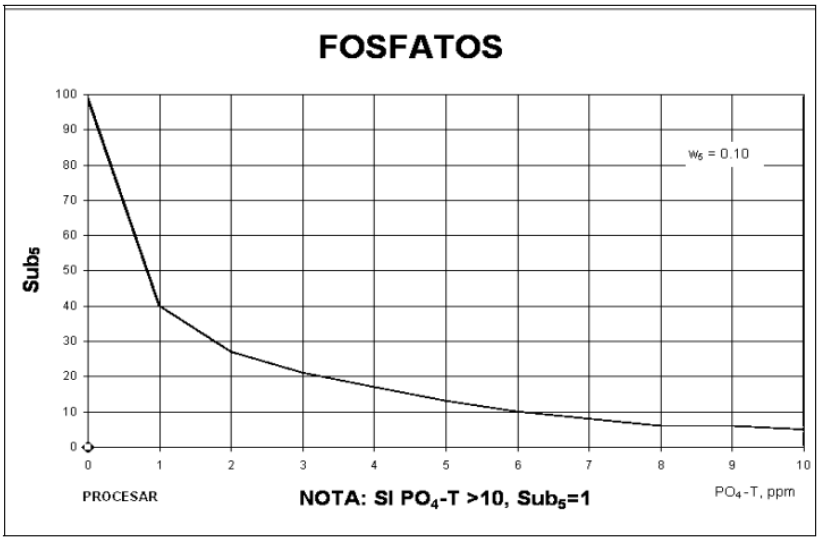
The phosphates are determined based on the graph of Figure 6, so for the case of $w_5 = 0.1$ the value for the sub_5 is taken depending on the value that corresponds to the graph.

Figura 6. Valoración de la calidad de agua en función de fósforo



Fuente: Landwehr y Denninger (1976)

In the case of temperature, the difference between the ambient temperature and the sample temperature is calculated for the sub_6 value first. If the value of the difference is greater than 15 ºC, the value of $sub_6 = 9$; if the difference is less than 15 ºC, the value corresponding to it is sought in the graph of figure 7.

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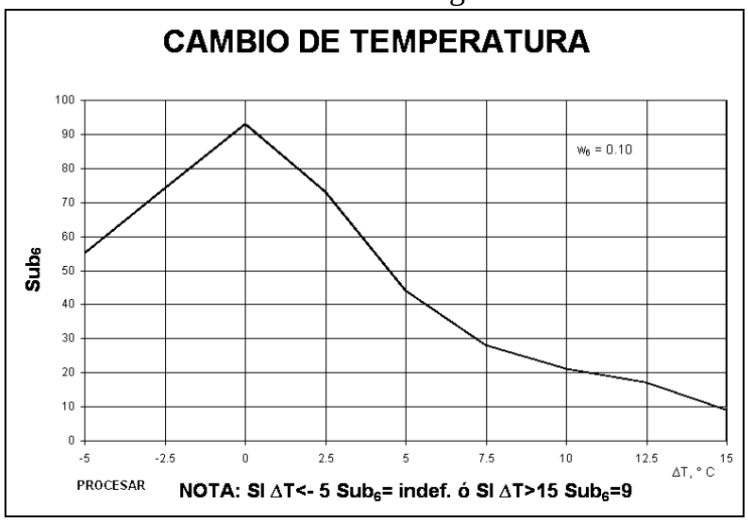
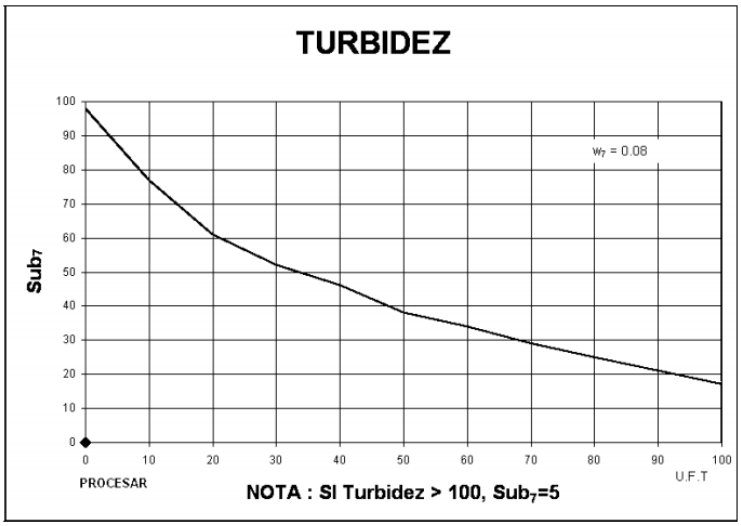
Figura 7. Valoración de la calidad de agua en función de la temperatura



Fuente Landwehr y Denninger (1976)

For turbidity, the graph of Figure 8 is taken into account, so for the case of $w_7 = 0.08$ the value of sub_7 is taken depending on what corresponds to the graph.

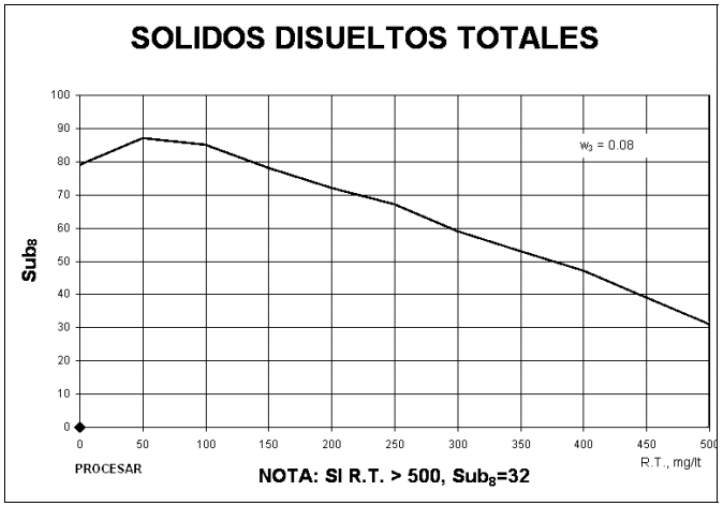
Figura 8. Valoración de la calidad de agua en función de la turbidez



Fuente: Landwehr y Denninger (1976)

In the case of total dissolved solids, the graph of Figure 9 is taken into account, so for the case of $w_8 = 0.08$ the corresponding value for sub_8 is taken as it corresponds to the graph.

Figura 9. Valoración de la calidad de agua en función del residuo total



Fuente: Landwehr y Denninger (1976)

For the dissolved oxygen (DO) parameter one must first calculate the saturation percentage of the OD in the water; for this, the saturation value of the OD must be specified according to the water temperature (see table 3). If the saturation percentage of the OD is greater than 140%, the $sub_9 = 47$. If the value obtained is less than 140% saturation of the OD, the value corresponding to sub_9 is searched in the graph of Figure 10, and the corresponding relative weight is $w_9 = 0.1$.

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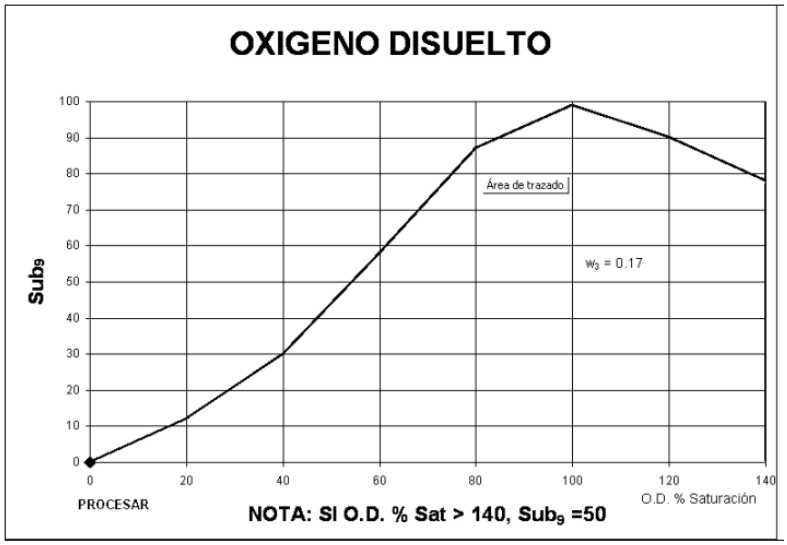
Tabla 3. Saturación del oxígeno disuelto según la temperatura

Temp. °C	OD *mg/l*	Temp. °C	OD *mg/l*	Temp. °C	OD *mg/l*	Temp. °C	OD *mg/l*
1	14.19	12	10.76	23	8.56	34	7.05
2	13.81	13	10.52	24	8.4	35	6.93
3	13.44	14	10.29	25	8.24	36	6.82
4	13.09	15	10.07	26	8.09	37	6.71
5	12.75	16	9.85	27	7.95	38	6.61
6	12.43	17	9.65	28	7.81	39	6.51
7	12.12	18	9.45	29	7.67	40	6.41
8	11.83	19	9.26	30	7.54	41	6.31
9	11.5	20	9.07	31	7.41	42	6.22
10	11.27	21	8.9	32	7.28	43	6.13
11	11.01	22	8.72	33	7.16	44	6.04

Fuente: Landwehr y Denninger (1976)

Figura 10. Valoración de la calidad de agua en función del % de saturación del oxígeno disuelto



Fuente: Landwehr y Denninger (1976)

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Materials and methods

The municipality of Tizapán el Alto was elevated to that category in the year of 1947, when Ramon Garza Madrigal was municipal president, and first delegate of El Volantín don Pedro Díaz. This is one of the oldest delegations, and was the territory of the Hacienda Corrales de Toluquilla.

Figura 11. Localización de la comunidad El Volantín

Fuente: Elaboración propia

The El Volantín dam was built at the time of General Lázaro Cárdenas, but was inaugurated in 1941. According to data provided by the National Water Commission (Conagua), the storage capacity of the dam is 14 billion cubic meters of water. In addition, it has a curtain downstream of 11.5 m in height, not conventional for its time, formed by rocks. Also, because of the type of rock arrangement, it can be classified as graded materials.

The samples taken at the dam were extracted from four points: El Casco, El Volantín, Las Canoas and Villa Madero (figure 12). Of these points, the one with drainage discharge is El Volantín.

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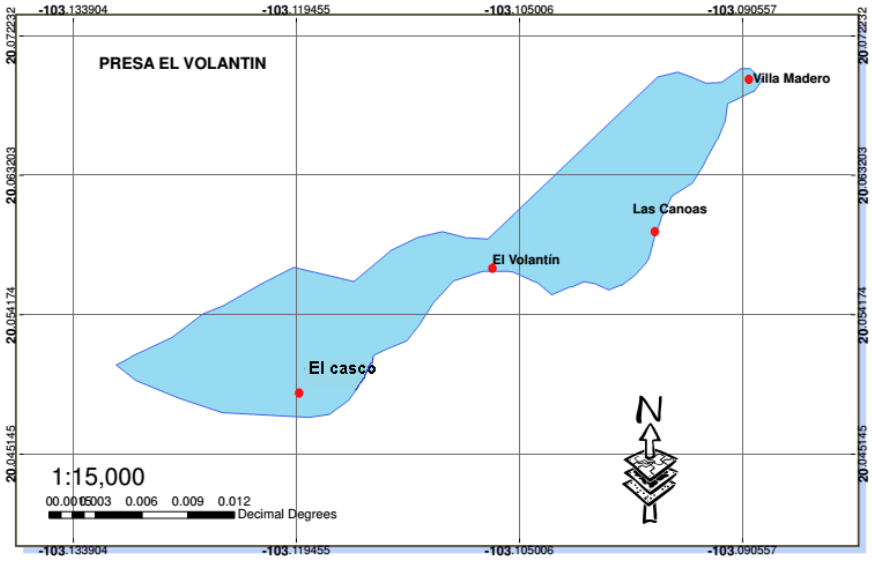
Figura 12. Diferentes puntos de muestreo en la presa El Volantín



Fuente: Elaboración propia

At each point, five samples were taken for analysis. Table 4 shows the date on which the samples were taken and the amount of water that the dam had at that time. In this way, the rainy season, not the rain, was covered. At each of the points a sample was taken at 30 cm below the water mirror measured with a ruler. This was placed in two plastic containers previously washed and sterilized, with capacity for one and three liters, respectively, which correspond to the standard of the samples. Each one was labeled with the name of the study area, the date and time of the sample.

Before the container was closed, the pH was measured in the field with reactive strips, and then in the laboratory with a potentiometer. Also, the temperature was measured with a mercury thermometer. This information was recorded on the container labels. Then the samples were deposited in a cooler for transfer to the laboratory of Microbiology and External Analysis of the University Center of Exact Sciences and Engineering (CUCEI). The transfer and analysis were performed on the same day that the samples were taken.

Tabla 4. Puntos donde se tomaron las muestras, la fecha y el nivel de agua

Muestra	Fecha	Nivel del agua	Puntos
1	22 de marzo de 2014	3 728 000 m^3	El Casco El Volantín Las Canoas Villa Madero
2	21 de junio de 2014	3 830 000 m^3	El Casco El Volantín Las Canoas Villa Madero
3	16 de septiembre de 2014	5 831 000 m^3	El Casco El Volantín Las Canoas Villa Madero
4	5 de enero de 2015	8 140 000 m^3	El Casco El Volantín Las Canoas Villa Madero
5	12 de abril de 2015	7 221 000 m^3	El Casco El Volantín Las Canoas Villa Madero

Fuente: Elaboración propia

The analysis of the samples was carried out in accordance with the provisions of the norm NOM-001-SEMARNAT-1996 in its section 2, referring to the procedures for the determination of the contaminants, and as established in the norm NOM-127-SSA1 -1994. Next, each of these is indicated:

- NOM-001-SEMARNAT-1996. It establishes the maximum permissible limits of contaminants in wastewater discharges in national waters and goods (clarification of April 30, 1997).
- NOM-127-SSA1-1994. Environmental health, water for human use and consumption - permissible limits of quality and treatments to which they must submit to water for purification.
- NOM-015-CONAGUA-2007. Artificial infiltration of water to aquifers, characteristics and specifications of works and water.

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Results and Discussion

As already explained, in each of the four points selected for this study (El Casco, El Volantín, Las Canoas and Villa Madero), five samples were taken to be analyzed in the laboratory. These were extracted the same day and at the same time. Table 2 shows the dates in which each of the samples was taken and the volume of water that at that time had the El Volantín dam. The results of the laboratory analysis for each of the samples are shown in table 5.

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Tabla 5. Resultados del análisis del laboratorio para los distintos muestreos

N.º de muestreo	Parámetros	EL CASCO	EL VOLANTIN	LA CANOA	VILLA MADERO
MUESTREO 1	Organismo coliformes fecales	40	93	21	0
	pH	8.7	9.2	9.2	9.3
	Demanda bioquímica de oxígeno (ppm)	200	400	253.1	127
	Nitratos (ppm)	1.2	4	4.2	4
	Color (unidades de Pt-Co)	750	250	125	250
	Turbidez (NTU)	26	8.8	8.4	7.7
	Sulfatos (ppm)	15.4	10	13.5	9.5
	Sólidos totales (ppm)	1240	390	380	470
	Sólidos sedimentables (ml/l)	3.5	0	0	0
MUESTREO 2	Organismo coliformes fecales	4	1150	150	9
	pH	8.5	7	9.5	9.6
	Demanda bioquímica de oxígeno (ppm)	118	730	95	110
	Nitratos (ppm)	1.8	1.5	2.2	1.7
	Color (unidades de Pt-Co)	60	120	50	100
	Turbidez (NTU)	6	9	5	5
	Sulfatos (ppm)	35	50	17	15
	Sólidos totales (ppm)	790	1225	448	450
	Sólidos sedimentables (ml/l)	0.5	0.1	0.1	0
MUESTREO 3	Organismo coliformes fecales	15	210	14	23
	pH	7.1	8.7	9.1	9.1
	Demanda bioquímica de oxígeno (ppm)	210	270	370	545
	Nitratos (ppm)	3	3.5	2.7	3.1
	Color (unidades de Pt-Co)	50	100	100	100
	Turbidez (NTU)	12	7	5	4
	Sulfatos (ppm)	47	36	37	33
	Sólidos totales (ppm)	270	410	300	250
	Sólidos sedimentables (ml/l)	0.1	0.2	0	0
MUESTREO 4	Organismo coliformes fecales	3	1100	93	43
	pH	7.9	8.8	8.8	8.5
	Demanda bioquímica de oxígeno (ppm)	298	300	281	245
	Nitratos (ppm)	1	1	1.4	1
	Color (unidades de Pt-Co)	100	75	100	100
	Turbidez (NTU)	8	5	5	8
	Sulfatos (ppm)	30	28	25	29
	Sólidos totales (ppm)	265	260	270	172
	Sólidos sedimentables (ml/l)	0	0	0	0
MUESTREO 5	Organismo coliformes fecales	9	21	9	93
	pH	8.4	8.7	8.4	8.5

	Demanda bioquímica de oxígeno (ppm)	108	100	95	120
	Nitratos (ppm)	2	0.9	0.9	0.7
	Color (unidades de Pt-Co)	150	150	150	150
	Turbidez (NTU)	6	2	5	2
	Sulfatos (ppm)	11	10	9	15
	Sólidos totales (ppm)	294	233.5	254	280
	Sólidos sedimentables (ml/l)	0	0	0	0

Fuente: Elaboración propia

The 8 parameters analyzed in each one of the samplings are observed in table 6, where having the value of the laboratory analysis, the values of sub_i and the values of w_i are multiplied to fill the Total column (table 6), and of the sum of this you get the value of $ICAa = \sum_{i=1}^{9}(sub_i * w_i)$, Brown y McCleland (1973).

Tabla 6. Parámetros que se analizaron para el ICA

N.º	Parámetro	*valor*	sub_i	w_i	*Total*
1	*Coliformes fecales*			0.15	
2	*pH*			0.12	
3	*Demanda bioquímica de oxígeno (DBO_5) ppm*			0.10	
4	*Nitratos (ppm)*			0.10	
5	*Sulfatos (ppm) (Fosfatos)*			0.10	
6	*Cambio de la temperatura*			0.10	
7	*Turbidez (NTU)*			0.08	
8	*Sólidos disueltos totales (ppm)*			0.08	
9	*Demanda de oxígeno (oxígeno disuelto, % de saturación)*			0.17	

Fuente: Elaboración propia

Then, in the graphs of figure 13, the results of the laboratory analysis are observed with the five samples and the four sampled points, specifically in the parameters fecal coliform organisms and biochemical oxygen demand:

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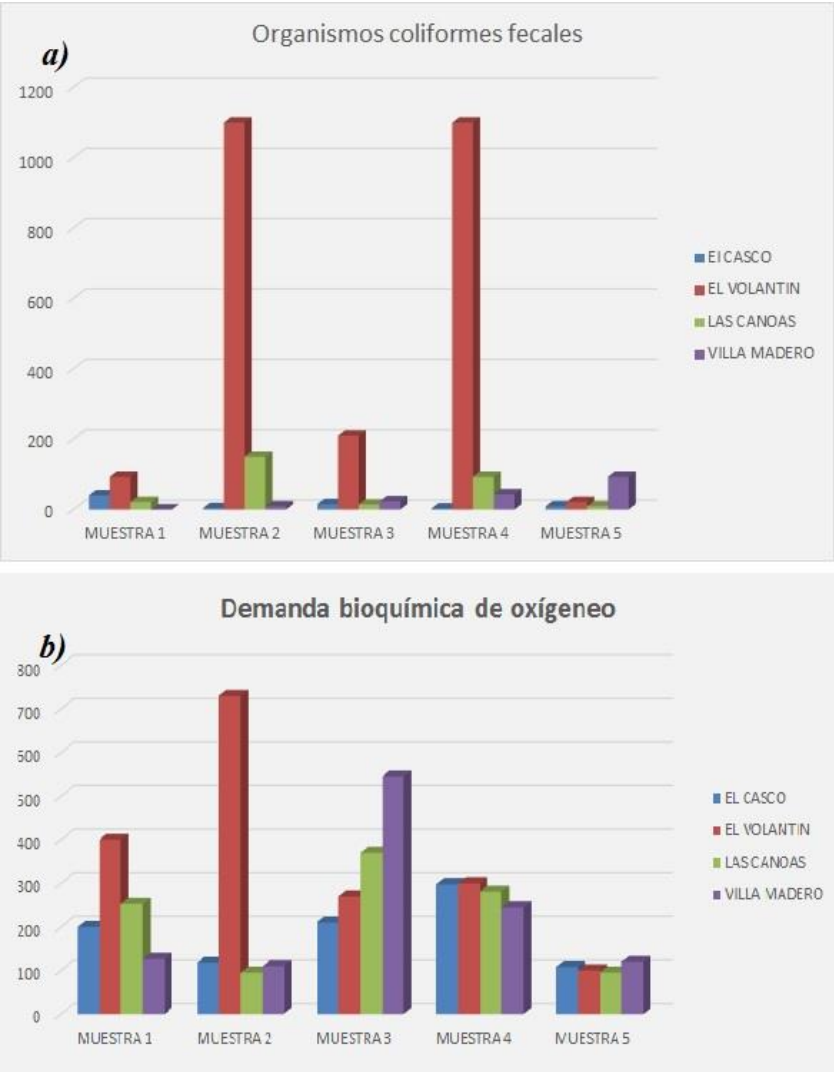
Figura 13. Parámetros *organismos coliformes fecales* y *demanda bioquímica de oxígeno* en los cuatro puntos muestreados y en las cinco muestras



Fuente: Elaboración propia

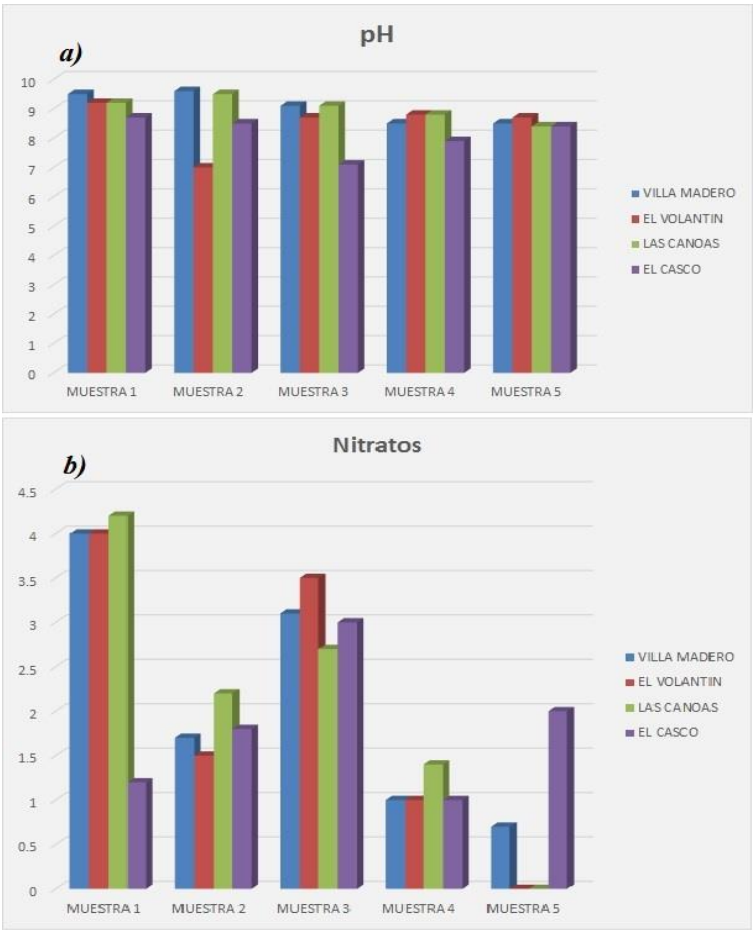
- For subsection a) fecal coliform organisms, it is observed that the largest quantity of these substances is found in each of the El Volantín samples, except in sample 5, where the Villa Madero point stands out. In addition, it is observed that samples 2 (taken on June 21) and 4 (taken on January 5) from El Volantín point show a large amount of fecal coliform organisms, in comparison with the others. This is because at that point the El Volantín community

drainage is discharged, and perhaps it is also due to vacationers, who visit the community during periods such as Easter and Christmas.

- For subparagraph b) biochemical oxygen demand, it can be seen that in sample 1 (taken on March 22) and 2 (taken on June 21) the El Volantín point with more of these substances stands out. In contrast, in sample 3 (taken on September 16) the highlight is Villa Madero.

Now, the graphs of Figure 14 show the results of the laboratory analysis with the five samples and the four points sampled in the parameters pH and nitrates:

Figura 14. Parámetros *pH* y *nitratos* en los cuatro puntos muestreados y en las cinco muestras



Fuente: Elaboración propia

- In part a) pH, it can be seen that in sample 1 all the points are outside the permissible limits, since the acceptable range is between 6.5 and 8.5. On the other hand, in sample 2, the points that exceed the norm are Las Canoas and Villa Madero. In sample 3, the points that exceed the permissible limits are El Volantín, La Canoa and Villa Madero, while in sample 4 this situation only occurs in El Volantín and La Canoa. Finally, in sample 5 only El Volantín is outside the permissible limits.
- In subsection b) nitrates, specifically in sample 1, all points are outside the permissible limits, since the acceptable range is between 6.5 and 8.5. In sample 2, the points that exceed the norm are La Canoa and Villa Madero. In sample 3, this happens with El Volantín, La Canoa and Villa Madero, while in sample 4 there are El Volantín and La Canoa. In sample 5, only El Volantín is outside the permissible limits.

In the graphs of figure 15 the results of the laboratory analysis are presented with the five samples and the four points sampled in the parameters color and turbidity:

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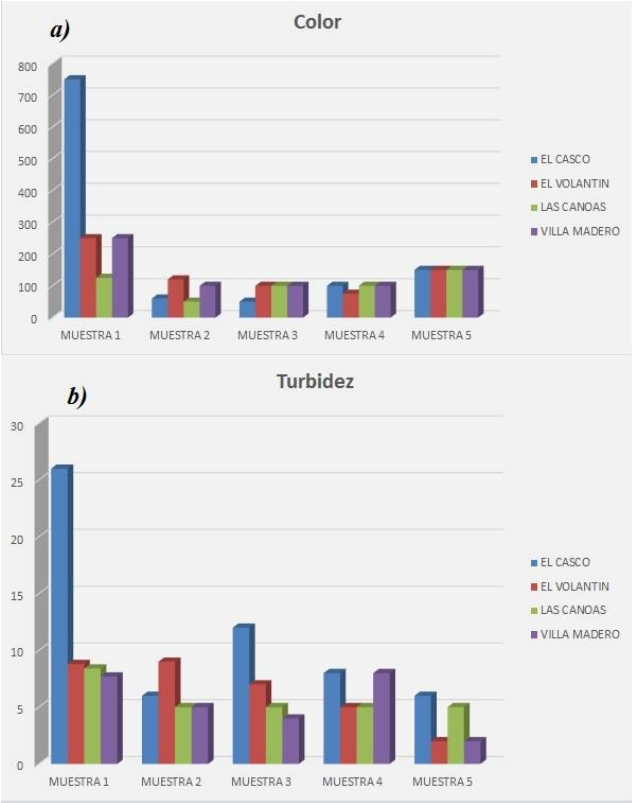
Figura 15. Parámetros *color* y *turbidez* en los cuatro puntos muestreados y en las cinco muestras



Fuente: Elaboración propia

- In part a) color, the El Casco point stands out in sample 1 (taken in March) because in that month the dam had less water and the surface was very flat (it had no depth).
- In part b) turbidity, in sample 1 (taken in March) all the points (mainly El Casco) exceed the limits, since the allowable are 5 UTN units. In samples 2 and 3, El Volantín and El Casco are overflowed, while sample 4 is made by El Casco and Villa Madero. Finally, in sample 5, only the El Casco point exceeds the limit.

The graphs of Figure 16 show the results of the laboratory analysis with the five samples and the four points sampled in the sulphate parameters and total solids:

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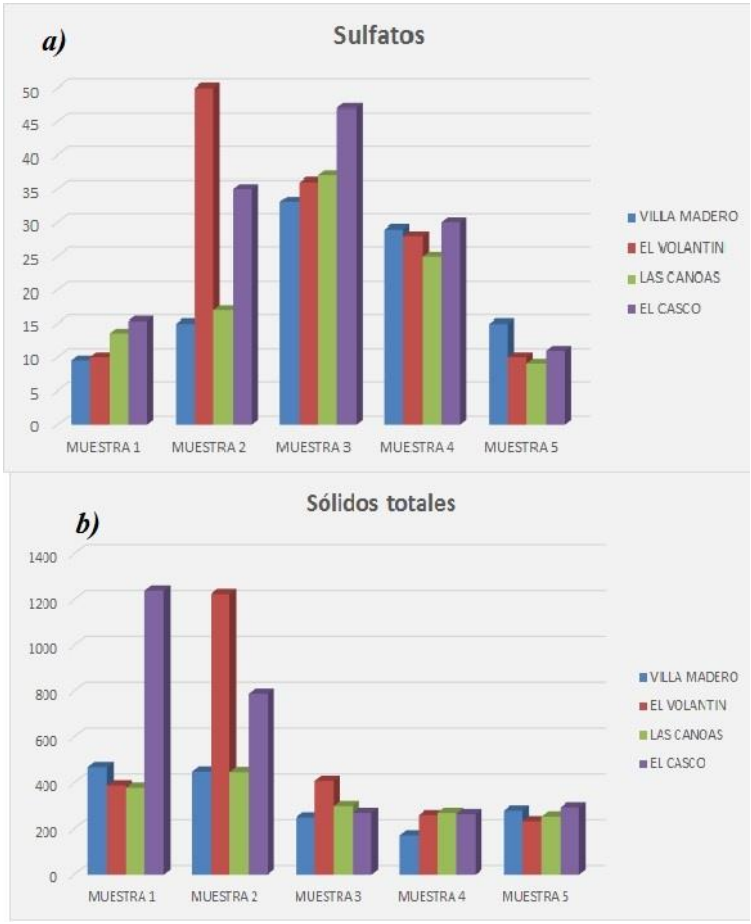
Figura 15. Parámetros *sulfato* y *sólidos totales* en los cuatro puntos muestreados y en las cinco muestras



Fuente: Elaboración propia

- In part a) sulphates, in sample 2, the El Volantín point stands out, while in sample 3 the El Casco point stands out.
- In section b) total solids, in sample 1 the one taken at El Casco stands out, while in sample 2, the one extracted from El Volantín point stands out more.

Evaluation of water quality indicators for the El Volantían dam

Based on the results obtained in the laboratory analyzes, the indicators can be evaluated to determine the value of the ICA in the El Volantín dam. In this sense, first calculate the values of each of the ICAa for each sample, as well as for each point, and at the end add up, according to the formula $ICAa = \sum_{i=1}^{9}(sub_{\mathrm{i}} * w_{\mathrm{i}})$ (Brown y McCleland, 1973).

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In the laboratory analysis for the case of fecal coliforms, the Las Canoas sampling point showed a value of 21; so $sub_1 = 62$ (based on the graph of figure 2) and $w_1 = 0.15$ (table 2), substituting in the formula ICAa for the first case we have:

$$ICAc = (62)(0.15) = 9.3$$

Now, performing the calculations of sample 1 for the sampling point Las Canoas, the results are shown in table 7, thus the ICA = 44.43, with this value for the ICA and taking the classification of table 1, the range in which results in poor water quality.

Tabla 7. Calculo de los $ICAa$ para la muestra 1 y en el punto Las Canoas

N.º	Parámetro	*valor*	sub_i	w_i	*Total*
1	*Coliformes fecales*	21	62	0.15	9.3
2	*pH*	9.2	42	0.12	5.04
3	*Demanda bioquímica de oxígeno(DBO_5) ppm*	253.1	2	0.10	0.2
4	*Nitratos (ppm)*	4.2	75	0.10	7.5
5	*Sulfatos (ppm) (fosfatos)*	13.5	5	0.10	0.5
6	*Cambio de la temperatura*	Temperatura ambiente 23 Temperatura 17 Diferencia 6	35	0.10	3.5
7	*Turbidez (NTU)*	8.4	80	0.08	6.4
8	*Sólidos disueltos totales (ppm)*	380	50	0.08	4
9	*Demanda de oxígeno (oxígeno disuelto, % de saturación)*	Temperatura 17 Demanda de oxígeno 9.65 DQO536.5	47	0.17	7.99
				SUMA	44.43

Fuente: Elaboración propia

Fig. 1. Thus, performing the calculations for each parameter in each sample, we have the results of Table 8, which, based on Table 1, serve to classify the water quality. That is, in sample 1 (conducted in March 2014, when the volume of water in the dam was 3,728,000 m3), at all points the result of water quality was poor.

Fig. 2. On the other hand, in sample 2 (conducted in June 2014, when the volume of water in the dam was 3,830,000 m3) at two points (Las Canoas and El Volantín) the water quality was poor, while in the other two (Villa Madero and El Casco) was regular.

Fig. 3. Also, in sample 3 (carried out in September 2014, when the volume of water in the dam was 5,831,000 m3) only at El Volantín point the water was bad, while in the other three (Las Canoas, Villa Madero and El Casco) was fair.

In contrast, in sample 4 (conducted in January 2015, when the volume of water in the dam was 8 140 000 m3), at all sampling points the result of water quality was regular, as it happened in all the points in the sample 5.

Tabla 8. Calculo de los $ICAa$ en cada muestra

	SITIO	ICA	CALIDAD DEL AGUA
Muestra 1 (22 de marzo de 2014)	Las Canoas	44.43	MALA
	Villa Madero	50.65	MALA
	El Volantín	41.97	MALA
	El Casco	41.88	MALA
Muestra 2 (21 de junio de 2014)	Las Canoas	44.81	MALA
	Villa Madero	51.27	REGULAR
	El Volantín	45.25	MALA
	El Casco	52.55	REGULAR
Muestra 3 (16 de septiembre de 2014)	Las Canoas	51.41	REGULAR
	Villa Madero	51.68	REGULAR
	El Volantín	46.39	MALA
	El Casco	54.68	REGULAR
Muestra 4 (5 de enero de 2015)	Las Canoas	53.2	REGULAR
	Villa Madero	58.45	REGULAR
	El Volantín	52.17	REGULAR
	El Casco	57.68	REGULAR
Muestra 5 (12 de abril de 2015)	Las Canoas	53.09	REGULAR
	Villa Madero	51.09	REGULAR
	El Volantín	54.16	REGULAR
	El casco	53.95	REGULAR

Fuente: Elaboración propia

Conclusions

Based on the results obtained, it can be affirmed that in the five samplings the levels of the biochemical oxygen demand, the chemical oxygen demand, the total suspended solids and the color are outside the permissible limits that appear in the norms NOM001- SEMARNAT-1996 and NOM-127-SSA1-1994, which means that the water quality is not good. In fact, there is contamination of domestic origin due to the high levels of organic matter in the El Volantín dam, since there is no wastewater treatment by the inhabitants of the surrounding communities. This can cause less diversity of aquatic organisms and progressively increase the growth of algae.

For this reason, it is recommended to monitor the direct drainage discharges to the dam, so that the amount of organic matter dissolved in its waters can be reduced. This can happen with the use of filters or treatment plants in the discharge of each of the drains so that the water that reaches the dam is of optimum quality.

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