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Parametric Measurement of Water Pollution in the Jihuite Microbasin in the Highlands of Jalisco, Mexico

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Abstract Much of human well-being depends on ecosystems, a body of water can be used in different ways: as a source of drinking water, for agricultural irrigation, including for the generation of energy, many water sources support the production of food, in synthesis life on our planet is sustained through sensitive interrelations with various natural resources such as water flows. In the particular case that the river is an ecosystem of great richness and complexity, necessary for the sustainability of the population centres, a true urban planning must consider the adequate conservation of the natural causes of water (rivers and streams among others), avoiding using these routes as waste and wastewater collectors. Through the results obtained in the present monitoring it is possible to appreciate that the water quality in the main water bodies of the microbasin such as the Tepatitlan river decreases sensibly, from its origin in the Jihuite stream to the exit of the municipality of Tepatitlan, due to among other factors; the population growth, the increase in agricultural production in the study area, resulting in point and diffuse discharges of effluents without treatment, both of domestic origin as well as of agricultural and industrial farms, together with the limitations in the systems for the adequate treatment of domestic wastewater. It highlights a high organic pollution at the exit of the municipality evidenced mainly by: the low Concentrations of Oxygen Dissolved, high values of Specific Conductance, Chlorides, Oxygen Potential Reduction and ammonic Nitrogen that cause critical conditions for sustaining aquatic life, the use for agriculture, human and animal consumption, as well as problems of environmental pollution.

Keywords Hydrological basin, Specific conductivity in water, Surface water quality, Tepatitlan River

Introduction

The hydrographic basin is a geographical and hydrological concept that is defined as the area of the earth's surface where rain, snow or thaw water drains and/or transits through a network of currents that flow into a main stream, and by this towards a common point of exit, which can be an internal water storage, such as a lake, a lagoon or a dam reservoir, in which case it would be an endorheic basin; When the discharges reach the sea it is called exorheic basin, usually the main stream is what defines the name of the basin. The main currents in the basins are regularly rivers, that is to say natural currents subjected to climatic changes and to the characteristics of the basin, the quality of its water varies naturally over time and its course due to the combination of environmental factors However, human activities alter, sometimes irreversibly, the physical, chemical and biological characteristics of water [1-2]. Among the main sources of contamination of surface water huts such as rivers and streams, are the discharges of municipal and industrial wastewater, as well as the return flows generated by agricultural activities. In recent years in our country, contamination of surface waters has been one of the problems that has begun to be studied and documented consistently [3], despite the multidimensional conceptual assessment of "quality of water ", has generated inconveniences, the handling of data as well as its interpretation are usually a complicated and often difficult work for the general public [4], specifically when seeking to standardize global quality, to the different applications, the situation becomes more complex. The geographic location of the Jihuite microbasin at municipality of Tepatitlan has the coordinates; 20°49'03''N, 102°45'26''W (Fig. 1).

Tepatitlan has a territorial extension of 1,388 km², altitude above sea level of 1806, its population in 2015 was 141,322 of which 95,534 people lived at the head municipal (67.6%), comparatively 3.8% higher than the population in 2010, it is estimated that with this rate, by 2020 the population will increase to 153,678 inhabitants [5]. Historical data of weather stations near the municipality indicates that most of the municipality (71.6%) has a semi-warm and semi-humid climate according to the classification made by Köeppen. According to the Jalisco Statistical and Geographic Information System, the annual average temperature recorded in this municipality is 17.8°C, while its average maximum and minimum range between 30.2°C and 5.4°C respectively, being in the month of June when the highest temperatures are recorded and the coldest month of January, the annual average precipitation of the municipality is 868 mm, as well as the annual average potential evaporation is 600 mm, presenting the months with the highest index, in March until June.

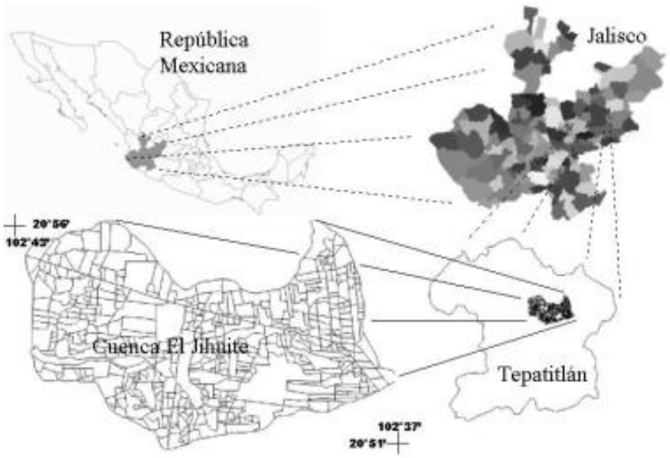


Figure 1: Location of the Jihuite microbasin

On the other hand, the value of agricultural production in Tepatitlan has shown growth during the period 2012–2016, having registered its highest level in 2016 (1,516,824 million pesos), this value in 2012 represented only 0.9% of the total State agricultural production and had its maximum participation in 2016 contributing 3.3% of the state total in that year, in the same way livestock production has maintained an increasing trend during the same period, being the year 2016 the one that registered the highest value (11,807,840 million pesos). In 2012, Tepatitlan's livestock production represented 15.5% of the total livestock production in the state, however in 2013 it stood out for a greater participation, reaching 16.9% of the state's production. In terms of urban solid waste, the municipality generates 1.47% of the state total, equivalent to 110.26 tons produced per day ([6-7].

The municipality of Tepatitlan according to the National Water Commission (CONAGUA), is within the administrative hydrological region VIII "Lerma-Santiago-Pacifico", in the hydrological region 12; "Lerma-Santiago", in the hydrological zone "Rio Santiago in the "Río Verde", "Río Santiago"and"Río del Valle"Hydrological Basins, in the"Lerma – Chapala"Hydrological Zone in the"Río Zula"Hydrological Basin.

The main currents in the municipality are the rivers: Tepatitlan, Verde, Calderon and Los Arcos (Fig. 2), it also has the streams: Laborcilla, Milpillas, Juanacasco, San Pablo, Tecolote, Jesus Maria, Peron, Mezcala, Guayabo, La Vieja, Jihuite and El Ocote, as well as the Carretas, Jihuite, La Red, Calderon, La Vieja and El Pantano dams.

Figure 2: Hydrography of the municipality of Tepatitlan Jalisco

The Tepatitlan River (Fig. 3) presents a route from northeast to southwest in the municipality of Tepatitlan and from east to north in the municipality of Acatic, originates from the Jihuite stream (Fig. 4), in which. In 1964, the dam Jihuite was built for a nominal capacity of 5 million m³, after 8 km, in the city of Tepatitlan, the Tecolote, Gloria and Durazno streams are fed mainly as well as others. Of temporary, to reach the dam of the lagoon in the municipality of Acatic and later 14 km later it flows into the Verde River, in the boundaries of the municipalities of Acatic and Cuquio.

Figure 3: Trajectory of the Tepatitlan River in the Tepatitlan municipality

Figure 4: Jihuite dam and stream

With this study, the parametric water quality was monitored in different parts of the Tepatitlan River, in its path within the municipality of Tepatitlan Jalisco, with three measurements in a chronological period of one year, evaluating its behavior and possible causes.

Materials and methods

The micro-basin of Jihuite is located northeast of the state of Jalisco, geographically it is located between the parallels 20°50'57" and 20°55'50" North, and the meridians 102°36'50" and 102°43'West (Fig. 5), with an altitude of 1900 to 2150 meters above sea level, with an approximate area of 5,850.63 hectares, plus 53.97 ha corresponding to the dam reservoir, for a total of 5,904.6 hectares, with a sub-humid temperate climate, with an average temperature of the hottest month exceeding 22°C and an average annual temperature of less than 18°C, with less than 5% of winter rain in relation to the annual average. The average annual rainfall is 816.3 mm, with 88 days of appreciable rainfall. The average annual maximum, minimum and average temperature is 25.6, 7.6 and 16.6°C, respectively [8].

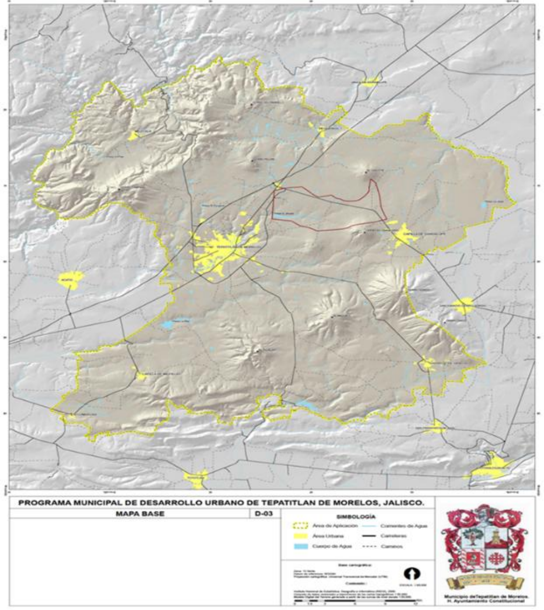


Figure 5: Jihuite's microbasin in the municipality of Tepatitlan Jalisco [5].

In 2005, the main land uses in Jihuite microbasin were for livestock activities and for agriculture (Fig. 6).

Figure 6: Land use in the microbasin of Jihuite

The predominant topography is hills with slopes of 1 to 58%, according to the cartography of the National Institute of Statistics, Geography and Informatics (INEGI), the soil is largely luvisol ferric, of clay texture or clay crumb, with depth of up to one meter, another type of soil that occurs in the northern part is the eutric planosol, of clayey texture with depth of 40 centimetres or less. The use of the land indicates that about 30% of the area is dedicated to annual crops, 10% to temporary meadows, 55% to land where cattle graze, with native species and 5% is used as roads, buildings and other uses.

The land ownership regime is small property, agricultural and industrial activities in the highlands of Jalisco represent an important supply of raw materials and basic foods, both for the region itself and for other parts of the country, however, and these activities affect the sustainability of natural resources such as water.

The Tepatitlan River has its origin practically in the confluences of the streams, coyotes and Jihuite within the urban spot of the Tepatitlan city, travels around 16.5 km in the Tepatitlan municipality and 18.6 km in the Acatic municipality until its mouth in the Verde River. Through geographical information such as the hydrographic features of the municipality of Tepatitlan, as well as field trips, 6 points were established for monitoring and sampling, its location is shown in Figure 7.

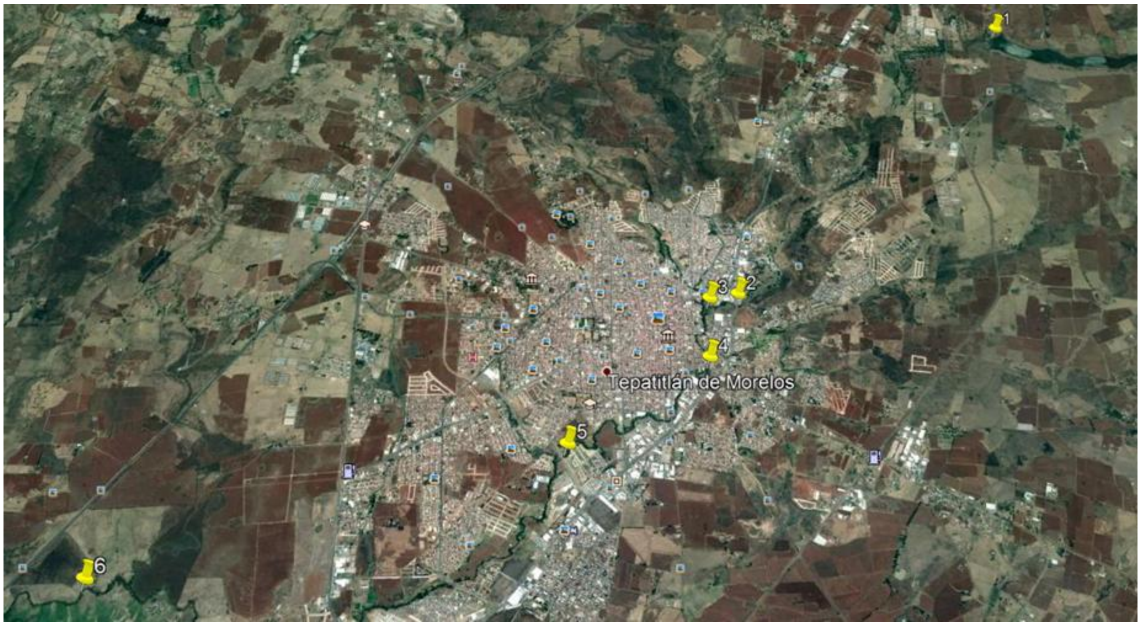


Figure 7: Location of monitoring and sampling points

For the quantification of the parameters that reflect water quality, a Hydrolab multiparameter probe model DS5X (OTT Hydromet) was used.

The quantified parameters and the sensors used in the probe were:

1) Temperature: by means of a variable resistance transmitter.

2) Hydrogen Potential (pH): using the electrochemical method for voltage difference between a sensitive glass electrode and a reference electrode.

3) Ammonia or ammonia nitrogen (N amon): it is one of the transitory components in water since it is part of the nitrogen cycle and is influenced by biological activity, it is also the natural product of decomposition of organic compounds nitrogenous, surface waters must not naturally contain ammonia, in general the presence of free ammonia (ammonium ion) is considered a chemical test of recent and dangerous contamination, its main origin is; industrial and livestock wastewater (animal excreta, fertilizer) and plant rot, its maximum permissible value in drinking water is 0.50 mg/L (NOM-127SSA1-1994).

4) Chlorides (Cl): they are anions commonly present in fresh water; their maximum permissible concentrations for drinking water are 250 mg/L (NOM-127SSA1-1994).

5) Dissolved Oxygen Concentration (COD): it is a measure of the amount of oxygen present in the water and available for breathing, this concentration is controlled by several factors, including the consumption of aerobic organisms such as bacteria and fish, the consumption of plants such as algae, temperature and depth, is a fundamental parameter to classify the level of contamination in surface waters by comparing their values at the same temperature conditions with saturated oxygen saturated water, for example at 20°C and a At atmospheric pressure, the oxygen saturation in water is 9.1 mg/L [9]. It was determined by optical measurement (luminescence technique), by an oxygen sensitive layer, excited by a blue LED.

6) Specific Conductance (SC): it is the ability of water to conduct electric current and depends on the amount of solid matter dissolved, it is an indirect measure of the amount of ions in solution (mainly nitrate, sulfate, phosphate, sodium, magnesium and calcium), untreated sewage discharges to water bodies usually increase their conductivity, the basic unit for measuring specific conductivity is millisiemens per centimeter (mS/cm), the SC is an important measure of water quality, since it indicates the amount of matter dissolved in it; significant changes can be indicators of specific pollution events. It was measured by 4 graphite electrodes in an open cell, salinity is derived from the measurements of these sensors.

7) Oxygen Reduction Potential or Redox potential (ORP): it is a measure of the oxidation state of a system, it measures the tendencies of electrons when flowing to / from a noble metal electrode, it is quantified in millivolts (mV) and is another indicator of water pollution.

The precision and resolution of the parameters is specified by the manufacturer of the equipment and can be checked in table 1 (DS5X -User Manual-, 2007).

Table 1: Parameters and specifications of the equipment used. Source: DS5X probe user manual

Parameter	Accuracy	Resolution	Range
Temperature (ºC)	± 0.10	0.01	-5 a 50
pH	±0.2	0.01	0-14
N amon. (mg/l-N)	± 2	0.001	0-100
Cl (mg/l)	± 2	0.0001	0.5 a 18,000
COD (mg/l)	± 0.01 de 0-8 ± 0.2 > 8	0.01	0-30
SE (mS/cm)	±1% of the value read	0.0001 units	O a 100
ORP (mV)	± 20	1	-999 a 999

The probe is connected to the Surveyor interface that shows the readings instantly of each parameter, with the option of storing the determinations for later downloading them to a computer.

Punctual samples of surface water were taken and the determinations were made in each of the 6 points designated above, during three sampling campaigns, ensuring the 2018 and 2019 season: the first one during March 2018, the second one in January 2019 and the third one in March 2019. The sampling, as well as the field determinations, were carried out respecting the international criteria recommended by the standardized methods [9].

Results

Practically the Tepatitlan river is born in the Jihuite microbasin, which has an extension of approximately 6,357 ha, with a length of the main channel of 15,321 km and a 3.55% average slope of the main channel, this river has several tributaries, mainly of It crosses the municipalities of Tepatitlán and Acatic, ending at the Verde River at the boundaries of the municipalities of Acatic and Cuquio (Fig. 13), between coordinates 20º39'40" at 20º55'00" North latitude and 102º48'12" to 103º02'10" West longitude; at a height of 1,685 meters above sea level.

The location of sampling points and their description of the Tepatitlan River’s trajectory are shown in table 2:

Table 2: Geographical location of the monitoring points in the Tepatitlan River (Source: Own elaboration)

Num.	**Key Identification**	**Municipality**	**Coordinates**			**Description**
			N	**W**	**Height(m)**	
1	PJ	Tepatitlan	20.854522	102.714976	1900	Jihuite dam
2	ET	Tepatitlan	20.817782	102.750996	1777	At the entrance of Tepatitlán
3	CAT	Tepatitlan	20.817325	102.754250	1779	Conjunction with stream Tecolote
4	CT	Tepatitlan	20.805192	102.759573	1770	Center Tepatitlan
5	ST	Tepatitlan	20.789854	102.779940	1763	At the exit of Tepatitlan
6	EMA	Tepatitlan -Acatic	20.788873	102.815082	1741	At the entrance of the municipality of Acatic

The parametric results of the three monitoring campaigns are shown in Table 3.

Table 3: Results in the three monitoring campaigns

		Mar/18	**Jan/19**	**Mar/19**
		10:15-12:45am	9:45-12:10	11:00-13:10
Temperature (°C)	1	19.80	17.49	19.71
	2	20.30	18.15	20.09
	3	20.72	18.72	20.25
	4	20.94	18.89	20.79
	5	21.36	18.45	21.11
	6	20.91	18.72	21.21
pH	1	7.14	7.37	7.03
	2	7.02	7.12	7.00
	3	6.94	7.02	6.84
	4	6.73	6.96	6.41
	5	6.87	6.83	6.36
	6	6.54	6.68	6.17
N amon (mg/L)	1	0.87	0.79	1.25
	2	1.78	1.33	2.08
	3	2.01	1.46	2.67
	4	2.36	1.89	2.81
	5	2.44	1.97	2.86
	6	3.57	2.47	4.47
Cl- (mg/L)	1	4534	3433	5650
	2	3672	2903	4771
	3	4870	3555	12771
	4	7650	6759	23572
	5	8761	7549	33663
	6	34764	10997	54334
COD (mg/L)	1	8.4	8.4	8.1
	2	7.1	7.4	6.2
	3	6.1	7.1	6.1
	4	5.8	6.7	5.3
	5	5.7	6.6	4.6
	6	1.1	2.3	1.0
SE (mS/cm)	1	111	97	138
	2	153	108	149
	3	236	147	348
	4	564	237	678
	5	638	343	769
	6	875	545	989
ORP (mV)	1	-131	-98	-149
	2	-142	-119	-168
	3	-279	-158	-335
	4	-311	-168	-359
	5	-337	-148	-373
	6	-337	-229	-418

The average temperature in the monitoring campaigns was 19°C, with a minimum of 17.49°C and a maximum of 21.36°C.

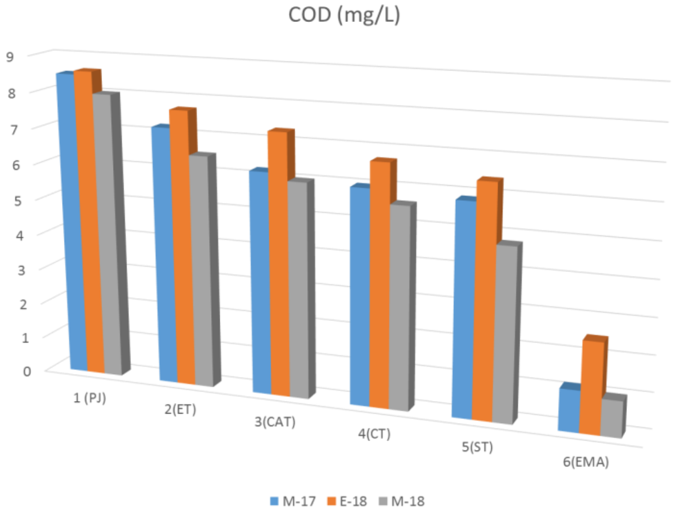
The pH variation did not become very significant; the range of variation was between 7.37 to 6.17.

The highest concentration of ammoniacal Nitrogen was presented at the exit of the municipality, at monitoring point 6, in March 2019, reaching 4.47 mg/L

The concentration of chlorides gradually increased to the maximum values at the exit of the municipality.

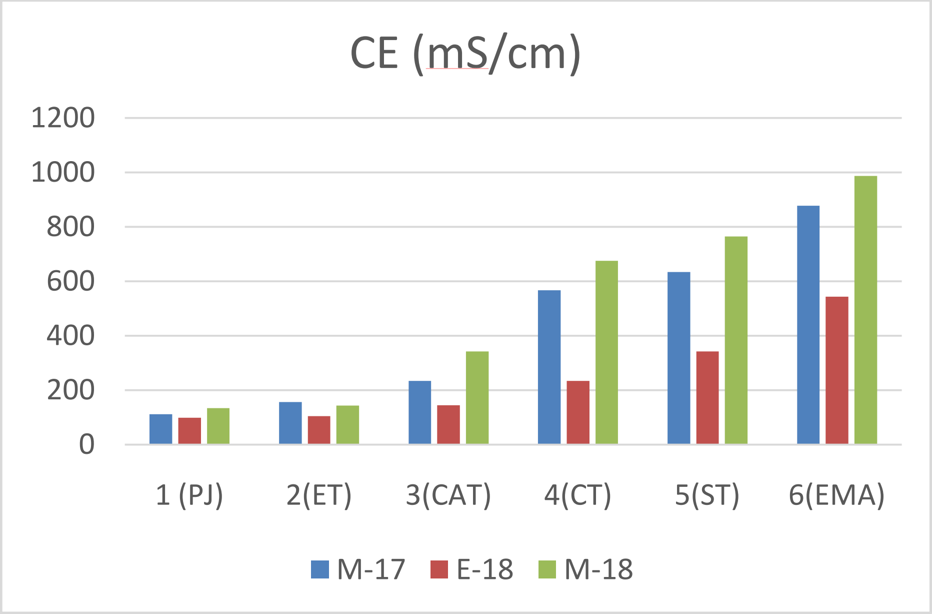
The complex of the Oxygen Reduction Potential (ORP), likewise indicates greater critical conditions at the exit, due to the increase of the anionic oxidative states greater at the exit.

The amount of oxygen dissolved drastically diminished, mainly at the exit, which reflects a high organic content in decomposition (Graph 1).



Graph 1: Concentration of Dissolved Oxygen (COD).

In the same way, the increase in the Specific Conductance confirms the persistence of greater quantities of dissipated particles at the exit (Graph 2).



Graph 2: Specific Conductance (SC)

Conclusion

The main body of water of the microbasin is the Tepatitlan River, which, when the dam of the same name was built more than 55 years ago, modified its hydrodynamics. Taking as reference, both international and current regulations in our country on the maximum permissible limits of contaminants in waters for human and animal consumption, specifically the official Mexican standards: NOM-127SSA1-1994, and NOM-003-ECOL- 1997, with the present study it is possible to deduce that the COD in the sampling points 4, 5 and 6 corresponding to the center of Tepatitlan, the exit of the urban spot and the exit of the municipality, presenting values lower than those required to sustain life aquatic at the corresponding temperatures (8 to 9 mg/L), other parameters showed a similar behavior as; the concentration of N ammonia, the SC and therefore the amount of dissolved chlorides, as well as the ORP, indicating that these waters are not suitable for human and / or animal consumption, possibly also for agricultural use, the previous situation is similar to other rivers in the region that receive wastewater discharges in treatment of urban centers [3]. In general, the low content of dissolved oxygen indicates a high content of organic matter, it is also evident that the tendency of the pollutants is to concentrate in the seasons of dryness (from March to May), since in these periods the flow significantly decreases of the river, likewise the presence of free ammonia (N ammonia) is considered as a chemical test of recent and dangerous contamination [10].

The non-point pollution originated both in the micro-basin of Jihuite and along the Tepatitlan river, is largely due to the excessive application of nutrients and manure on agricultural land, as well as the extensive application of pesticides and waste from livestock in the prairies, which during the rains run superficially reaching the various bodies of water, as well as overgrazing, deforestation and the insipid plantation of tequila agave aggravate the problem in the study region [8].

As can be seen in the results obtained the water quality of the Tepatitlan river decreases significantly, from the Jihuite stream to the exit of the municipality. Along the river, both before reaching the city of Tepatitlan (between monitoring points 1 and 2), as well as at the exit of the city, various agricultural holdings are located that eventually discharge their wastewater to streams that flow in the river itself. Likewise, it is evident that the greatest pollution of the river is recorded as it passes through the urban spot, most likely due to untreated effluent discharges and punctual and diffuse solid waste, it is worth mentioning that between monitoring points 5 and 6, It locates the Tepatitlan wastewater treatment plant that has a capacity of 200 liters per second (lps), however, it is not enough to properly treat the more than 450 lps generated by the city.

The population increase, the increase in the agricultural production of the study area, as well as the limitations in the systems for the treatment of domestic wastewater, can mainly explain the increasing deterioration observed in the waters of the Tepatitlan river since its origin in the Jihuite stream and mostly as it passes through the urban spot of the city of Tepatitlan.

Acknowledgments

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