AP AGRO PRODUCTIVIDAD

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# Determining water quality of the lower basin of the Usumacinta River in Tabasco, Mexico

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**ABSTRACT**

**Objective**: To determine the water quality of the lower basin of the Usumacinta River (Tabasco, Mexico), based on its physicochemical and microbiological characteristics.

**Design/methodology/approach**: There were taken 11 monthly samplings of surface water during the rainy season, from June to December, 2017 and in the dry season, from April to May, 2018, in three different sites. The parameters of temperature, Hydrogen potential (pH), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), total phosphorus (TP) and Nitrogen nitrate (N-nitrate) were evaluated. Significant statistical differences ($p \leq 0.05$) between seasons and among sites were determined.

**Results**: The results obtained were compared with Mexican regulations and Ecological Criteria for water quality. The parameters such as EC, TDS, TSS and TP showed substantial differences among seasons. Values for temperature, pH, EC and N-nitrate, did not exceed the maximum permissible limits for the use of irrigation water, urban public use and protection of aquatic life. However, the presence of *E. coli* and total coliforms from 530 to >24,196 MPN 100 $mL^{-1}$ were recorded throughout the study period.

**Findings/conclusions**: Parameters under study did not show significant differences among sites. The rainy season had an important effect on the increase in concentrations of TSS, TP, N-nitrate and total coliforms. Also, maximum concentrations were recorded during the study period in the sampling sites of Boca del Cerro (R1) and Puente Chablé (R2).

**Keywords**: Diffuse contamination, anthropogenic pollution, physicochemical and microbiological parameters, protection of aquatic life, Usumacinta River.

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## INTRODUCTION

The basin of the Usumacinta River in the state of Tabasco, Mexico, is one of the regions with great biodiversity and importance in the Maya Biosphere Reserve, in Mexico. In addition, it is classified as one of the water bodies with high vulnerability due to the impact of anthropogenic activities (Cotler *et al.*, 2010; López, 2011). Some sources and activities that contribute to the contamination of the environment and the deterioration of the water quality of Rivers, lakes, aquifers and coastal waters in various parts of the world are: human settlements, percolation of landfill leachates, diffuse pollution, sediments, pathogens, and metals (Mateo-Sagasta *et al.*, 2017; FAO, 2018). The increase of nutrients such as nitrogen and phosphorus in aquatic systems produce the eutrophication of water bodies with algal blooms causing these conditions mortality of aquatic organisms (Elser, 2012). The objective of this study was to evaluate the water quality of the lower basin of the Usumacinta River based on the determination of its physicochemical and microbiological characteristics according to the Official Mexican Norm NOM-001-SEMARNAT-1996 and the Ecological Criteria of water quality CE-CCA-001-1989.

## MATERIALS Y METHODS

### Study area

This research was carried out in the lower basin of the Usumacinta River, Tabasco, in the municipalities of Tenosique de Pino Suárez, Emiliano Zapata and Jonuta (Figure 1). The Usumacinta River basin has 106,000 km$^2$ of territory located between the states of Chiapas, Tabasco and Campeche in Mexico. Its water presents currents from south to north, flowing into the Gulf of Mexico with an approximate load of 105,200 million m$^3$ of water per year. According to García (2018), the sites of Puente Boca del Cerro (R1), Puente Chablé (R2) and Puente Jonuta (R3) presented maximum flow during the rainy season in October, 2017. These were 3278.3, 4901.24 and 3457.28 m$^3$ s$^{-1}$ respectively. While lower values were recorded during the dry season in April, 2018, these were 376.3, 827.34 and 444.87 m$^3$ s$^{-1}$ for each sampling site, respectively.

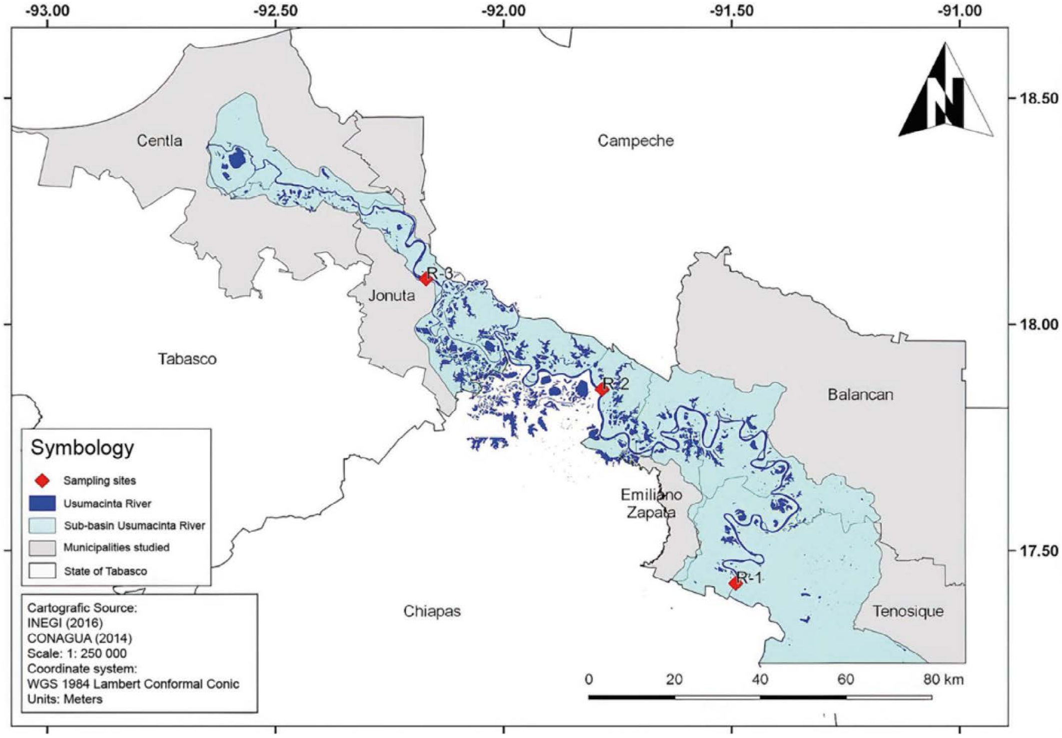


**Figure 1**. Sampling sites in the lower basin of the Usumacinta River in Tabasco, Mexico. R1 (Puente Boca del Cerro) 17.427387° N, 91.490958° W; R2 (Puente Chablé) 17.856130° N, 91.784002° W; R3 (Puente Jonuta) 18.100300° N, 92.143470° W.

**Water sampling**

Three sampling sites were selected, which are located in: Tenosique de Pino Suárez (R1, Puente Boca del Cerro), Emiliano Zapata (R2, Puente Chablé), and Jonuta (R3, Puente Jonuta). The samplings were made monthly, based on the procedure NMX-AA-003-1980; from June to December, 2017 and from April to May, 2018. According to the hydrograph of CONAGUA (2017), it was taking into account the rainy season, in the period from June to October, 2017 and the dry season, from November, 2017 to May, 2018. Temperature, EC and pH measurements were made *in situ*, with two HATCH multi-parameter probes (sesIONTM+Portable Meter and sesIONTM+MM150).

The samples were collected between 09:00 and 16:00 h at a depth of 20 cm below the water mirror. The sample volume to determine TDS (Total dissolved solids), TSS (Total suspended solids), N-nitrate $\left(\text{N-NO}_3^-\right)$ and total phosphorus (TP) was 500 mL, which was collected in transparent polyethylene bottles. For the bacteriological analysis, sterile bags of 120 mL were used. All water samples were refrigerated at 4° C. The reading of physicochemical parameters *in situ* was carried out under procedures of test methods established in the standards NMX-AA-007-SCFI-2013 and NMX-AA-008-SCFI-2016. The methods for the determination of each of the parameters were: TDS and TSS (NMX-AA-034-SCFI-2015), N-nitrate (NMX-AA-079-SCFI-2001/US EPA-353.2-1993) and total phosphorus (NMX-AA-029-SCFI-2001/US EPA-365.1-1993). The determination of coliforms was performed by the most probable number method per 100 mL (MPN 100 $mL^{-1}$) with the Colisure and Quanti-Tray Chromogenic Substrate Laboratory/Quanty-Tray/2000.

**Statistical analysis**

An analysis of descriptive statistics was made to the results of the concentrations, applying a normality test of Shapiro-Wilk. To determine significant statistical differences between seasons, the following tests were used: U Mann-Whitney ($p \leq 0.05$) and t-student ($p \leq 0.05$); and the Kruskal-Wallis test ($p \leq 0.05$) to determine differences among sites. The analyzes were performed using the IBM® SPSS® Statistics Version 25 program.

**Maximum permissible limits (MPL)**

To determine water quality, the MPL of the official Mexican standard (NOM-001-SEMARNAT-1996) and the ecological criteria of water quality (CE-CCA-001-1989) were used. This, in the areas of use of agricultural irrigation, urban public use and protection of aquatic life. The parameters that are not included in any of the previous references were compared individually with reference values obtained in other research works.

## RESULTS AND DISCUSSION

In this study, the temperature varied from 25.6 to 30.7 °C in the rainy season, while in the dry season it oscillated between 22.96 and 33.88 °C in R1 and R3, respectively (Table 1).

**Table 1**. Contrast of the Maximum Permissible Limits (MPL) according to NOM-001-SEMARNAT-1996, the Ecological Criteria of Water Quality CE-CCA-001/89, with regards to the concentration of the parameters analyzed for the lower basin of the Usumacinta River, Tabasco, Mexico.

| MPL | T (°C) | pH | EC ($\mu$S $cm^{-1}$) | N-$NO_3^-$ (mg $L^{-1}$) | TP (mg $L^{-1}$) | TDS (mg $L^{-1}$) | TSS (mg $L^{-1}$) | TC (MPN 10 $mL^{-1}$) | FC (MPN 100 $mL^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| NOM-001-SEMARNAT-1996 | 40[1,2,3] | n/s | n/s | 40[1,2] 15[3] | 20[1,2] 5[3] | n/s | 150[1], 75[2], 40[3] | 1000 | n/s |
| CE-CCA-001/89 | n/s | 4,5-9[1] | 1000 | n/s | 0.1[3] | 500[1] | 50[1] | 1000[1] | 1000[1] |
| Rainy season | | | | | | | | | |
| Maximum | 30.7 | 8.93 | 51.40 | 0.638 | **0.461** | 335 | **300** | **14 136** | Presence |
| Minimum | 25.6 | 7.50 | 31.96 | 0.0015 | 0.0334 | 198 | **70** | 571 | - |
| Dry season | | | | | | | | | |
| Maximum | 33.88 | 8.13 | 83.83 | 0.459 | **0.65** | **616** | **73** | **>2419.6** | Presence |
| Minimum | 22.96 | 7.68 | 45.66 | 0.091 | 0.022 | 330 | 0 | 530 | - |

MPL: Maximum permissible limits; T °C: Temperature; pH: Hydrogen potential; EC: Electrical conductivity; N-$NO_3^-$ : Nitrogen nitrate; TP: Total phosphorus; TDS: Total dissolved solids; TSS: Total suspended solids; TC: Total coliforms; FC: Fecal coliforms; n/s: not specified. Bold letters are data above the MPL. [1]For agricultural irrigation; [2]Urban public use; [3]Protection of freshwater aquatic life.

Due to the fact that the state of Tabasco has a humid and a dry period, with abundant rainfall almost all year round, surface water registers significant variations in temperature, being April the driest month in the state of Tabasco, with higher (environmental) temperatures. However, in this study the maximum temperatures recorded were in May with 33.8 °C and followed by April with 31.2 °C.

The pH values during the rainy season varied from 7.50 to 8.93 in R1 and R2, while in the dry season it varied from 7.68 to 8.13 in R2 and R3, respectively. CE-CCA-001/89 considers water suitable for agricultural irrigation to all those that maintain a pH between 4.5 to 9.0 (Table 1). The pH values were found within the range of 6 to 9.1, similar to those reported by Ramos-Herrera *et al.* (2012), in the Usumacinta River.

The EC had a range of 31.96 to 51.40 $\mu$S $cm^{-1}$ during the rainy season at R3. In the dry season, the EC ranged from 45.66 to 83.83 $\mu$S $cm^{-1}$ at R2. According to CE-CCA-001/89, waters suitable for agricultural irrigation are all those that maintain a value below 1000 $\mu$S $cm^{-1}$ (Table 1).

When EC values lower than 250 $\mu$S $cm^{-1}$ are recorded in surface water, this is considered excellent for agricultural use (Guzmán-Quintero *et al.*, 2007), as recorded in this investigation. EC values in this study showed a tendency to increase during the dry months. According to López (2011), the EC is related to salts dissolved in water. This author suggests that the behavior of the EC values in the Usumacinta River are directly related to the concentrations of TDS, and to the temperature increase in surface water (Solís-Garza *et al.*, 2011).

TDS ranged from 198 to 335 mg $L^{-1}$ at sites R2 and R3 during the rainy season and from 330 to 616 mg $L^{-1}$ during the low season at R1. The average values in the rainy season were 265.7 mg $L^{-1}$ and in the low season 469.16 mg $L^{-1}$. CE-CCA-001/89 indicate that water for agricultural use should contain less than 500 mg $L^{-1}$. In April and

May 2018, all the sites exceeded the MPL, with the exception of R3 in the low season, which was 499 mg $L^{-1}$ (Table 1). TDS in this study showed an increasing tendency pattern in the dry season. The elevation of TDS concentration is attributed to the concentration of anions and cations, minerals or contaminants present in the water, since the scarce availability of water hinders the dilution of the solids, which produces turbidity in the water (López, 2011). TSS oscillated between 70 and 300 mg $L^{-1}$ in the rainy period at R3 and R2; while in low tide, values from 0 to 73 mg $L^{-1}$ were recorded at R1 and R2. According to the standard NOM-001-SEMARNAT-1996, the TSS content must be less than 150 mg $L^{-1}$ for agricultural use, less than 75 mg $L^{-1}$ for urban public use and less than 40 mg $L^{-1}$ to preserve aquatic life. The ecological criteria of water quality (CE-CCA-001/89) indicate that for agricultural use the concentration of TSS must be less than 50 mg $L^{-1}$. The value of the average concentrations recorded for the rainy and low season were 114.27 and 32.16 mg $L^{-1}$, which indicates that in the rainy season the MPL of the three water use classifications are exceeded. This was also observed in the dry season at the three sites during November and in December at R1. The average values in the rainy season were 114.27 mg $L^{-1}$ and in the dry season 32.16 mg $L^{-1}$ (Table 1). Maximum values of TSS in this study, 300 mg $L^{-1}$, were lower than those reported by Ramos-Herrera *et al.* (2012), in the Usumacinta River, in the municipalities of Emiliano Zapata and Jonuta. However, the minimum concentrations, 4 and 1 mg $L^{-1}$, recorded were much lower than those in this study, 13 and 14 mg $L^{-1}$.

The N-nitrate values recorded in the rainy season ranged from 0.0015 to 0.638 mg $L^{-1}$ at R2; while, in the dry season the values were from 0.091 to 0.459 mg $L^{-1}$ at R3 and R1. According to the norm, surface water with nitrate concentrations lower than 40 mg $L^{-1}$ can be used as irrigation water and for the urban public sector, while waters with concentrations lower than 15 mg $L^{-1}$ are safe for aquatic life, since they do not represent a risk for the species (Table 1). In this study, the registered N-nitrate concentrations were not higher than 0.638 mg $L^{-1}$ during the rainy season, but with a tendency to rise during this season. The highest concentrations were registered at site R2 and R3 during the rainy season, which can be attributed to anthropogenic nitrogen entry from the town of Chablé. This, through waste run-off from clandestine garbage dumps, domestic, as well as effluents from backyard animal farms and application of fertilizers in rainfed crops, located on the banks of the Usumacinta River (Romero *et al.*, 2011). The study area produces mainly cattle, swine and poultry. The crops with the largest area planted and cultivated are corn, sugarcane, oil palm, pumpkin, sorghum, and beans, among others (INEGI 2015). Applying as fertilizer, Urea (46% nitrogen), Triple 20-30-10 (NPK), Triple 17 (NPK) and DAP 18-46-00 (NP), plus irrigation with well water, river and rain (key informants).

The total phosphorus concentration during the rainy season was 0.0334 to 0.4661 mg $L^{-1}$ at R3 and R1, while during the dry season it ranged from 0.022 to 0.65 mg $L^{-1}$ at R3 and R1. In this study, phosphorus concentrations are within the permissible limit according to NOM-001-SEMARNAT-1996. On the other hand, CE-CCA-001/89 indicate that in order to avoid the development of undesirable biological species and to control accelerated eutrophication, total phosphorus values in surface water should not exceed 0.1 mg $L^{-1}$. However, mean values of 0.105 mg $L^{-1}$ were obtained during the rainy season. Thus, in accordance with CE-CCA-001/89, site R1 exceeded the permissible limits in both seasons (Table 1). The tendency of increase of the registered concentrations of total phosphorus during the rainy season in some places was similar to the study by Musálem-Castillejos *et al.* (2018). The concentrations reported for this study ranged from 0.033 to 0.46 mg $L^{-1}$ during the rainy season, and 0.022 to 0.65 mg $L^{-1}$ in the dry season. The above can be attributed to the hauling of material, dumping and dragging of fertilizers applied to rainfed crops (Romero *et al.*, 2011). In this study the highest concentrations of total phosphorus were observed in the sites with constant presence of human activities. The highest levels of phosphorus, 0.119 and 0.65 mg $L^{-1}$, were recorded at R1. Considering that the population of Boca del Cerro has inhabitants established on the banks of the river, which would explain why the waste produced by these, plus the runoff, is discharged directly to the Usumacinta. In this study, concentrations of total phosphorus and N-nitrate did not exceed the maximum permissible limits of the norm for agricultural irrigation, urban public use and protection of aquatic life. However, due to the tendency of increasing concentrations of both during the rainy season, there is a condition that leads water systems towards eutrophication during rainy periods, which represents a limitation for their use and a risk for the aquatic life (Romero *et al.*, 2011).

The presence of total coliforms during the rainy season was 571 to 14 136 MPN 100 $mL^{-1}$ at R3 and R1 and at low water levels it ranged from 530 to greater than 24 196 MPN 100 $mL^{-1}$ at R1 and R2. In R3 in September 2017, 8704 MPN 100 $mL^{-1}$ was registered, these concentrations would be close to the MPL (Table 1). The values of the average concentrations were 4076.7 and 4551.2 MPN 100 $mL^{-1}$ in the rainy and dry season respectively. It should be mentioned that the presence of *E. coli* was detected in all the sites and seasons of this study (Table 1). Physicochemical properties of water are related to the presence of coliform bacteria, where their presence and levels are closely related to temperature, pH, suspended solids (Hong *et al.*, 2010), total solids (Qi *et al.*, 2008) and organic and inorganic nutrients in the water; with greater magnitudes in the presence of precipitation, especially in reservoirs close to urban or industrial areas (Hong *et al.*, 2010). For Mateo-Sagasta *et al.* (2017), fecal coliforms are related to intensive grazing and the presence of cattle feedlot pens.

The results of the microbiological analyzes show fecal contamination of the water and presence of total coliforms with a tendency to increase during the rainy season (571 to 14 136 MPN 100 $mL^{-1}$). This behavior is similar to that recorded by Musálem-Castillejos *et al.* (2018). Thus, variations in coliforms at all sites during the study period may be related to the contribution of organic matter and solids through runoff and soil washing, and points of discharge of: wastewater, animal breeding, agricultural and domestic, that do not present any type of treatment (Romero *et al.*, 2011).

There were not found significant differences in the parameters of temperature, pH, total coliforms and N-nitrate ($p>0.05$). In the observed parameters there were significant differences between seasons for EC, TDS, TSS and total phosphorus ($p<0.05$) with an CI (Confidence Interval) of 95% (Figure 2).

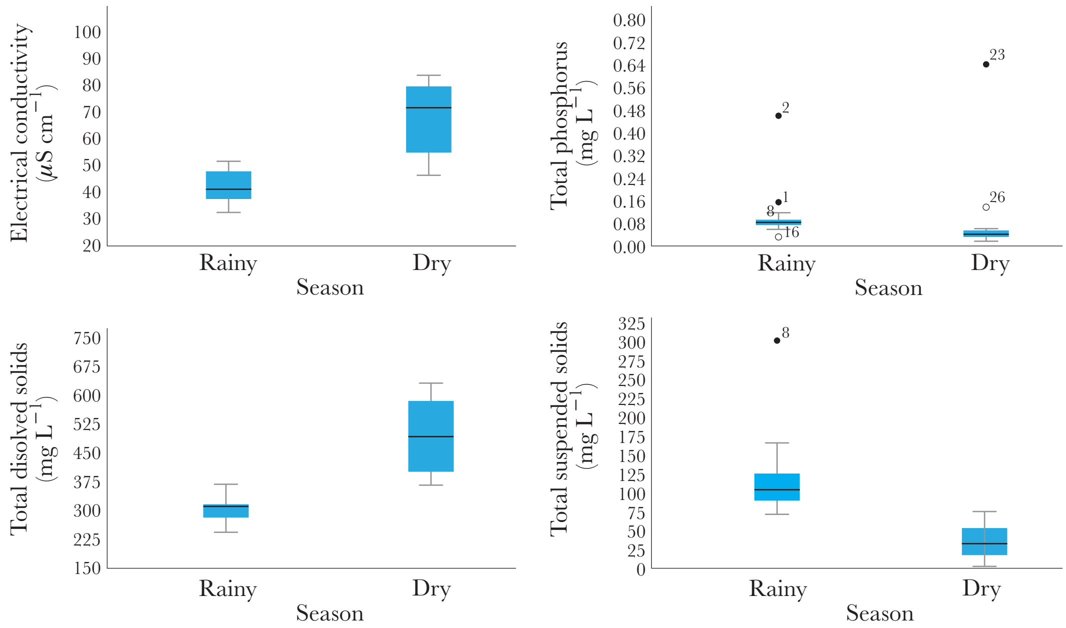


**Figure 2**. Statistical analysis (95% CI) between parameters and seasons, Electrical Conductivity, Total Phosphorus Total Dissolved Solids and Total Suspended Solids for the lower basin of the Usumacinta River, Tabasco, Mexico.

## CONCLUSIONS

Anthropogenic activities and characteristics such as type and use of soil in areas near the sampling sites did not significantly influence temperature, pH, EC, TDS, TSS, total phosphorus and N-nitrates during the study period. However, the presence of frequent and high intensity rainfall during the rainy season, together with the planting and fertilization activities in rainfed crops, shows a tendency for an increase in the concentrations of TSS and total phosphorus. The decrease in river flow during the dry season causes an increase in surface water temperature and low availability of water for the dilution of solids, which marks an increase in the concentrations of TDS and electrical conductivity. It was determined that during the study period, the maximum values of TDS, TSS, total phosphorus and total coliforms exceed the permissible limits of NOM-001-SEMARNAT-1996 and the Ecological Criteria of Water Quality. Likewise, the presence of *Escherichia coli* was recorded in all the sites and during all the sampling months. This represents a contamination risk for the users of river water in these localities. In this study, diffuse contamination may be one of the factors that increase the concentrations of phosphorus and dissolved solids, particularly at the R1 Boca del Cerro and R2 Puente Chablé sites.

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