1

Water Quality at the Cárdenas-Comalcalco Basin, México

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1. Introduction

Water is a resource with an economic, social and environmental value. For this reason when decisions concerning water management, analysis and planning are made, the relationships between the economy, society and the environment should be considered. The study of water resources has great importance when it is developed in a basin's geographical frame.
A basin is defined as an area in which rainfall flows through a number of different water channels which in the end converge into one major water body. The water flows towards a common point, which forms a hydrographic unit made up of a group of river bed systems, summits and the outlets, whose limits are marked by "watershed lines" (Dourojeanni and Jouraviev, 2001; Nebel and Wrigth, 1999; ECLAC, 1997).
Cárdenas-Comalcalco basin is located in the hydrological region of Tonalá river, and del Carmen-Machona lagoons. It is bordered by the protected wetland areas to the west of the State of Tabasco and also by the mangrove forests located along the edges of the afore mentioned lagoons.
The objectives of this study were to characterize the water bodies and to determine the chemical and biochemical properties of the water from rivers, lakes and artesian wells of the Cardenas-Comalcalco basin. The results are relevant to water ecosystems management policies and planning since it is a prime resource for both the humans and the wild life which inhabits the area.

2. Materials and methods

2.1 Localization of study area

The study was carried out in the Cárdenas-Comalcalco basin which belongs to the hydrological region of the Tonalá river, and del Carmen-Machona lagoons, located in western Tabasco. It occupies an area of 274 255 ha, situated between the coordinates 17°52´ and 18°39´ latitude north and 93°13´ and 94°00´ longitude west. It covers, totally or partially, four municipalities of state of Tabasco: Huimanguillo, Cárdenas, Comalcalco and Paraíso. The basin has an important hydrological system formed by a number of water bodies such

as the lagoons El Carmen, La Machona, Redonda, El Cocal, El Paso del Ostión and El Arrastradero. The rivers San Felipe, Naranjeño and Santa Ana are also part of this system.

2.2 Selection of supervision sites

The hydrological characterization of the basin was carried through the analysis of satellite images and observations in the field, both in land and water ecosystems. The study area was divided into nine subareas, which were assigned a number ordered from west to east and north to south. For the water quality analysis, 57 supervision sites were set. The selection was made according to their representativeness, and previous studies carried out in the area. The sites were distributed as follows: four at Naranjeño river, four at Santa Ana river and four at San Felipe river. Four sites were also established in the lagoons, El Carmen, four at Machona, four at Redonda and four at El Arrastradero. Three sites were established in the lagoon El Cocal, three at El Paso del Ostión and three at Las Palmas. Twenty artesian wells were selected. These were located in places with high urban influence (Figure 1).

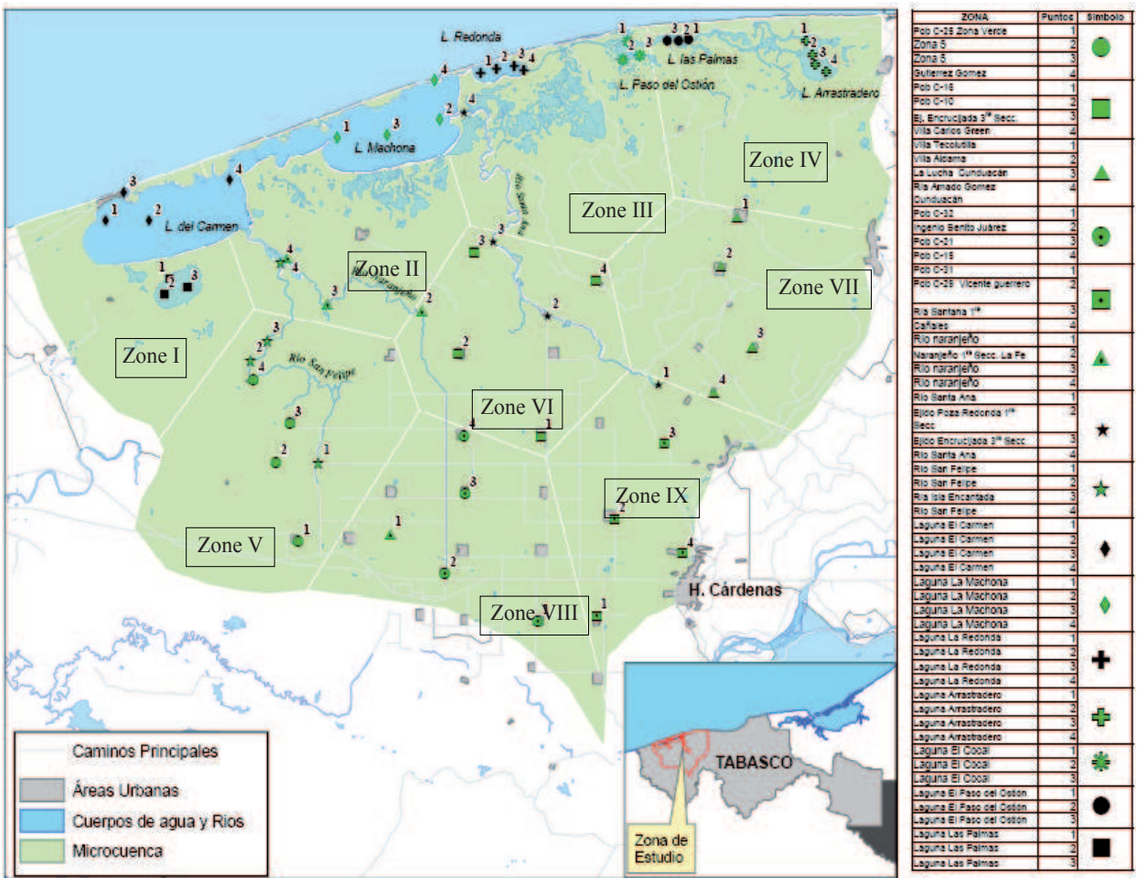

Fig. 1. Localization of samplings places in different water bodies of The Cárdenas-Comalcalco basin.

In order to understand the seasonal variations of water quality, samples were taken during the three distinct season of the year: the dry season, during the 'nortes' (windy) season and rainy season, taking two samples of water in each supervisory place, a superficial one and the other at a depth of 1 meter, with a pvc Alpha Horizontal Van Dhorn bottle, of 4.2 liters

KIT (1140-H42) for water bodies samples, and an acrylic Horizontal Alpha bottle 2.2 liters KIT (W1120-G42) for samples in artesian wells (Arce 2007). Water samples were placed in plastic recipients of 2 liters and 90 milliliters, respectively, which were transported to the laboratory in a cooler with ice to maintain a temperature of 4°C, to be analyzed.

The parameters that were analyzed to determine water quality were: **biochemical parameters**: oxygen biochemistry demand (DBO), dissolved oxygen (OD) and total solids; **chemical parameters**: ammonium, nitrates, total chlorine, phosphates, heavy metals: zinc (Zn), vanadium (V), cadmium (Cd), lead (Pb) and nickel (Ni); potential hydrogen (pH), electric conductivity (CE), dissolved salts: potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na); **biological parameters**: fecal coliforms and the total number of coliforms.

Observations of physical characteristics of the water, such as: depth, turbidity, temperature, color, scent and surrounding vegetation were also carried out. Chemical analyses were carried out with methodology used in the Soil, Waters and Plants Analysis Laboratory, of Colegio de Postgraduados, Campus Tabasco, according to Mexican Official Standards.

3. Results, analysis and discussion

In order to save space and for ease of handling, the information in the following tables shows only the average and median values obtained in analyses.

3.1 Wells

A variation was observed in water quality over the various sampling seasons in several of study sites (Table 1). In most of the sampled wells nitrates levels were above 10 mg/L as defined by the Mexican Official Standard (NOM-127-SSA1-1994) as limit for human consumption and general usage of water. The highest levels were detected in the norte season. Zone 8, that covers the towns C-32, C-21, C-15 and Ingenio Benito Juárez, turned out to be the most polluted in the rainy and norte seasons; while in dry season, in the well of the town Gutiérrez Gómez (Z-5) there were recorded 206.8 mg/L of nitrates. This represents the maximum value obtained in the wells.

Nitrates are the main pollutant of underground water in rural areas, especially in those areas dedicated to intensive cattle raising. High levels of nitrates in the water (greater than 10 mg/L) have been known to cause methemoglobinemia known as blue baby illness. Although nitrates levels that affect small children usually do not affect older children and adults, they are indicative of bacterial contamination and pesticides presence.

Nitrates in drinking water, at levels which range from 100 to 200 mg/L affects the population's health in general, because once consumed, they can be transformed into salpenter that, under proper circumstances, it can combine with amines to form nitrosamines, compounds which are carcinogenic.

There is no a simple way to eliminate nitrates from water since it can not be evaporated with boiling; in fact, boiling water more than 10 minutes can increase their concentration and, if the water is boiled in aluminum recipients, the nitrate can become saltpeter (National Research Council, 1995).

Nitrate levels found indicates a higher risk of contracting cancer by means of water consumption from artesian wells in the mentioned locations, and risk of contracting methemoglobinemia for children of practically the whole basin.

Season	Dry				Rain				Norte			
	Nitrate	Amm.	Phosph	Chlor.	Nitrate	Amm.	Phosph	Chlor.	Nitrate	Amm.	Phosph	Chlor.
Limits	10	0.50	0.0059	15	10	0.50	0.0059	15	10	0.50	0.0059	15
	mg/L											
Zone 5												
Average	53.35	0	0.45	0.125	29.7	0.225	0.65	0.0625	12.1	0.285	0.59	0.1375
Median	8.8	0	0.4	0	15.4	0.24	0.68	0.1	13.2	0.12	0.56	0.15
Zone 6												
Average	11	0.225	0.91	0.1875	17.6	0.255	1.02	0.0375	28.05	0.33	0.71	0.125
Median	11	0.18	0.72	0.1	8.8	0.24	0.88	0	30.8	0.24	0.76	0.1
Zone 7												
Average	19.25	0.105	1.88	0.1625	13.75	0.255	0.72	0	22	0.15	1.08	0.1125
Median	8.8	0.12	2.44	0.2	8.8	0.24	0.52	0	22	0.12	0.68	0.1
Zone 8												
Average	24.2	0.405	1.17	0.6375	36.3	0.195	0.74	0.025	110.5	0.21	1.8	0.1125
Median	17.6	0.12	1.2	0.2	19.8	0.18	0.44	0	105.6	0.24	1.6	0.1
Zone 9												
Average	17.325	0.525	0.6	0.05	3.875	0.1625	5.625	0.1375	44	0.09	0.36	0.0875
Median	15.4	0.6	0.56	0.05	3.5	0.15	5	0	30.8	0.12	0.32	0

Table 1. Nitrates, Ammonium, Phosphate and Chlorine Average Values in Wells of the five study areas in the Cárdenas-Comalcalco basin, Tabasco.

Most of sampled wells maintained ammonium levels below the 0.5 mg/L indicated in the Mexican Official Standard (NOM-127-SSA1-1994) and European Standards for Human Consumption Water (1998).

Within the Mexican, nor the World Health Organization or The European Union Standards there are no limits in reference to phosphorus levels in water for human consumption because phosphates are necessary micro nutrients for the operation of the human body and under normal concentrations found in water they pose no risk to health. In The Ecological Criteria of Water Quality (DOF, December 13 1989) for the protection of wild life is set at a maximum of 0.0059 mg/L of phosphates for fresh water, values that were surpassed in all sites and in all three sampling seasons (there were detected up to 3.36 mg/L).

However, these values do not pose threat for human health, since the minimum recommendation in the human diet is of 800 mg/day and a normal diet provides between 1000 and 2000 mg/day; it has been noted that a higher consumption can cause renal illnesses and osteoporosis (http://www.lenntech.com/Periodic-chart-elements/P-en.htm; consulted on 29/04/08).

In the case of Cl, concentrations were below 15 mg/L that OMS recommends as good for human consumption. However, in accordance with Mexican Standard for Wildlife Protection, in some stations concentrations greater than the permissible maximum level of Cl were detected (0.2-1.5 mg/L).

Although there were no significant differences related with turbidity between the different towns and season of year, Table 2 is shown, that in general, values were lower in the dry season, while in the rainy and norte seasons several wells surpassed permissible limits of 5 NTU. As outlined in the Mexican Official Standards for Environmental Health (NOM-127-SSA1-1994) and for Water Quality for Normal Use and Human Consumption.

Season	Dry				Rain				Norte			
	Turbid	OD	DBO	TotSol	Turbid	OD	DBO	TotSol	Turbid	OD	DBO	TotSol
Limits	5			1000	5			1000	5			1000
	NTU	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L
Zone 5												
Average	1.45	1.81	2.4	302.56	14.36	1.68	0.93	499	27.31	2.01	0.98	318.63
Median	1.24	2	0	198	3.93	1.51	1.09	462	21.37	2.03	0.765	293
Zone 6												
Average	8.29	2.94	9.02	448.12	12.11	2.37	1.45	574.88	5.66	3.05	0.82	464
Median	1.95	2.38	12	500	6.74	1.21	1.59	627	5.79	3.49	0.51	463.5
Zone 7												
Average	1.44	3.26	7.76	277.05	10.04	3.57	1.24	333.38	21.56	4.083	0.51	233.25
Median	1.21	3.65	8.9	329	6.92	3.43	0.96	346.5	7.5	4.22	0.43	252
Zone 8												
Average	1.08	1.04	7.19	340.17	13.56	2.70	0.95	478.5	8.92	2.62	0.83	408.75
Median	0.60	0.91	4.41	348.5	5.86	2.86	0.96	437	6.78	2.61	0.7	412.5
Zone 9												
Average	5.77	1.29	3.52	493.5	8.84	1.16	0.70	494.38	6.48	2.05	0.75	364.63
Median	3.3	1.24	3.9	490	3.67	0.715	0.735	559	6.12	1.465	0.89	383.5

Table 2. Turbidity, dissolved oxygen, oxygen biochemistry demand and total solids values in artesian wells of the Cárdenas-Comalcalco basin, Tabasco

In the rainy season only four wells were within the guidelines established in the standard at the two sampling depths. While in the norte season, that increased to 5, the number of wells with acceptable turbidity, in general, values increased in this season. Only the well Z5-03 located in Zona Verde was within the quality standard in all three seasons.

In the dry season, the median was of 1.55 NTU which is very below the limit of permissible turbidity. However in the wells located in the village Carlos Green (Z-6) and Cañales (Z-9) were found to have extremely high values, 27.8 and 14.6 NTU, respectively.

In rainy season, turbidity was greater, with an average value of 11.78 NTU. The median was set in 5.55, both values surpassed the permissible limit; in this season only water of wells Zona Verde 3 (Z-5), Poblado C-16 (Z-6), Villa Tecolutilla (Z-8) and C-29 (Z-9) had the levels of turbidity as required by the established norms.

During the norte season turbidity even increased, detecting values of up to 60.6 and 52 NTU in Gutiérrez Gómez (Z-5) and Poblado C-25 (Z-5), respectively. In this case only wells in Zona Verde 3 (Z-5), Poblado C-10 (Z-6), Poblado C-32 and C-21 Ingenio Benito Juárez (Z-8) and Cañales (Z-9) fulfilled the standards of quality over the two sampling depths.

The Average and median values for turbidity, considering all the wells and depths, was 13.99 and 6.44 NTU, respectively, both above the rates found in the established norms. The high turbidity values found are of great concern, since consumption of very muddy waters constitutes a risk factor for human health, since the mud can protect to pathogen organisms of disinfectants effects, besides stimulate bacterial growth and increase chlorine demand. Due to the absorption capacity of some particles, they can have present harmful organic compounds which should not be present in water designated for human consumption (Safe Drinking Water, 1980).

There were not found reference values for OD in the consulted standards and references, because concentrations up to saturation point in water have no effect on human health.

However, in Poblado C-10 (Z-6) and Villa Aldama (Z-7) in the dry and rainy seasons there were detected high oxygen values, which suggests that there exists primary productivity in the wells and, consequently, considerable N and P quantities. Although presence of green algae in water does not necessarily affect human health, primary productivity is generally accompanied by an increment in bacterial populations, which can create a series of infections for consumer.

In general pH was between 6.5 and 8, within limit allowed by Mexican Official Standard NOM-127-SSA1-1994, for Water for Human Consumption (Table 3), although in some places the value surpassed 8 in some of the three seasons studied. In one case a location had high pH values in the three samplings.

Season	Dry					Rain					Norte				
	pH	CE	T°	C-T	C-F	pH	CE	T°	C-T	C-F	pH	CE	T°	C-T	C-F
	6.5-8			0	0	6.5-8			0	0	6.5-8			0	0
Zone 5															
Average	7.39	0.77	26.15	274.6	266.1	7.84	0.91	27	180.8	173.5	7.66	0.58	27.68	179.5	176.6
Median	7.47	0.38	26.15	297.5	287	7.83	0.84	27	161.5	153.5	7.71	0.53	27.7	142.5	142
Zone 6															
Average	7.76	0.79	25.11	209.4	201.8	7.69	1.11	27.4	158	150.8	7.87	0.85	27.9	183.6	178.9
Median	7.84	0.89	25	219.5	210.5	7.73	1.23	27.5	74	72	7.98	0.84	27.8	182	176
Zone 7															
Average	7.60	0.54	25.38	187.5	174	7.68	0.61	28	201.9	195.6	7.74	0.43	28.16	126.6	124.5
Median	7.66	0.60	25.45	187	162	7.84	0.63	27.8	166	162.5	7.77	0.46	28.25	120	117
Zone 8															
Average	7.72	0.72	26.09	143.5	135.5	6.96	1.71	27.5	165.8	160	7.68	0.74	28.68	130.4	129.9
Median	7.83	0.73	25.95	116	108	7.80	0.81	27.5	97	94	7.61	0.75	29.1	128	128
Zone 9															
Average	7.61	0.90	26.04	131.6	125.1	7.51	0.9	27.4	291.3	282.4	7.60	0.66	28.52	99.75	97.8
Median	7.73	0.89	26.25	134.5	131	7.56	1.02	27.4	253.5	248.5	7.61	0.70	28.39	89.5	85
Units. CE: dS m^{-1}; T°: °C; C-T y C-F: NMP/100 mL															

Table 3. pH, electric conductivity (CE), temperature (T°), total (C-T) and fecal (C-F) coliforms values in artesian wells of the Cárdenas-Comalcalco basin, Tabasco.

The values for total and fecal coliforms in the wells sampled were very high in regards to the limits set by Mexican Official Standard (NOM-127-SSA1-1994) and Water Quality Standards of World Health Organization. They outline safe limits between 0 and up to 2 NMP/100 ml of fecal and total coliforms, in water for human consumption. There were found concentrations of up to 505 NMP/100 ml, and values above of 200 NMP/100 ml were the most common. Only in well of Poblado C-31 (Z-9) were detected values smaller than 100 NMP/100 ml in the three samplings.

Although high coliforms concentrations were maintained over the three sampling seasons, a considerable decrease was detected in the norte season, when most of sites had concentrations bellow 200 NMP/100 ml. This decrease is attributed to the increasing phreatic level during that time. The bacteria are diluted in greater quantity of water.

Implications of these results for health of basin's population are considerable. Most of coliforms bacteria cause no illnesses; however, its presence in water is important for public health because they can indicate presence of such pathogenic microorganisms as bacteria, virus and protozoa. Illnesses associated to water polluted with these organisms involve symptoms similar to flu, vomiting, diarrhea and fever (Pontius, 2002).

Salts concentrations (Na 8.7 meq L^{-1}), (Mg 8.33 meq L^{-1}) and (Ca 5 meq L^{-1}) in all wells studied were below established limits; no reference, in the existent legal framework, has been found relating to the maximum K levels in water for human consumption; the other parameters studied were inside the limits allowed (Table 4).

Season	Dry				Rain				Norte			
	K	Ca	Mg	Na	K	Ca	Mg	Na	K	Ca	Mg	Na
Limits		5	12.15	460		5	12.15	460		5	12.15	460
	Meq L^{-1}											
Zone 5												
Average	0.20	3.16	2.95	5.45	29.7	0.23	0.65	0.06	12.1	0.29	0.59	0.14
Median	0.18	3.02	1.86	5.49	15.4	0.24	0.68	0.1	13.2	0.12	0.56	0.15
Zone 6												
Average	0.10	3.47	3.60	5.45	17.6	0.26	1.02	0.04	28.05	0.33	0.71	0.13
Median	0.07	3.36	2.06	5.31	8.8	0.24	0.88	0	30.8	0.24	0.76	0.1
Zone 7												
Average	0.11	2.65	1.27	2.53	13.75	0.26	0.72	0	22	0.15	1.08	0.11
Median	0.1	2.69	1.24	1.55	8.8	0.24	0.52	0	22	0.12	0.68	0.1
Zone 8												
Average	0.20	3.91	1.88	3.46	36.3	0.20	0.74	0.03	110.5	0.21	1.8	0.11
Median	0.20	4.00	1.77	3	19.8	0.18	0.44	0	105.6	0.24	1.6	0.1
Zone 9												
Average	0.035	4.17	3.37	3.57	3.88	0.16	5.63	0.14	44	0.09	0.36	0.09
Median	0.04	4.07	3.50	3.02	3.5	0.15	5	0	30.8	0.12	0.32	0

Table 4. Dissolved salts values: potassium, calcium, magnesium and sodium in wells of the five study areas in the Cárdenas-Comalcalco basin, Tabasco

3.2 Rivers

The obtained results do not show a specific pattern which indicates that any of the rivers have suitable water quality conditions, there were no significant differences in any of the parameters studied neither between rivers and sampling seasons.

Taking as a reference Ecological Criteria of Water Quality (DOF, December 13, 1989) that establish 0.04 mg/L of nitrates, as the maximum permissible for the protection of marine aquatic life, it can be observed that in general, all sampling points were polluted in all three seasons of year. Except for stations 3 and 4 of The Naranjeño river, station 4 of The Santa Ana river and station 4 of The San Felipe river which were below the standards only during the dry season.

In fact, water generally was less polluted by nitrates in dry season (average was in 5.3 and median in 4.4) than in the rainy and norte seasons, when nitrates concentration increased almost twice (Table 5). Evidently, the increase in nitrates concentration coincides with precipitation increase. Also, the study basin is characterized to contain a vast surface of sugar cane cultivation, in which fertilizers and other chemical products are intensively used, some of which are dragged into the rivers by the effects of the rains, causing a marked increase in their concentration in seasons of more pluvial precipitation.

Season	Dry				Rain				Norte			
	Nitrate	Amm.	Phosph	Chlor.	Nitrate	Amm.	Phosph	Chlor.	Nitrate	Amm.	Phosph	Chlor.
Limits	0.04	0,02	0.1	0.011	0.04	0,02	0.1	0.011	0.04	0,02	0.1	0.011
	mg/L											
Naranjeño river												
Average	7.15	0.2	0.96	0	7.15	0.24	0.69	0.025	6.05	0.12	0.92	0.1
Median	4.4	0.2	0.28	0	8.8	0.24	0.72	0	6.6	0.12	0.92	0.1
Santa Ana river												
Average	4.95	0.1625	0.69	0.175	7.7	0.345	1.07	0.375	8.25	0.105	1.24	0.1125
Median	4.4	0.15	0.28	0.05	8.8	0.36	0.96	0	8.8	0.06	1.28	0.1
San Felipe river												
Average	3.85	0.075	1.31	0.1375	7.15	0.72	1.63	0.1	7.625	0.105	1.02	0.0875
Median	4.4	0	0.6	0	8.8	0.48	1.8	0.1	8.5	0.12	0.84	0.1

Table 5. Nitrates, ammonium, phosphates and chlorine values in three rivers studied in The Cárdenas-Comalcalco basin, Tabasco.

Similar behavior was detected in ammonium concentration, although in Mexico there is no official standard that makes reference to tolerance limits. The Ecological Criteria of Water Quality (DOF December 13 1989) only considers ammoniacal nitrogen within the listed pollutants, establishing 0.06 mg/L ammonium as maximum permissible for protection of aquatic life (in fresh water). Although some authors (López et. al, no date) have used 0.50 mg/L as maximum reference value, according to standard (NOM-127-SSA1-1994) in this work it was not used because it refers to water for human consumption.

Aquatic animals are more sensitive to ammonium than mammals. If we apply the previously referred limit of 0.50 mg/L, almost all obtained values would be below it, which would disguise the results obtained in relation to effect on aquatic organisms. Therefore, it was decided to take as reference the tolerance limit for fish, of 0.02 mg L^{-1} of NH_3.

Excepting station 1 of The Naranjeño river, and stations 1, 2 and 3 of The San Felipe river which quantities were non-detectable in dry season, the same as for station 3 of The Naranjeño river and station 3 of The Santa Ana river in that of the norte season, in general, in all seasons, very high levels of ammonium were observed. These levels are very superior to the maximum tolerance for fish (Table 5).

Ammonium averages and median were around 0.1 in the dry and norte seasons, while in rainy season they increased dramatically up to an average of 0.435, showing values of up to 2.16 mg/L. Being a toxic compound, its presence at these concentrations will have noxious effects for aquatic life.

The nitrates and ammonium high concentrations effects on aquatic life have not been studied in this basin. However, it is known that their excess causes water acidification, eutrophication and the occurrence of toxic algae, as well as having a toxic action on aquatic animals in the form of gills epithelium damage, which can cause asphyxia, glycolysis stimulation and Krebs cycle suppression that causes acidosis and reduction of blood's oxygen transporting capacity; unpairing oxidative phosphorylation that causes inhibition of ATP production in brain's basilar region; interference of immune system that increases susceptibility to bacterial and parasitic illnesses (Camargo et. al., 2007).

Practically in all sampling sites and in the three seasons of year phosphates were also superior to the limits allowed in Ecological Criteria of Water Quality (CE-CCA-001/89 12.13.89) for Aquatic Life Protection that is of 0.1 mg/L of total phosphates for rivers and streams and 0.002 mg/L for marine water.

Only the station 1 of The Santa Ana river showed slightly lower levels (0.08) in dry season. As in the case of nitrates and ammonium, values were lower in dry season.

Phosphate excess is one of main causes of eutrophication of natural water bodies (Ramírez et. al., 2005), but few studies exist on effects that high phosphate concentrations in water can have on aquatic animals, although is known that it can negatively affect mollusks reproduction and fish eggs appearance (Russo, 1985; Reynolds and Guillaume, 1998).

A progressive increase was detected in residual chlorine levels from the dry season to that of the rainy season. In the first case, only sample station 3 The Santa Ana river had levels above standard in two depths.

In the rainy season there were 5 stations that surpassed allowed limits (3 The Naranjeño river, 1 The Santa Ana river and 1 and The San Felipe river). During the norte season all sampling stations practically surpassed limits allowed by Ecological Criteria of Water Quality (CE-CCA-001/89 12.13.89) for Aquatic Life Protection that, for the case of fresh water it allows concentrations of up to 0.011 mg/L of residual chlorine.

During in the dry season as well as in that of the rainy season most of sites were inside acceptable turbidity limits for the development of aquatic communities (40 NTU) according to water contamination control (UNESCO, 1995), except for stations 1 The Naranjeño river, station 4 The Santa Ana river and station 4 The San Felipe river that, during the dry season surpassed these limits.

However, in the norte season, sampling stations of the San Felipe river had highest values, of up to 86 NTU, as well as station 3 of the Naranjeño river, with more than 89 NTU, which surpasses maximum permissible limits. In the rainy season there were the lowest values. Turbidity is caused by the leaching of inorganic fertilizers excessively used in agriculture and by erosion provoked by excesses of human activity in higher lands, such as immoderate pruning of forests and mining.

The turbidity can cause a decrease in water O_2 concentration, with a rising negative effect on fish, and reduction of light penetration in water column, which diminishes rate of photosynthesis activity and, consequently, it reduces the primary productivity of the phytoplankton that is the aquatic animals basic food.

A primary productivity reduction can collapse at superior trophic levels. On the other hand, turbidity could also negatively affect populations of invertebrates and to interfere with behavior, feeding and growth of many fish species and cause damages, due gills abrasion and obstruction; it has also been found that increases the susceptibility of fish to illnesses, since mucous secreted by them in answer to the high concentrations of suspended solids attracts bacteria and mushrooms (Scottish Natural Heritage, 1996).

Regulation for waters contamination prevention and control (DOF, March 29 1973) states that dissolved oxygen (OD) level should never be lower than 5.0 mg/L in waters for recreational use, without primary contact and for the exploitation of fish. This concentration is necessary to guarantee aquatic fauna good development.

In general, there were found levels much below this limit in almost all sampling stations and seasons (Table 6), in the three rivers the highest were detected in the dry season, although the San Felipe river always kept below acceptable levels; in the rainy season the concentration, in general, diminished reaching its lowest level in the norte season. This is contrary to expectation, since as water volume increases, nutrients concentrations trend to diminish which works against algae proliferation. In general, low OD concentrations detected seem to be result of accumulation of nutrients leached from the land by rains, those that promote algae excessive development and system eutrophication. Low OD concentration in water interferes with fish growth and reproduction, increases propensity to illnesses and, in extreme cases, it can cause their death (Shoji, et. al 2005). Studies carried out by Breitburg et al. (1997) demonstrated that low OD concentrations alter trophic nets in natural waters bodies when reducing efficiency of larvae and juvenile fish of escaping from their predators.

Season	Dry				Rain				Norte			
	Turbid	OD	DBO	SolTot	Turbid	OD	DBO	SolTot	Turbid	OD	DBO	SolTot
Limits	40	5.0	60	40	40	5.0	60	40	40	5.0	60	40
	NTU	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L
Naranjeño river												
Average	41.98	5.16	22.79	154.25	14.5	5.24	1.89	2562.9	32.96	2.57	1.13	978.34
Median	17.15	6.245	20.71	59	13.4	5.12	1.86	363	19.30	2.44	1.13	285.5
Santa Ana river												
Average	25.85	6.16	13.41	45.1	11.01	4.94	1.58	7035.3	20.44	2.77	1.44	5780.6
Median	10.42	6.24	12.20	45	9.37	4.81	1.95	3970	15.75	2.81	1.47	1199
San Felipe river												
Average	18.06	2.39	122.05	71.5	15.63	1.40	0.89	3233.9	55.04	1.43	1.44	1144.3
Median	15.45	1.275	55.99	54	12.70	0.38	0.53	1263	62.75	1.585	1.56	906.5

Table 6. Turbidity, dissolved oxygen, Oxygen Biochemistry Demand and Total Solids values in three rivers studied in The Cárdenas-Comalcalco basin, Tabasco.

Base on The Mexican Official Standard (NOM-001-ECOL-1996), water of the sampled sites in all seasons of year is located in permissible maximum limit for biochemical demand of oxygen (DBO), set at 60 mg/L as the daily average.

However, in the dry season values of three stations of the San Felipe river greatly surpasses that level reaching up to 527 mg/L in site 1 at 1 meter deep. This can be due to the fact that the river is located in the margins of some industry or big earth extensions with intensive agricultural activity that discharges a great quantity of organic waste in the system. A factor could also be a decrease in water flowrates limits, its flow being stagnated. When nutrients do not flow the biological activity concentrates. The high levels of ammonium and phosphates are related with a high content of organic matter, these levels usually cause decrease in values of OD and increase in those of DBO, which is what seems to be the case. The above-mentioned can be linked in particular with high indexes of organic decomposition that cause diverse adverse effects on aquatic organisms, particularly on the fish.

Total suspended solids were very high in the three sampling seasons, although in dry season this diminished in 5 of 12 stations, especially in those of the Santa Ana river (Table 6). This is attributed to the fact that in the rainy season, the rivers of flood plains of Tabasco drag a great quantity of material from soil coming from the mountains of Chiapas and that ends in Gulf of Mexico. The concentration of total solids in water were dramatically far from what the Mexican Official Standard specifies (NOM-001-ECOL-1996) on Permissible Maximum Limits for Basic Pollutants in Residual Water Discharges, that establishes a maximum of 40 mg/L as a daily average for rivers, because in this case an average of 4277 was detected in the rainy season and 2634 in that of the norte.

Most of pH values are within allowed range in the standard for discharges of residual waters (NOM-001-ECOL-1996) that goes from 5 to 10. All sampling sites of the Naranjeño river showed superior values at 8.5 in dry season, probably because of discharges of Ingenio Benito Juárez; in the same season station 1 of The San Felipe river showed acid pH, smaller than 6.5 (Table 7).

Season	Dry					Rain					Norte				
	pH	CE	T°	C-T	C-F	pH	CE	T°	C-T	C-F	pH	CE	T°	C-T	C-F
	6.5-8			<200	<200	6.5-8			<200	<200	6.5-8			<200	<200
Río Naranjeño															
Average	8.65	0.28	27.83	2400.1	2400	7.89	4.71	30.10	95.75	93.25	7.25	1.78	29.73	105.9	104.6
Median	8.89	0.24	27.5	2400	2400	7.92	0.66	29.9	91	89	7.28	0.52	29.65	111	109.5
Río Santa Ana															
Average	7.49	2.35	28.26	2400.	2400	7.57	12.79	30.5	324.9	299.8	7.39	14.26	27.36	68.25	68
Median	7.43	0.51	28.4	2400	2400	7.60	7.20	30.6	203.5	190.5	7.43	4.67	28.75	66	62.5
Río San Felipe															
Average	6.64	1.52	25.40	739.84	457.55	7.67	5.87	29.7	223.6	216.6	7.05	2.08	29.15	172	165.9
Median	7.07	0.84	28.85	299.32	132.46	7.59	2.3	29.6	255.5	246.5	7.02	1.65	29.15	184	176
Units. CE: dS m^{-1}; T°: °C; C-T y C-F: NMP/100 mL															

Table 7. pH, electric conductivity, temperature, fecal and total coliforms values in the three rivers studied.

As for coliforms, the maximum limit of 200 NMP/100 ml set in The Ecological Criteria of Water Quality (CE-CCA-001/89, 12.13.89) for Protection of Aquatic Life of fresh water was surpassed in most of stations of three rivers studied in dry season.
The maximum value reached was 2400 NMP/100 ml. In rainy and norte seasons concentration of total and fecal coliforms decreased dramatically, in fact, in The Naranjeño river permissible levels were reached in these two seasons, while in The Santa Ana river this was only obtained in norte season. The San Felipe river was still classed as polluted, during the norte season. Coliforms reduction observed in rain and norte seasons was due to increases of water volume, these organisms are then dispersed and head out to sea.
The coliforms presence in the basin is of supreme importance for environmental and human health, since many aquatic organisms for human consumption, such as fish and crustaceans, are contaminated causing, in turn, gastrointestinal illnesses to consumers. The high concentrations of these organisms in the rivers are indicative of a continuous flow of black waters toward these water bodies, coming from towns and homes located on the shore. To solve this problem it is necessary to fulfill the normative on the handling of residual waters.
The Ca determined in all sites was below 18 meq/L^{-1} and it allows placing water of three rivers as soft water. The concentrations of Mg had big fluctuations between rivers and sampling seasons, being smaller those of The Naranjeño river and those of the rainy season. The behavior for Na levels was similar, the smallest corresponded to The Naranjeño river, but the season of lowest concentration was the dry season.
In the season of rains there were very high concentrations in the rivers Santa Ana and San Felipe (Table 8). The above-mentioned could be due to that there are carried out agricultural activities with more intensity in the margins of these rivers, since leaching of inorganic fertilizers contributes to salinization of natural water bodies (Wong and Rowell, 1994).

Season	Dry				Rain				Norte			
	K	Ca	Mg	Na	K	Ca	Mg	Na	K	Ca	Mg	Na
Limits		18				18				18		
	Meq L^{-1}											
Naranjeño river												
Average	0.08	0.98	2.85	1.65	0.88	4.53	11.17	38.73	0.42	1.95	3.36	6.59
Median	0.08	0.43	0.70	1.51	0.13	3.22	1.92	4.30	0.15	1.82	1.09	1.13
Santa Ana river												
Average	0.44	2.64	5.69	17.05	2.94	7.94	29.41	141.8	3.11	6.41	21.76	81.25
Median	0.09	2.25	1.93	1.46	1.31	5.22	11.48	53.95	0.92	2.85	6.58	20.07
San Felipe river												
Average	0.21	2.71	2.03	4.95	1.02	4.14	12.48	47.88	0.45	1.19	3.04	9.61
Median	0.21	2.24	2.07	4.96	0.44	2.83	5.02	18.25	0.37	1.14	1.97	5.72

Table 8. Dissolved salts values: potassium, calcium, magnesium and sodium in the three rivers studied.

3.3 Lagoons

The Ecological Criteria of Water Quality (DOF, December 13 1989) set 0.04 mg/L of nitrates as the maximum permissible for protection of marine aquatic life, in this sense, all the

lagoons surpassed this value during the rainy and norte seasons. In the dry season all lagoons, except for sampling site 3 of El Cocal lagoon, were below the reference value.
In most of the sampling sites nitrates were found in non-detectable quantities, however, these increased until surpassing reference value in rain season (Table 9), with concentrations between 4.4 and 13.2 mg/L.
This trend continued during the norte season, being detected up to 15.4 mg/L in sampling site 1 of Las Palmas lagoon, although on average concentrations were greater in the rainy season, with 8.2 mg/L than in that of the norte (6.6 mg/L). Although there were extreme values, there were also found sites with very low nitrate concentrations such as sites 2 and 3 of Arrastradero Lagoon.
Increase of nitrates quantities during rainy and norte seasons seems to be result of the influence of a greater water volume, rich in nutritious material coming from human activities that the rivers catch; since in dry season entrance of seawater with its tides allows to take out a great amount of pollutants toward Gulf of Mexico.

Season	Dry				Rain				Norte			
	Nitrato	Amonio	Fosfato	Cloro	Nitrato	Amonio	Fosfato	Cloro	Nitrato	Amonio	Fosfato	Cloro
Límites	0.04	0.02	0.02	0.0075	0.04	0.02	0.02	0.0075	0.04	0.02	0.02	0.0075
	mg/L											
El Carmen lagoon												
Average	-	0.41	0.22	-	9.35	0.17	0.78	-	5.50	0.24	0.30	0.09
Median	-	0.36	0.16	-	8.80	0.12	0.60	-	4.40	0.24	0.32	0.10
Machona lagonn												
Average	0.55	0.23	0.25	0.03	7.70	0.15	0.37	0.01	8.35	0.27	0.29	0.05
Median	-	0.24	0.24	-	8.80	0.12	0.40	-	9.90	0.24	0.32	0.05
Redonda lagoon												
Average	-	0.29	0.32	0.04	7.15	0.32	0.35	0.03	7.15	0.22	0.16	0.11
Median	-	0.24	0.32	-	8.80	0.36	0.32	-	6.60	0.24	0.16	0.10
Arrastradero lagoon												
Average	0.55	0.27	0.29	0.01	7.15	0.29	0.80	0.01	2.20	0.24	0.86	0.08
Median	-	0.24	0.24	-	6.60	0.24	0.48	-	2.20	0.24	0.84	0.10
Cocal Lagoon												
Average	2.20	0.22	0.29	0.05	8.07	0.30	0.40	0.02	7.33	0.27	0.19	0.10
Median	2.20	0.24	0.24	0.05	8.80	0.24	0.36	-	8.80	0.24	0.16	0.10
El Paso del Ostión Lagoon												
Average	-	0.28	0.29	0.07	8.07	0.18	1.17	-	6.60	0.28	0.40	0.12
Median	-	0.24	0.32	0.05	8.80	0.18	0.68	-	6.60	0.30	0.40	0.10
Las Palmas lagoon												
Average	-	0.46	0.17	0.05	10.27	0.34	0.48	-	9.90	0.28	0.32	0.08
Median	-	0.42	0.20	-	8.80	0.36	0.56	-	11.00	0.30	0.32	0.10

Table 9. Values of nitrates, ammonium, phosphates and chlorine in the seven lagoons studied.

In water, ammonium can be shown in two chemical species whose proportion depends on hydrogen potential (pH) and temperature. One of them is ionized ammonium or NH^{4+} and the other is ammonia or not ionized ammonium (NH_3) which is much more toxic and, by its property of being liposoluble, it can cross biological protection barriers and to cause toxicological damage such as generating methemoglobinemia in fish, which impedes blood oxygenation, as well as degrading cellular membranes, and destroying gills with which fish breathe (Mangas, 2000).

Ammonium detected in the systems studied kept an almost constant level in three sampling seasons (Table 9). Although average values slightly varied, median in each one of sampling seasons was of 0.24 mg/L. All detected values thoroughly surpassed maximum value of ammonia nitrogen set in The Ecological Criteria of Water Quality (DOF, December 13 1989) for Protection of Aquatic Life (seawater) of 0.01 mg/L and tolerance limit for fish of 0.02 mg/L of NH3 (EIFAC, 1973).

Practically in all sampling sites and in the three seasons of year phosphates were also above the limits allowed by the Ecological Criteria of Water Quality (CE-CCA-001/89 12.13.89) for Protection Aquatic Life, which in the case of coastal systems allows concentrations of up to 0.02 mg/L.

In all sampling sites of the seven lagoons and in the three considered seasons, phosphates values greatly surpassed the limits, most of the values detected being around 0.24 mg/L in dry season, 0.4 mg/L in that of rainy season and 0.32 in that of norte season.

Results obtained in this study coincide with that found by INE (2000) in lagoon system Carmen-Machona, where it was reported that orthophosphates (PO_4) and nitrates (NO_3) values exceeded maximum limits for protection of seawater life in The Ecological Criteria.

Residual chlorine levels are relatively low in dry and rain seasons, excepting stations 3 of El Cocal lagoon and 2 of Paso de Ostión lagoon that, in the dry season surpassed limits set in the Ecological Criteria of Water Quality (CE-CCA-001/89 12.13.89) for Protection of Seawater Life, it is of up to 0.0075 mg/L. In the norte season only stations 1 of Machona lagoon and 4 of Redonda lagoon had residual chlorine of non-detectable concentrations, between 0.1 and 0.36 mg/L.

Except for some few cases, mainly in dry season, turbidity generally stayed below the 40 NTU that is maximum acceptable for development of aquatic communities, according to water contamination control (UNESCO, 1995) (Table 10). This was expected due continuous exchange of fresh water and salt water with the sea 'allows diluting' organic matter coming from rivers.

In general, in the lagoons studied there were found to be appropriate levels of O_2 in dry and rain seasons, according to The Ecological Criteria of Water Quality (DOF, December 13 1989) for Protection Seawater Life (marine) that set OD levels superior to 5.0 mg/L.

Contrarily, for the norte season it was found a considerable number of sites with concentrations smaller than those allowed for protection of seawater fauna, specifically in Redonda, Cocal and Las Palmas lagoons. The above-mentioned could be due to a considerable haulage of organic matter toward the lagoon through rivers that promoted proliferation of heterotroph organisms, which consume large quantities of oxygen. That contrasts with DBO data, since in all lagoons, in the three sampling seasons the detected levels were very below the 75 mg/L that the Mexican Official Standard (NOM-001-ECOL-1996) sets as permissible maximum limit as daily average.

Season	Dry				Rain				Norte			
	Turbid	OD	DBO	SolTot	Turbid	OD	DBO	SolTot	Turbid	OD	DBO	SolTot
Limits	40	5.0	75	40	40	5.0	75	40	40	5.0	75	40
	NTU	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L
El Carmen lagoon												
Average	8.47	8.21	19.88	12760	10.72	7.16	1.18	19595	10.33	6.56	0.69	19999
Median	8.09	7.92	20.01	14333	8.25	6.83	1.20	19999	9.81	6.63	0.67	19999
Machona lagoon												
Average	7.55	8.12	15.27	13134	12.36	7.36	1.64	19366	9.24	6.75	1.43	19364
Median	7.35	8.10	15.30	16877	12.70	7.46	1.64	19999	8.49	6.97	1.29	19606
Redonda lagoon												
Average	23.63	6.86	18.15	1691.2	17.35	6.13	20.99	19999	15.83	4.77	0.54	16714
Median	23.40	6.76	22.12	1708.5	10.47	6.42	1.75	19999	11.85	4.76	0.50	16766
Arrastradero lagoon												
Average	28.64	6.17	16.17	572.04	14.53	6.51	1.12	4519.2	14.95	6.47	1.19	423.25
Median	26.55	6.56	10.66	715.50	13	6.98	1.09	4652	10.20	6.63	1.14	420
Cocal lagoon												
Average	66.90	7.24	16.62	1642	6.11	1.85	0.40	447.25	6.03	0.81	0.84	16242
Median	60.75	7.23	16.53	1780.5	3.67	1.93	0.26	448	6.12	0.80	0.92	17116
El Paso del Ostión lagoon												
Average	32.87	4.90	11.79	831.21	13.34	5.54	1.33	12743	11.47	5.45	0.93	16242
Median	31.65	4.82	10.78	1008	11.65	5.84	1.39	12485	10.85	5.01	0.83	17116
Las Palmas lagoon												
Average	24.24	6.17	18.59	5951.8	16.50	5.95	1.93	14710	20.45	4.11	2.24	19999
Median	16.60	6.47	16.83	7504	16.50	6.05	1.92	17681	19.40	4.02	2.33	19999

Table 10. Turbidity, dissolved oxygen, biochemistry oxygen demand of and total solids values in the seven lagoons studied

Values of total suspended solids were very above the 125 mg/L (daily average) set as the permissible maximum limit in the same standard (NOM-001-ECOL-1996) for estuaries in the three sampling seasons, especially in those of rain and norte. Increment of total suspended solids in the water coincides with the values obtained in the rivers studied that drag a great quantity of materials from the soil that are carried to coastal lagoons in high precipitation season to be finally deposited in Gulf of Mexico.

Almost all pH values reported are within the allowed range in the standard (NOM-001-ECOL-1996) for residual water discharges in waters and national goods that goes from 5 to 10, and of Canadian Guide of Environmental Water Quality (December, 2003) that allows values between 6.5 and 8.5. The average values of obtained pH were 7.4, 7.5 and 7.3 for the dry, rainy and norte seasons, respectively (Table 11).

The same as for rivers, concentrations of total and fecal coliforms were extraordinarily high in dry season, decreasing up to concentrations bellow the limit in the rainy and norte seasons; the mean values were 931, 195 and 10 NMP/100 ml for dry, rain and norte,

respectively. Values of dry season were greater than minimum of 200 NMP/100 ml that are set by The Ecological Criteria of Water Quality (CE-CCA-001/89 12.13.89) for Protection of Seawater Life (marine water).

Época	Secas					Lluvias					Nortes				
	pH	CE	T°	C-T	C-F	pH	CE	T°	C-T	C-F	pH	CE	T°	C-T	C-F
	6.5-8			<200	<200	6.5-8			<200	<200	6.5-8			<200	<200
Laguna El Carmen															
Average	7.35	31.59	27.78	1086	712.9	7.66	43.36	28.26	126.13	119.75	10.33	6.56	27.7	19999	7369.9
Median	7.39	28.63	27.65	716	590.0	7.66	45.21	28.35	129.00	120.50	9.81	6.63	27.5	19999	7321.5
Laguna Machona															
Average	7.61	41.62	28.06	827	450.3	7.60	46.21	28.83	157.38	149.13	9.24	6.75	27.8	19364	7284.9
Median	7.57	32.74	28.75	345	290.5	7.58	48.82	28.85	144.00	137.00	8.49	6.97	27.9	19999	7302.5
Laguna Redonda															
Average	7.64	3.49	28.38	2237	574.4	7.26	44.36	29.59	115.00	108.13	15.83	4.77	28.2	19442	7236.6
Median	7.66	3.23	28.40	2400	500.0	7.22	44.50	29.45	100.50	97.00	11.85	4.76	28.3	19606	7217.5
Laguna Arrastradero															
Average	7.97	1.23	28.85	1992	792.5	7.73	9.27	30.55	125.88	119.88	11.95	6.56	28.7	16714	7614.5
Median	7.81	1.31	28.80	2400	675.0	7.68	8.52	30.20	93.00	91.00	11.10	6.63	29.1	16826	7713.0
Laguna Cocal															
Average	7.74	2.83	28.68	2400	1098.3	7.24	27.19	29.87	295.17	283.00	10.44	4.09	28.5	15213	7089.0
Median	7.72	2.59	28.50	2400	1075.0	7.24	27.04	29.70	295.50	280.00	11.00	3.94	28.5	15636	7042.5
Laguna El Paso del Ostión															
Average	6.72	1.79	28.83	2325	1220.8	7.37	23.15	30.72	494.33	456.67	11.47	5.45	28.1	16242	7305.3
Median	7.50	1.84	28.75	2400	1040.0	7.31	22.69	30.65	602.50	530.00	10.85	5.01	27.9	17116	7381.5
Laguna Las Palmas															
Average	7.28	14.82	28.47	2250	2070.0	7.40	33.99	28.17	243.67	230.17	10.45	4.11	27.6	19999	6989.3
Median	7.23	14.82	28.55	2400	2400.0	7.39	35.68	28.20	215.00	211.00	9.40	4.02	27.9	19999	6960.5
Unidades de medida. CE: dS m^{-1}; T°: °C; C-T y C-F: NMP/100 mL															

Table 11. pH, electric conductivity, temperature, and total and fecal coliforms values in the seven lagoons studied.

The most polluted lagoons, whose higher values surpassed the standard in dry and rainy seasons were El Paso del Ostión, Las Palmas and Cocal, because they are water bodies which are relatively closed and that only have communication with other lagoons in growing season, between October and November, which means that in dry season they do not receive replacement of sea water, and this is the reason why nutrients and microorganisms remain concentrated.

Presence of high concentrations of total and fecal coliforms in lagoons studied represents a serious problem for regions economic activities, in principle because fishing is an important economic activity in surrounding communities.

This has serious effects on fish and captured crustacean quality and it influences negatively in sale price. The most dramatic case is that of oyster production (*Crassostrea viginica*) that,

being of high commercial value, it is seen that in the region, it reaches only marginal prices due to accumulation of coliforms consequence of their screening food habits.
Oysters generally are edible in fresh or smoked, in which coliforms imply serious risks to human health. On the other hand, the study area has potential for tourism development, due to its natural beauty; however, coliforms contamination excludes it as non-appropriate area for recreational use, according to the Ecological Criteria of Water Quality (DOF, December 13 1989) that set a maximum of 200 NMP/100 ml.
In the current normative there were not maximum values of concentration for K, Ca, Mg and Na; however, the detected values are normal for lagoons and coastal estuaries. They were considered appropriate for aquatic life (Table 12).

Season	Dry				Rain				Norte			
	K	Ca	Mg	Na	K	Ca	Mg	Na	K	Ca	Mg	Na
	Meq L^{-1}											
El Carmen lagoon												
Average	6.04	12.50	71.24	261.74	10.00	18.39	105.18	530.98	9.87	18.87	93.75	275.54
Median	5.49	12.38	67.00	251.10	10.00	18.25	107.35	528.25	10.09	19.16	92.52	250.00
Machona lagoon												
Average	6.41	10.62	58.20	295.16	9.94	18.35	107.93	507.08	9.39	17.41	103.52	229.35
Median	6.08	12.01	62.50	283.50	9.90	18.60	109.35	495.65	10.17	19.81	113.90	258.70
Redonda lagoon												
Average	0.69	1.99	6.78	28.08	8.98	17.26	101.98	440.21	7.51	12.12	68.77	176.41
Median	0.65	1.96	6.15	25.05	9.05	17.20	102.80	450.00	7.56	12.07	69.08	167.39
Arrastradero lagoon												
Average	0.23	1.35	2.23	7.80	1.53	5.46	21.10	71.64	5.57	11.22	108.24	242.55
Median	0.25	1.49	2.20	8.18	1.55	4.89	20.15	68.50	5.55	11.17	57.15	238.48
Cocal lagoon												
Average	0.04	4.17	3.37	3.57	3.88	0.16	5.63	0.14	44.00	0.09	0.36	0.09
Median	0.04	4.07	3.50	3.02	3.50	0.15	5.00	-	30.80	0.12	0.32	-
El Paso del Ostión lagoon												
Average	0.33	1.57	3.30	12.62	3.75	11.33	51.93	188.78	5.26	9.85	60.03	204.64
Median	0.34	1.54	3.25	12.45	3.70	11.00	50.55	187.80	5.33	10.30	60.03	216.74
Las Palmas lagoon												
Average	2.60	5.42	25.48	116.52	7.40	15.45	85.67	383.00	9.38	18.32	101.29	276.09
Median	2.52	5.09	28.35	107.60	9.20	17.55	99.95	473.95	9.58	18.69	101.97	267.39

Table 12. Potassium, calcium, magnesium and sodium values in the seven studied lagoons

Finally, it is important to mention that analyses of heavy metals of all wells, rivers and lagoons, were in non-detectable quantities, therefore they are considered clean of these dangerous compounds for wild life and human health. According to The Ecological Criteria of Water Quality (DOF, December 13 1989) maximum permissible values in coastal lagoons for

Pb, Ni and Zn is 0.006, 0.008, 0.09 mg/L. In the actual norm there were no references to safe Va concentrations in water, however, the standards of European Union for Marine Water establish a maximum value of 100 μgV/L (http://www.ukmarinesac.org.uk/activities/water-quality/wq4_1_2.htm).

4. Conclusions and recommendations

4.1 Conclusions

The greatest source of contamination in The Cárdenas-Comalcalco basin are high concentrations of total and fecal coliforms that exceed to a major degree the maximum permissible for the protection of human health and wild fauna. Up to this moment this is a problem of public and environmental health that seems not to be studied by the involved sectors.

Sources of water chemical contamination in the basin are nitrates and the phosphates. The presence of nitrates in wells for human consumption can represent a continuous risk for population, since impact can occur in long term and to go unseen by the population.

Nitrates, ammonium and phosphate concentrations in natural water bodies were very high. Although scope of this study did not contemplate to measure effects on the biological community in the locations studied, there is solid evidence that levels similar to the ones found in the area have an adverse effect on fauna and water productivity. The negative outcome to environmental and to economic activities is unknown, but, according to similar studies, it could be considerable.

Concentrations of organic and inorganic pollutants tend to increase in the rainy and norte seasons due to run off of urban and agricultural organic residuals due the rain flows. Concentrations of these pollutants were smaller in lagoons that are connected to sea due to water exchange between both systems.

4.2 Recomendations

Implementation of a program to improve underground and superficial water quality of basin is necessary. The establishment of a legal base that allows the application of effective standards of environmental quality is required. It is necessary for greater control on agrochemicals used in agricultural activities and the design and construction of septic graves and drainage systems and appropriate treatment of residual waters in rural areas. In the same way, it is necessary to regulate existent industrial activities and that environmental quality standards are met in new industries.

It is recommended the implementation of well handling training programs at homes, and also educational programs focused to prevention of gastrointestinal illnesses caused by water polluted with coliforms and nitrogenated compounds.

It is necessary the realization of studies that allow to measure with more detail conditions of this basin, in which are carried out finer measurements of heavy metals to determine very small concentrations.

In the same way, it is necessary to carry out works that contemplate a greater number of sampling stations and a greater number of measurements throughout the year. Also, it is important to contemplate smaller water bodies that remain closed most part of the year, since results of this work indicate that in fact it is in these type of water bodies, where there are concentrated the greatest quantities of pollutants. The above-mentioned would allow obtaining enough information to propose reparation programs.

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