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Hydrocarbons and heavy metals in Macuspana, Tabasco, Mexico: key stakeholders

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ABSTRACT

The objective of the research was through key actors to identify the contamination by hydrocarbons and heavy metals in water and the main sources of contamination in the municipality of Macuspana, Tabasco.

Methodology: A diagnosis was made, by applying questionnaires through interviews directed to the inhabitants of the municipality of Macuspana and workers in the oil sector. The data were processed with frequency analysis, Kruskal Wallis, analysis of variance, and multivariate with two factors.

Results: It was shown that there has been historical contamination, for 30 years, there is evidence of dead organisms in the water bodies, and the presence of various diseases in the population due to exposure to contaminants from hydrocarbons and heavy metals that derive from the oil activity. There is evidence of a negative impact due to the presence of spills from disabled wells due to a lack of maintenance programs.

Implications: The economy in most of the Gulf of Mexico is based on the extraction, processing, and distribution of hydrocarbons. This industry´s growth increased the number of exploration and production of oil wells, generating a direct impact on aquatic environments. The state of Tabasco is one of the largest oil producers, as well as fishing resources of commercial and environmental importance, which are directly affected by oil activity.

Findings: The study found cases of diseases in the population correlated with exposure to hydrocarbons.

Conclusions: There is little interest from the oil sector about public health problems in the population and environmental damage to the ecosystems in the municipality of Macuspana, Tabasco.

Keywords: Fishery resources, key players, oil.

INTRODUCTION

In Mexico, a volume of 1.6 to 2.2 million barrels of oil per day was produced from 2016 to 2020 (CNH, 2020). The state of Tabasco, Mexico, has the highest production of liquid hydrocarbons and gas (PEMEX, 2020). Tabasco has the most important land fields for the extraction and exploitation of hydrocarbons (INEGI, 2011), some of the most important is at the community of Macuspana, and the "Activo Integral de Producción de Samaria Luna", which have wells within this municipality in the "Bitzal" river and the "Reserva de la Biosfera de Los Pantanos de Centla".

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The Macuspana watershed is in southeastern Mexico and has an area of continental 7,300 km^2 and approximately 1,800 marine km^2 (Guzman and Aranda, 2002). One of the main ecological problems in modern society is the increasing pollution of natural resources as a result of anthropogenic activities, such as industrial activities, services, domestic activities, urban and agricultural activities, and the oil sector has grown at an accelerated rate due to the energy demand worldwide (González, 2009; Santana *et al*., 2012).

Hydrocarbons can be grouped into aliphatics (with 18 to 35 carbon atoms) and aromatics (with one or more benzene, naphthalene and phenanthrene rings). Polycyclic aromatics are of low molecular weight, formed with two or three aromatic rings, which makes their mobility in water easier (Murphy and Morrison, 2002; Acuña *et al*., 2010).

The hydrocarbons with the greatest effects on male reproductive function are halogenated, aromatic, phthalates, biphenyls, polychlorinated (PBS); toxic agents such as hydrocarbons can act on the hypothalamic-pituitary-testicular axis, directly affecting the male gamete, and causing alterations during fertilization, implantation and embryonic development (Romay and Pousa, 2019).

Worldwide, hydrocarbons that come from lakes, phreatic zones, rivers, and soil by biological and chemical processes are concentrated in the sea and oceans (Shahidul and Tamaka, 2004). It has been estimated that between 0.1 and 0.2% of the world's oil production is discharged into the sea, which represents about three million tons that pollute the sea annually (Reis, 1996).

In Chile, the sources of pollution associated with small boats using outboard motors are the cause of oil pollution on Robinson Crusoe Island (Bonert *et al*., 2006). There are reports of spills in the Gulf of Mexico from the Ixtoc-I well, off the coast of Campeche, where up to 3100 00 barrels of crude oil were dispersed in marine waters during 1978, which was considered the greatest impact worldwide; but hydrocarbon inputs to the ocean may have other sources of contamination. However, atmospheric transport, coal and wood-burning, and automobile combustion, which produce polycyclic aromatic hydrocarbons, may have other effects. Oil exploitation in the Gulf of Mexico in coastal regions, inhabited by large quantities of marine species such as fish, crustaceans and mollusks in the Atlantic coast, has ecologically impacted and altered the aquatic organisms communities, ecosystems and human habitat (Botello, 2005).

The state of Tabasco has been impacted in up to 0.07% of its total area by hydrocarbon contamination in the soil (Ferrera *et al*., 2006). For the population near the sectors of the PEMEX city gas processing complex in Mascupana, Tabasco, the oil industry has generated negative impacts and effects on biodiversity overall; among the identified activities, the generation of gas increases the concentration of greenhouse gases is of great impact. Gas treatment through compressors causes noise pollution, for the people living near the area and disturbs the flora and fauna; storage, transportation, and the dismantling of the site generate water and soil contamination that has impacts on biodiversity, in addition to acts of vandalism during the transportation of hydrocarbons through pipelines and have direct impacts on the health inhabitants (López *et al*., 2019). Because of the above, the contamination by hydrocarbons and heavy metals in the area by the use and consumption of water from different sources in the municipality of Macuspana, Tabasco, Mexico, was identified.

MATERIALS AND METHODS

The municipality of Macuspana, Tabasco, is located at 17° 45' 17'' N, and 92° 33' 32'' W. The municipality is in the Grijalva-Usumacinta hydrological region (RH30), within the Grijalva Villahermosa basin (the most extensive state, represents 41% of the global surface) sub-basin of the Chilapa River. Its climate is warm humid, with abundant summer rains; It has a mean annual temperature of 23.6 °C, the maximum monthly average in April, with 30.1 °C and the minimum mean in May, with 29.8 °C; the absolute minimum and maximum reach 21.2 °C and 30.1 °C (INAFED, 2017).

The Macuspana area was surveyed, to assess the key actors and define the activities and document the opinions of the inhabitants. The tour survey covered the area occupied by the Bitzales rivers and the town of Jonuta, which borders the "Reserva de Los Pantanos de Centla" as well as the municipality of Macuspana. During these visits, the current state of the wells from "Pemex Exploración y Producción" was observed, identifying hydrocarbon stains in the water. Also, during the assessment, the conditions of the tenants and public services such as drainage, easily accessible drinking

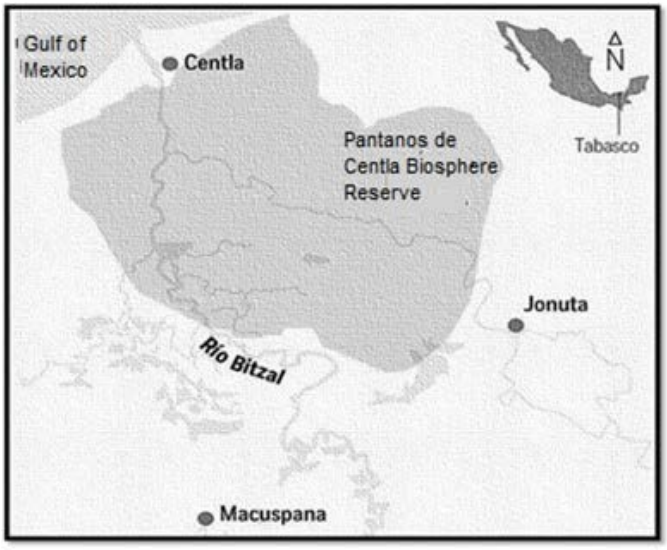

Figure 1. Location of the study area in the state of Tabasco, Mexico.

water and the exposure of people to contamination by hydrocarbons and heavy metals were analyzed. The prospecting assessment allowed to identify the main activity carried out by the inhabitants, such as fishing. It was also determined that most inhabitants have boats with internal combustion engines. This was an important factor to carry out the application of the survey and plan the strategy for its implementation.

Direct interviews

A survey was undertaken via direct face-to-face interviews with the tenants, fishermen and personnel who work at the Macuspana bodies of water; the survey theme was the contamination by hydrocarbons and heavy metals. In the assessment in Macuspana, a total of n=66 questionnaires were applied using key informants for the application of the questionnaires. A non-probabilistic chain sampling method was used to identify contamination, damage to public health, location of the wells, and impact of the presence of hydrocarbons.

The questionnaire was structured with open and closed questions, divided into different sections, such as general data, productive activity, resource management and the development in the tourism sector. To know and determine which are the activities with the greatest impact, public opinion and the knowledge they have about water pollution and management were surveyed.

In the productive activity section, 16 questions were asked, focused on the fishing activity to evaluate its infrastructure, the fishing volume and aspects of contamination of the lagoon. To gather information on fish mortality the presence of hydrocarbons and heavy metals was determined, as well as the opinion of the inhabitants and fishermen regard the oil sector. In the resource management section, 18 questions were asked focused on the type of species caught, capture frequency, location regarding the oil wells in the Macuspana lagoon and the type of maintenance that they observe on the wells.

The analysis information consisted of a qualitative and quantitative analysis using the statistic version 10 software, performing a frequency analysis and a Kruskal Wallis analysis of variance with ($p \leq 0.05$), and multivariate analysis with two factors.

RESULTS AND DISCUSSION

Among the main key actors involved in the hydrocarbon pollution phenomenon were: Pemex (Petróleos Mexicanos), Asea (Agency for security, energy and environment), Semarnat (Secretariat of the environment and natural resources), Conagua (National Water Commission), Government of Tabasco and the inhabitants of the municipality of Macuspana. Thirty-one percent of the surveyed families are made up of four people, 32% have a high school education, 78% of the families are engaged in fishing activities and are organized in fishing cooperatives. Twenty-five percent of fishermen obtain "mojarra" as their main product, followed by 12% of fishermen dedicated to capturing mojarra and shrimp (Figure 2). Regard the knowledge on the contamination by hydrocarbons and heavy metals, it was noted that more than 80% of people know about this issue (Figure 3A). This is because more than 75% of the people report having found dead fish as evidence of contamination in water bodies (Figure 3B).

Among the main cleaning treatments fish products are subjected to before consumption, 34% of the fishermen boiled and washed their product, and another 34% treated the products with lemon and chlorine. The main sources of contamination in Macuspana are contamination from oil activity, as more than 65% of those interviewed mentioned, it is due to the presence of oil wells and the activities related to carrying out the transport of catch fish with motorboats (Figures 4A; 4B).

They interviewed villagers mention that most of them have identified a total number of 38 oil wells located in the area, which generate a negative impact on the environment. The interviewees mention that they have

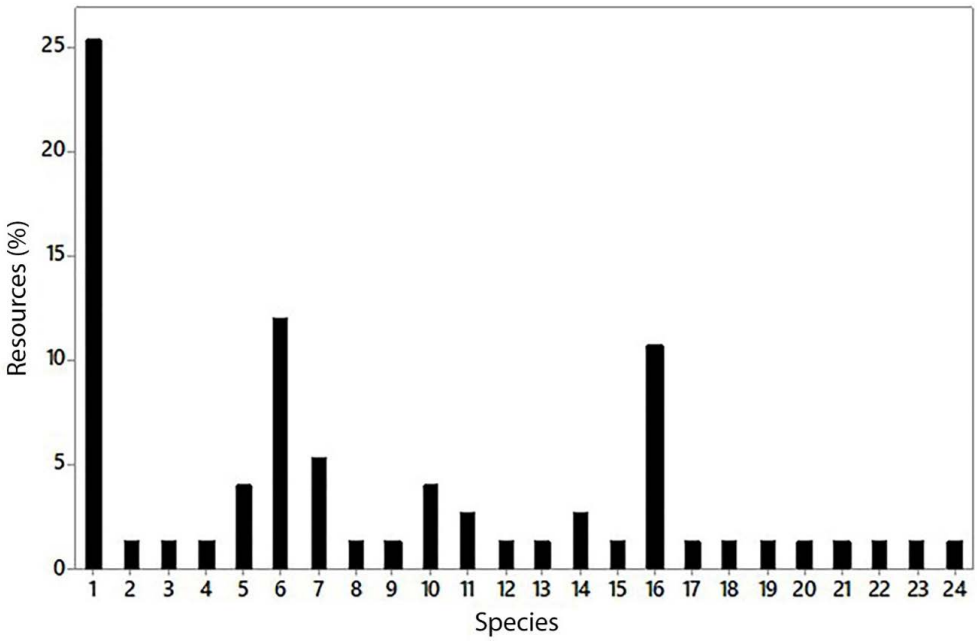

Figure 2. Main fishing resource that is extracted in the Macuspana lagoon, Tabasco. Mojarra (1), Carp-Tilapia (2), Common snook-Pejelagarto-Shrimp (3), Shrimp-Mojarra-Carp (4), Carp (5), Mojarra-Shrimp (6), Mojarra-Pejelagarto (7), Mojarra-Shrimp-Guabina (8), Carp-Mojarra-Shrimp (9), Tilapia (10), Tilapia-Shrimp (11), Common snook-Mojarra (12), Common snook-Mojarra-Pejelagarto (13), Carp-Mojarra (14), Mojarra-Corn (15), Shrimp (16), Mojarra-Common snook-Pejelagarto (17), No response (18), Mojarra-Carp-Hervíbora Carp (19), Common snook-Tilapia (20), Common snook (21) , Carp-Pejelagarto (22), Shrimp -Mojarra- Common snook (23), Mojarra-Pejelagarto-Shrimp (24).

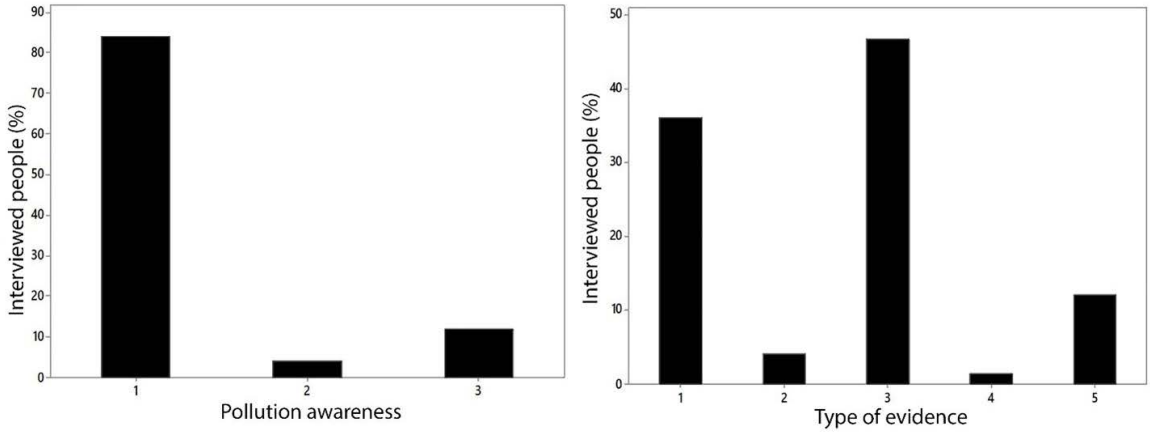

Figure 3. Left A). People's knowledge of the contamination by hydrocarbons and heavy metals. Yes (1), No (2) and They did not answer (3). Right B). Type of evidence of contamination. Death of fish (1), Effects on people (2), Death of fish and effects on people (3), Contamination of fish (4), They did not respond (5).

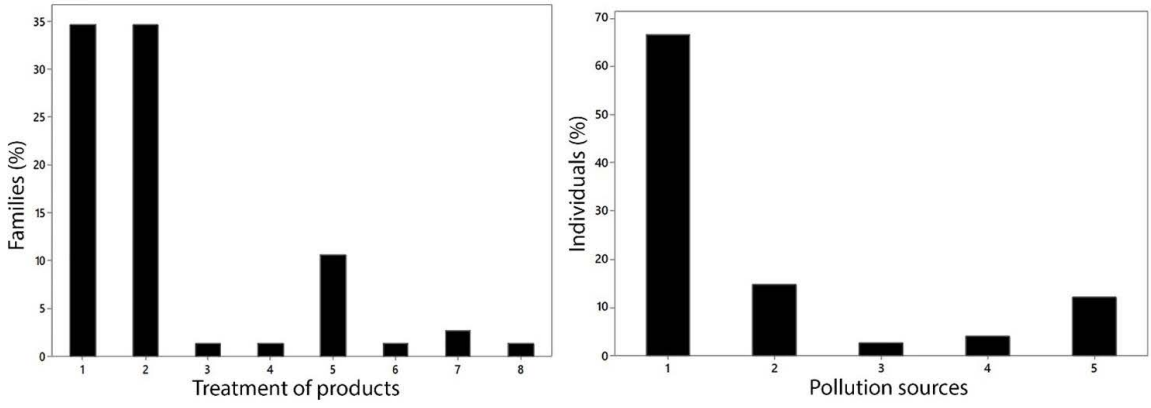

Figure 4. A). Treatment that is given to the products before consuming: Boiled-Wash (1), Wash (2), Lemon and chlorine wash (3), Wash with chlorinated water (4), Boil (5), Boil-Wash with chlorine (6), Washing with chlorinated water (7), No treatment (8). B). Source of contamination by hydrocarbons and heavy metals: Oil wells (1), Oil wells-Boats (2), Effluents (3), Oil wells-Effluents (4), They did not respond (5).

witnessed skin damages and gastrointestinal problems. Although, there is a small group that testifies having cancer problems, due to the presence of hydrocarbons and heavy metals in the water (Figure 5).

When comparing the years that fishermen have been exposed in the contaminated areas by hydrocarbons and heavy metals in Macupasna, significant statistical differences were identified between fishermen from the localities of Ejido San José, Tomo de la Bola and San Miguel; these were different from the localities of Emilio Narvaez, Criollo Narvaez, Bitzal 3 and Bitzal. Fishermen, 35 years on in the fishing activity in areas with the presence of oil wells and fishermen with a minimum of 20 years in the same areas were observed (Figure 6).

When relating all the contaminating variables with the productive activities in the Macuspana area, the multivariate analysis by two factors reports that there is a relation between the fishing destination, the volume of fishing and the affectation caused by the increase of oil in the area.

It was also observed that the interviewees have a relationship with the knowledge of fuel contamination and oil changes in boat engines, meaning that there is

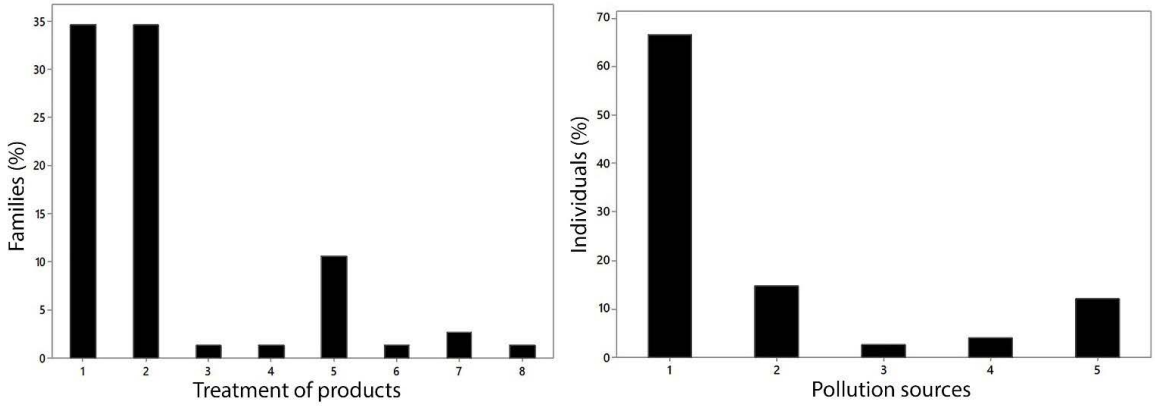

Figure 5. A). Number of oil wells in the Bitzal river area and in the Pantanos de Centla area, Tabasco: 0 (1), 3 (2), 4 (3), 5 (4), 6 (5), 8 (6), 10 (7), 15 (8), 16 (9), 20 (10), 25 (11), 30 (12), 23 (13), 33 (14), 34 (15), 35 (16), 36 (17), 37 (18), 38 (19), 40 (20), 50 (21), 60 (22), 90 (23), 100 (24), 200 (25). B). Types of health problems in the population of the towns of the municipality of Macuspana: Skin sores (1), Skin (2), Urticarias-Skin sores (3), Diarrhea (4), Diarrhea-Stomach (5), Skin -Stomach (6), Stomach (7), Itchy skin (8), Did not respond (9), Urticaria-Diarrhea (10), Gallbladder-Liver (11), Stomach-Vomiting (12), Skin sores- Diarrhea (13), Skin-Gastrointestinal (14), Urticaria-Vomiting (15), Liver Cancer (16), Kidney Cancer (17), Liver Cancer and Renal Insufficiency (18), Cancer (19), Urticaria (20) , Diarrhea-Vomiting (21), Skin spots (22), Skin allergies (23), Unanswered (24).

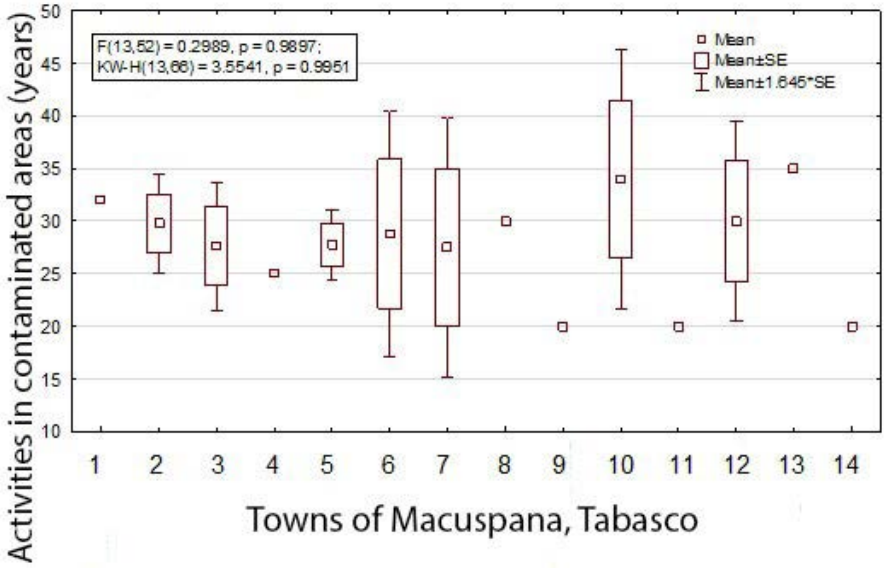

Figure 6. Years of fishing within areas contaminated with oil wells. Criollo Narváez (1), Ejido San José (2), Tomo de la bola (3), San Miguel (4), San José (5), Ejido el venadito (6), Bitzal 2 (7), Bitzal 4 (8), Emiliano Narvaez (9), Chichicaxtle (10), Criollo Narvaez (11), Ejido el Pibe Sanchez (12), Bitzal 3 (13), Bitzal 1 (14).

an impact due to poor management of boat systems for fishing activities in the area's bodies of water (Figure 7).

In Mexico there are soils contaminated by oil activity, due to the fact that hydrocarbons are obtained from activities such as exploration, refining, lack of maintenance and the theft of fuel are carried out. This panorama affects the social sphere, for example, a diagnosis carried out in the city of Puebla, showed that producers do not know preventive or reactive safety measures, and there is no organization for specialized care for exposure to hydrocarbons and other trace compounds such as heavy metals that are generated from oil activity (Cavazos *et al*., 2014).

In Macuspana, given the pollution indicators, it was determined that the facilities and activities carried out by PEMEX are causing a significant impact in the localities and in the health sector; the lives of the inhabitants are at risk due to the release of sulfur and other toxins derived from sour gas production. It is important to note that the localities surrounding oil facilities are classified as marginalized due to the lack of public services (López *et al*., 2019). PEMEX has several wells within the water bodies of the municipality of Tabasco, in operation and in recess, which represents a point source of hydrocarbon contamination. All pollutants are considered to be their final destination in the Gulf of Mexico; this impacts marine life and fishing activities due to the presence of pollutants. In the Corcovado Gulf in Chile, in sediment samples, the presence of aliphatic hydrocarbons from terrestrial plants was detected and in Quellón the presence of fuel derived from petroleum (Bonert *et al*., 2010).

The deterioration in the quality of water and soils due to the exploitation of oil wells, uncontrolled spills and inadequate procedures in the handling of petroleum hydrocarbons, as well as the deterioration of pipes and ducts with the presence of corrosion, is the consequence of the lack of maintenance by the PEMEX company.

In the Mexican Republic, the distribution and location of oil pipelines and pipelines have been identified, it is necessary to monitor regulatory compliance for maintenance programs and prevent them from becoming sources of contamination (Orozco, 2010; Schmidt-Etkin, 2011). In this study, it was evidenced that there are pipes and wells in poor condition which negatively affect water bodies. Dead aquatic organisms such as crappies, carp and manatees were also recorded. Since the eighties, the activities of PEMEX in Tabasco have impacted the environment, the economy of the fishing social sector and the public health of the population; it has led, in general increase in diseases and politically affecting the inhabitants directly and indirectly (Pinkus and Contreras, 2012).

In the low alluvial plain of the state of Tabasco, in the oil district of Cinco Presidentes, 70 ng g^{-1} of polycyclic

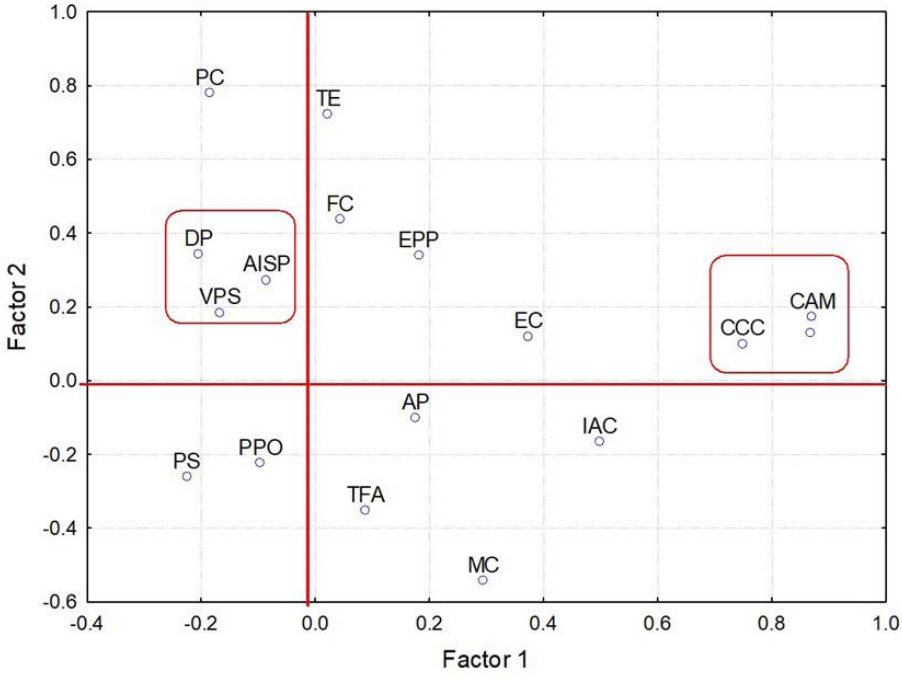

Figure 7. Multivariate analysis by two factors of the contamination of hydrocarbons and heavy metals, Knowledge of Fuel Contamination (CCC), Monthly Oil Change (CAM), Evidence of Contamination (EC), Time of Fish Production (EPP), Environmental Impact due to Fuel (IAC), Types of Diseases (TE), Sources of Pollution (FC), Years as a Fisherman (AP), Cancer Diseases (PC), Increase in the Oil Sector (AISP), Fishing Volume Weekly (VPS), Type of water source (TFA), Death from Cancer (MC), Fishing Destination (DP), Oil Wells in Operation (PPO), Health Problems (PS).

aromatic hydrocarbons were found in livestock land use, 45 ng g^{-1} were found in natural vegetation, and in the soil of a coconut production area was found 10 ng g^{-1} (Ortiz *et al.*, 2012). Despite the knowledge we have about contamination, it is necessary to initiate programs for the restoration of the affected areas or to implement measures of good hydrocarbon management. There is evidence in countries such as Venezuela on the impact of the management of wastewater from oil wells, in the State of Monagas, in savannah areas affected by the drilling and management of oil wells, it was found that wastewater management does not present an environmental risk due to the good drainage and precipitation of the sandy ultisol soils, which allowed the solubility of sodium (Na), in addition to the Na concentrations in wastewater treated with the coagulation and flocculation technique, decreased the levels of soluble aluminum in the soil, and high levels of Fe, Mn, Cu and Zn metals were not found (López *et al.*, 2020).

Implementing public policy options and bioremediation practices for hydrocarbons and heavy metals, with the use of microbial communities for their elimination from aquatic environments, as a strategy to solve this environmental problem (Alvares, 2015) is another alternative. The hypothesis that there is chronic pollution with risks to public health due to hydrocarbons and heavy metals that are generated from this activity is accepted, according to studies carried out on the water used and consumed by the inhabitants of Macuspana, Tabasco.

CONCLUSIONS

The oil sector has an impact on Macuspana, Tabasco, and towns such as Jonuta and Pantanos de Centla, considered the latter a biosphere reserve. It was observed that pollution problems in water bodies have existed for many years, and impact the aquatic life of endangered species, as well as species of commercial interest. The key actor's report and evidence damage to public health due to exposure to contamination by hydrocarbons and heavy metals.

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