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Diagnosis of environmental impacts on the Mexican coastal zone with a comprehensive ad-hoc database

Vivianne Solis-Weiss[1] and Alejandro Granados Barba[2]

[1]Instituto de Ciencias del Mar y Limnologia, UNAM
Apdo Postal 70-305. Mexico, DF 04510, Mexico
(present address: Laboratorio di Biologia Marina, Via A. Piccard 54, 34010 Trieste, Italy)
E-mail: solisw@mar.icmyl.unam.mx

[2]Centro de Ecologia y Pesquerias, Universidad Veracruzana
Apdo. Postal. 663 CP 91000, Xalapa, Veracruz, Mexico

Abstract

Mexico, with 11,500 km of littorals and almost 3.106 km² of marine Economic Exclusive Zone is ideally located for a large array of coastal habitats to thrive. Its main sources of revenue: petroleum, tourism and shrimp catch, are all closely related to the coastal zone. The current booming development of this area which boasts now the highest population growth in the country, contrasts with the lack of knowledge, adequate legislation or ecological protection measures.

The Mexican government financed this project in order to have an integrated knowledge of what data already existed to assess water quality in its coasts. A custom-built database would help in defining the necessary policies to ensure its adequate development and recognize what needs to be further done in research.

Integrated in the RAISON software and based on a comprehensive bibliographic search, 126 parameters were chosen as indicators of water quality and divided in: Physico-chemical (32), Persistent Organic Compounds (34), Hydrocarbons (21), Metals (24), Biological (10) and Geological (5). Of those, 119 were recorded from water, 108 from sediments, 71 from organisms, and they can be divided by States (17).

The main activities were divided in: Fishing and Aquaculture, Petroleum extraction, Tourism, Port activities, and Urban and Industrial development. Anthropogenic impact, as contamination by fecal coliforms, was ubiquitous and sometimes found in very high concentrations and/or already incorporated into sediments.

The information was then valued and analyzed to assess environmental impacts. Since norms only exist for water parameters in Mexico, international legislation and literature reports were used for sediments and organisms. A diagnosis of the coastal localities emerged, which combined with our evaluation at the State level, allowed us to make a general diagnosis of the coastal zone in Mexico.

Keywords: Mexican coastal zone; Coastal pollution; Environmental policies; Database.

Introduction

Mexico is a country that ranks 12th in the world for its extensive coastline of about 11,500 km (Merino-Ibarra, 1990). Its littorals, in contact with both the Atlantic (Gulf of Mexico and Caribbean, 32%) and the Pacific (Mexican Pacific and Gulf of California, 68%) (Fig. 1), include tropical as well as subtropical and, to a less extent, temperate zones, with an impressive marine

Exclusive Economic Zone (EEZ) of about 3.106km2. Several biogeographic provinces are found in Mexico: the Californian and Panamian provinces in the western coasts (Brusca, 1980) and the Carolinean and Caribbean to the east (Briggs, 1995). Thus, a large variety of climatic conditions exist which, complemented by a high diversity of geomorphologic features, make for a wide spectrum of marine habitats to thrive, among the most valuable: about 130 coastal lagoons (Lankford, 1977; Contreras Espinosa, 1993) (12,500 km2) and estuaries (16,000 km2), islands (6,606 km^2), coral reefs, extensive mangrove areas (more than 600,000 ha (Lot and Novelo, 1990), seagrass beds and beautiful sandy and rocky beaches. In turn, these contribute to a rich variety of fauna and flora (largely unknown), as well as a vast array of renewable and non renewable exploitable resources.

Fig. 1. Study area: the Mexican coastal zone with its main coastal ports and cities, visited sites and boundaries of the coastal states.

In contrast with this extension, variety and richness, the development of the coastal zone in Mexico has been remarkably low, to the point of being qualified about twenty years ago as a country that lived with its back turned to the sea. This situation had historical roots since, from the start, human settlements in the coastal zone were more hazardous than in the high plains due to the proliferation of infectious diseases, typical of the tropical humid areas covered by rich vegetation, pirate attacks, etc. Then, following the Spanish conquest, the economic development of colonial Mexico was directed towards more profitable activities such as mining (it is to this day the first silver producer in the world), cattle breeding and agriculture, all done in high lands away from the sea. To this day, the three most important cities in Mexico (Mexico City, Guadalajara and Monterrey) are all far away from the sea.

However, since the discovery of the rich oilfields in the Gulf of Mexico about 30 years ago, followed by their continuously increasing exploitation, the growth of fisheries and aquaculture and the thriving tourist 'industry' directed mostly at its spectacular beaches, the development of the coastal zone has been in constant expansion. Nowadays, these three activities, all closely related to the coastal zone, are the most lucrative in the country and the first sources of foreign currency for Mexico.
However, the high benefits already obtained by these rich resources coupled with the high potential for further development of these and other activities, also imply definite dangers for the environmental health of the country and its sustainable development in the face of the high economic profits at stake and conflicting interests arising from their contemporaneous exploitation.

In fact, this booming growth has proceeded until very recently with very few controls: the lack of knowledge, adequate legislation or guiding plans for the harmonious development of the zone was striking considering not only the resources and potential but also the growing interest at international levels for sustainable development and protection of the environment first addressed with most governments' commitment at the Rio Earth Summit UNCED Conference (1992). The Mexican government, recognizing these problems, and as signatory of international treaties such as Agenda 21 and the OCDE, considered as a priority in its official Program for the Environment 1995-2000 (Poder Ejecutivo Federal, 1996), to carry out this project named: 'Environmental diagnosis and development of a database for the Coastal Zone of Mexico' through the National Institute of Ecology (INE), a branch of its Environment Ministry.
The INE in fact, among its duties, is in charge of formulating, conducting and evaluating the official policies at the national level for the protection of the environment and to ensure preservation and restoration of the ecosystems, their rational and sustainable use and their correct management.
The aim of this project, the first of its kind in Mexico, was thus to have an integrated state of the art knowledge of what had been done in the country to assess water quality of the coastal waters, in a custom-built database, which would help to define the necessary policies to ensure an adequate development of that area and could also be used to recognize what needs to be done in research to complement this effort. The results would be available to all interested parties (scientific, public or private). Water quality was chosen as the indicator, because it can help to assess the local situation as well as that 'upstream', in the global sense. We are aware of the implicit reductionist view in this approach, but it was retained necessary at this point since this was the first attempt to a complete overview of the problem at the national level. Besides grouping all the available information on the subject, the study aimed also at an evaluation of the sources and of the data gathered and a diagnosis at the States level which, when grouped, can give a synthetic idea of the state of water quality and research needs of the whole coastal zone as it is known today.

Methodology

A comprehensive bibliographic search was performed in the 69 libraries of research centers, government agencies and public institutions around the country (48 cities and resort centers) where available published data existed on water quality of the coastal zone. The 42 coastal cities and centers of coastal development considered as the most important in the country were visited

(Fig. 1), and the bibliographic data (taken from 1990 to 1997) were complemented with interviews of key officials of public agencies or involved individuals (from businessmen to fishermen); a photographic survey of areas of particular interest to check the real state of the coast completed the overview. Data from before 1990 were not retained necessary to compile because of the intrinsic changing characteristics of the parameters under study, but were taken into account for analyses purposes.

In the absence of a satisfactory and universally accepted definition of 'coastal zone', and especially its boundaries, for the purposes of this project the coastal zone was defined as the interface between marine and terrestrial habitats, with the boundaries set, towards sea, at the end of the continental shelf and towards land up to where marine influence can be assessed (which is not always a clear-cut boundary). 'Water quality' is another hard to define parameter, when seawater is involved, since otherwise it amounts to determine its drinking quality. However, for seawater, very large variations in the concentration of many compounds are normal (as a single example, consider salinity in estuaries). For water quality assessment, in this case we resorted to comparison between our data and published official permissible concentrations of different parameters (from coliforms to phosphates or hydrocarbons), and in accordance with the intended use (recreational, industrial, port activities…) at national or international levels

The RAISON software (Regional Analysis by Intelligent Systems on a Microcomputer) developed by Environment Canada, already used by the ONU for the GEMS studies (Global Environmental Monitoring System) was chosen to manage the information, in order to integrate the database, with an Excel Spread Sheet and a graphic editor to visualize the results in maps and figures.

All data were validated and only incorporated into the database if the following quality criteria were met: published, georeferenced, dated and available for confrontation. The data were organized by parameters divided in: Physico-chemical, Persistent Organic Compounds (POC), Hydrocarbons, Metals, Biological and Geological, and separated by source of the data: water, sediment, and/or organisms: They are also presented by locality and State. The references used were listed also by state, to facilitate consultation for selected areas (see internet site cited below) in addition to a general section.

The main official normative references regarding water quality in Mexico which were used to analyze and evaluate the impacts of the different parameters known to influence water quality in coastal waters were:

1. the NOM-001-ECOL-1996 (Norma Oficial Mexicana (= Official Mexican Norm) (published officially Jan 6, 1997), which is the only one with legal status (Diario oficial de la Federacion, 1996);
2. the 'Reglamento para la Prevencion y Control de la Contaminacion de las Aguas' (= Regulations for prevention and control of water pollution) (published officially March 29, 1973);
3. the 'Criterios Ecologicos de la Calidad del Agua' (= Ecological criteria for water quality) (CE-CCA-001/89, 1989) (officially published Dec. 2, 1989).

At all sites where studies existed, comparison of the values measured and the official permissible concentrations was performed in order to assess the water quality of the particular

Table I. List of parameters used for the assessment of coastal waters quality in the Mexican coastal zone

PHYSICO-CHEMICAL		11	DDE	20	Saturated Hydrocarbons
1	Ammonium	12	DDT	21	Toluene
2	Biochemical Oxygen Demand	13	Dieldrin	**METALS**	
3	Chemical Oxygen Demand	14	Durban	1	Aluminium
4	Colour	15	Endosulfan	2	Antimonium
5	Dissolved Oxygen	16	Endosulfan I alfa	3	Arsenic
6	Dissolved Solids	17	Endosulfan II beta	4	Barium
7	Fats and Oils	18	Endosulfan Sulphate	5	Berillium
8	Nitrates	19	Endrin	6	Boron
9	Nitrites	20	Endrin aldehyde	7	Bromine
10	Organic Dissolved Nitrogen	21	Heptachlorine	8	Cadmium
11	Organic Dissolved Phosphorus	22	Heptachlorine Epoxid	9	Cyanure
12	Organic Matter	23	Lindane	10	Cobalt
13	Organic Particulate Nitrogen	24	Malathion	11	Copper
14	Organic Particulate Phosphorus	25	Metoxychlorine	12	Chromium
15	pH	26	p,p´-DDD	13	Fluorine
16	Phenols	27	p,p´-DDE	14	Iron
17	Phosphates	28	p,p´-DDT	15	Lithium
18	Redox Potential	29	Parathion	16	Magnesium
19	Salinity	30	Pertane	17	Manganese
20	Sampling Depth	31	Ronnel	18	Mercury
21	Substances Active to Methylene Blue	32	TDE	19	Molybdene
22	Sulphites	33	Toxaphene	20	Nichel
23	Sulphures	34	Triazine Derivatives	21	Silver
24	Suspended Solids	**HYDROCARBONS**		22	Lead
25	Total Alcalinity	1	2,6 Dimetylanthracene	23	Vanadium
26	Total Depth	2	Acenaphtene	24	Zinc
27	Total Nitrogen	3	Acenaphtylene	**BIOLOGICAL**	
28	Total Organic Carbon	4	Anthracene	1	Clorophyll A
29	Total Phosphorus	5	Aromatic Polynuclear Tot Hydrocarbons	2	Faecal Coliforms
30	Transparency or Turbidity	6	Benzo(a)anthracene	3	Faecal Streptococci
31	Water Renewal time	7	Benzo(a)pyrene	4	Heterotroph bacteria
32	Water Temperature	8	Benzo(b)fluoranthene	5	Hydrocarbonoclastic Bacteria
POC'S		9	Benzo(ghi)perylene	6	Indicator Species
1	2,4,5-T Derivatives	10	Benzo(k)fluoranthene	7	Primary Productivity
2	2,4-D Derivatives	11	Crisene	8	Respiration

Table I (cont.)

3	Aldrin	12	Flourene	9	Total Coliforms
4	Arsenic	13	Fluoranthene	10	Total Streptococci
5	BHC alfa	14	Indo(1,2 Cd)pyrene	**GEOLOGICAL**	
6	BHC beta	15	Naphtalene	1	% Gravel
7	BHC gamma	16	Petroleum (Aliphatic Hydrocarbons)	2	% Muds
8	Carbamates	17	Petroleum Hydrocarbons	3	% Sand
9	Clordane	18	Phenanthrene	4	Sediment Type
10	Cumafos	19	Pyrene	5	Sedimentation Rate

site. Since these norms only exist for water parameters in Mexico, for values recorded in sediments and organisms we resorted to international legislation and literature reports.

To evaluate the degree of impact of any given parameter, the averages of reported values for each parameter were confronted with the reference value (highest permissible monthly average value) or Norm (defined for each one in the NOM-001-ECOL-1996) to calculate the number of times that these parameters surpassed the Mexican Norm (NOM), according to the intended use of the local water body, *i.e.*: different concentrations of any parameter are considered for bathing and tourist activities, or fishing and aquaculture than for industrial or port areas. The results were then grouped by class (from 0= no impact, average values inferior to the Norm, 1= low impact, average values equal to norm, 2= moderated impact, average values equal to two times the norm, 3= intense impact, average values equal to three times the norm, 4= severe impact, average values equal to four times the norm, 5= extreme impact, average values equal to or larger than 5 times the norm).

With these results, regional maps were constructed which show the impact of the different sets of parameters according to the intended use of the coastal areas evaluated. Since all regions and all uses where data existed are compiled and shown in the figures, in this paper it would be impossible to show them all, so we will only use a few of them when necessary as examples of the results. However, all the tables and figures used for this project, which would also be too many to show here, can be directly consulted in the INE site at http://sepultura.semarnat.gob.mx/dggia/zcoster/index.html,where they have been inserted since 2001. The same stands for the literature used and the research centres visited, for the same reasons of space constraints.

Results

A total of 126 parameters were chosen as the main indicators of water quality. Of these, 32 correspond to Physico-chemical parameters, 34 to POC's, 21 to Hydrocarbons, 24 to Metals, 10 to Biological and 5 to Geological; 119 of them were recorded from water, 108 from sediments and 71 from organisms.

379 publications were found on the subject, from which 186 (49.1%) were formal publications (129 in national journals and 57 in international journals),165 (43.5%) theses (123 B Sc level, 34 MSc and 8 PhD) and 28 (7.4%) Technical Reports. From the total, 221(58.3%) publications

refer to the Pacific Ocean (161 in the Northern Pacific and 60 in the Southern Pacific), 145 (38.3%) to the Gulf of Mexico, and 13 (3.4%) to the Caribbean. Of those, only 159 publications met the quality standards required for incorporation into the Database (92 or 57.9% from the Pacific, 59 (37.1%) for the Gulf of Mexico and 8 (5.0%) for the Caribbean. This means that the quality of the analyses done until then was very often inadequate. Also, quite often, we found out that the information required can only be obtained at the personal level and is never found in publications.

There are 17 States in Mexico (out of 32) with coastal boundaries (Fig. 1). For each State, information of general interest was included and schematically presented such as: surface, population, cities, climate, land use (%), coastal ecosystems present and their surface, number of research centers, natural protected areas, ports, main fishing resources and production (Fig. 2.).

The literature results for that State were then presented, evaluated (number and type of publications) and commented (Fig. 3). An analysis of the main parameters measured in the different important sites of the State is then presented along with maps with all the georeferenced sampling stations considered (Fig. 4). Finally, a diagnosis is made at the State level based on the analysis of the main impacts found to influence its water quality.

From water measurements, the states where more records were found were Oaxaca and Tabasco (40 parameters each: 17 and 18 respectively for physico-chemical data, 4 and 7 for metals, 15 and 13 for hydrocarbons, no data for POC's, and Sinaloa (30 parameters: 20 for physico-chemical data, 5 for POC, 5 for biological, no data for metals or hydrocarbons).
Those with less records were Baja California Norte (17: 10 physico-chemical data, 3 for metals, 4 biological, no data for POC's or hydrocarbons), Yucatan (14: 13 for physico-chemical data , 1 for biological), Baja California Sur (13: 11 physico-chemical, 2 biological, no data for POC, hydrocarbons or metals) and Guerrero (11 parameters, 9 for physico-chemical data and 2 for biological).
From sediments, physico-chemical records are also the most abundant. The States with more data are: Tabasco (26 parameters: 2 physico-chemical, 6 metals, 15 hydrocarbons and 3 geologic), Veracruz, (25 parameters: 1 physico-chemical, 8 metals, 13 hydrocarbons, 1 geologic and 2 biological), Oaxaca (25 parameters: 5 metals, 16 hydrocarbons and 4 biological).
The states with less records were: Michoacan and Guerrero, with no data at all from sediments, and Tamaulipas, (2 parameters: 1 metal and 1 geologic).

Measurements made from organisms were scarce, and all related to metals and hydrocarbons: from these Veracruz with 20 parameters (8 metals and 12 hydrocarbons) and Oaxaca (19 parameters: 4 metals and 15 hydrocarbons) were the ones with more data, while Sonora, Jalisco, Michoacan, Guerrero, Chiapas, Yucatan and Quintana Roo had no data at all.
Physico-chemical parameters measurements were those which were more often found in the Mexican coastal zone since they were recorded from 43 coastal water bodies. Our results showed that 'extreme' impacts existed due to high concentrations of total suspended solids in some water bodies of Sonora, Jalisco, Colima, Campeche and Quintana Roo; the same was true for Phosphates, Nitrites, Nitrates Sulphurs or Phenols, in some areas of Sonora, Jalisco, Guerrero, Oaxaca and Quintana Roo; and with Substances Reactive to Methylene Blue (indicating detergents) in some water bodies of Sonora, Sinaloa, Colima, Guerrero, Oaxaca, and Quintana Roo.

Veracruz

Ecosistemas Principales:

- Laguna Pueblo Viejo
- Laguna de Tamiahua
- Laguna de Tampamachoco
- Laguna Grande
- Laguna Verde
- Laguna Farallón
- Laguna la Mancha
- Laguna Mandinga
- Laguna Camaronera
- Laguna de Alvarado
- Laguna Pajaritos
- Laguna Catemaco
- Laguna Sontecomapan
- Laguna Ostión
- Río Tuxpan
- Río Cazones
- Río Tecolutla
- Río Misantla
- Río Actopan
- Río Jamapa
- Río Papaloapan
- Río Coatzacoalcos
- Río Tonalá
- Río Panuco

Áreas Naturales Protegidas Costeras:

- Reserva Especial de la Biosfera Sierra de Santa Martha"
- Reserva Especial de la Biosfera"Volcán de San Martín"
- Parque Marino Nacional "Sistema Arrecifal Veracruzano"

Población por Municipio Costero (1995)

Veracruz	425,140 hab.
Coatzacoalcos	259,096 hab.
Papantla	171,167 hab.
San Andrés Tuxtla	137,435 hab.
Boca del Río	135,060 hab.
Tuxpan	127,622 hab.
Martínez de la Torre	113,560 hab.
Alvarado	48,490 hab.
Pueblo Viejo	48,054 hab.
Agua Dulce	46,404 hab.
Catemaco	44,321 hab.
Actopan	41,884 hab.
Angel R. Cabada	34,312 hab.
Soteapan	28,888 hab.
Ursulo Galván	28,158 hab.
Tamiahua	27,398 hab.
Alto Lucero de Gutiérrez B.	27,331 hab.
Tecolutla	25,730 hab.
Cazones de Herrera	23,621 hab.
La Antigua	23,529 hab.
Mecayapan	22,764 hab.
Lerco de Tejada	20,810 hab.
Vega de Alatorre	19,412 hab.
Tampico Alto	13,604 hab.
Pajapan	13,073 hab.
Nautla	9,599 hab.

Coordenadas Extremas:

22°28'-17°09' Lat. N. 93°36'-98°39' Long. O.

Superficie:

68,940.27 km^2, que constituye el 3.7% del total nacional.

Longitud de la Línea de Costa:

745.14 km

Superficie de la Plataforma Continental:

22,935 km^2

Superficie de Lagunas Litorales:

1,166 km^2

Amplitud de la Plataforma Continental:

Máxima: 56 km frente a Las Barrillas.
Mínima: 22 km frente a la barra de la Laguna de Tamiahua.

Tipos de Climas Dominantes:

A(w) cálido subhúmedo–52.30%
Am cálido húmedo–27.76%

Población Total:

6,737,324 habitantes (1995)

Ciudades Costeras Principales:

- Tuxpan
- Veracruz
- Coatzacoalcos
- Alvarado

Uso del Suelo: (Hectáreas (1994))

Agrícola	4,458,249.5
Pecuario	2,119,330.3
Urbano	72,792.1
Industrial	60,677.5
Forestal	292.6

Recursos Pesqueros Principales:

141,486 toneladas en volumen de captura en peso desembarcado a nivel nacional (1996)

Tilapia	16,086
Ostión	17,996
Lebrancha	4,674
Jaiba	4,809

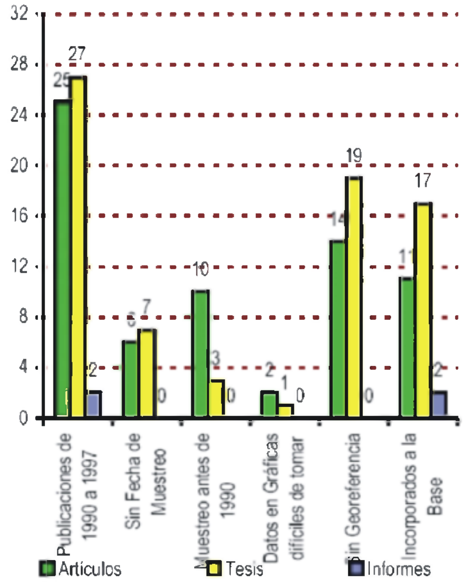
Puertos Principales:

- Veracruz (Industrial, Mercante, Pesquero, Turistico).
- Tuxpan (Industrial, Mercante, Pesquero).
- Coatzacoalcos y Pajaritos (Industriales, Mercantes, Pesqueros).
- Alvarado (Pesquero).

Centros de Investigación Costera:

- Facultad de Biología de la Universidad Veracruzana (UV).
- Instituto de Ecología, A.C.
- Instituto Tecnológico del Mar (ITMAR) Veracruz.
- Instituto de Investigaciones Oceanográficas del Golfo de México y Mar Caribe, SEMAR.
- Centro Regional de Investigación Pesquera (CRIP-Veracruz).

Fig. 2. Example of the presentation of data by State (here Veracruz): General data.



Zona Nerítica			
AGUA	máx.	mín.	prom.
NH4 mg/L	3.383314	0	1.128981
PO4 mg/L	0.370808	0	0.104417
GyA mg/L	15.73	8.27	12
NO3 mg/L	1.496122	0	0.22766
NO2 mg/L	0.10626	0	0.032066
OD mg/L	10.9	2.15	6.287357
pH	8.265	7.074	8.024031
PM m	200	0	26.43913
Cl a mg/L	0.002671	0.000805	0.001625
CF NMP	34100	136	17118
CT NMP	50100	433	25266.5
SEDIMENTOS	máx.	mín.	prom.
Cd µg/g	9.59	8.3	8.885
Cu µg/g	7.47	6.16	6.981667
Cr µg/g	20.97	19.71	20.27667
Fe µg/g	100.57	43.69	69.61667
Mn µg/g	14.081	0.59	12.00333
Ni µg/g	40.46	33.7	37.265
Pb µg/g	105.73	72.8	88.23667
Zn µg/g	14.03	9.75	12.06333

Fig. 3. Example of the presentation of data by State (here Veracruz): Literature evaluation and analysis of impacts.

Fig. 4. Example of the presentation of data by State (here Veracruz): sites sampled in the neritic zone, georeferenced stations.

Important concentrations of Fats and Oils were recorded from Bahia de Banderas (Jalisco), Manzanillo (Colima), and Cancun Lagoons (Quintana Roo) where, in addition, Phenols are significantly present. Dissolved solids and low levels of Oxygen were found in front of Chetumal (Quintana Roo). Impacts are considered 'extreme' in Acapulco Bay where very low concentrations of dissolved Oxygen were found, in addition to suspended solids in abundance as well as Fats and Oils.

Data about POC's and Hydrocarbons were definitely scarce and the records came from small sampling areas. This only enabled us to report 'moderate' impacts: in the case of POC's they are associated to intense agricultural activities (like in Sonora). This scarcity of information is troubling since those compounds are widely used in agriculture and their high environmental toxic potential is already well documented. Hydrocarbons are only recorded from areas where petroleum industry or related activities prevail, like Veracruz, Tabasco and Oaxaca: they were already present in water, sediments and organisms in Salina Cruz, Oaxaca, all water bodies of Tabasco and all lagoons and estuaries in southern Veracruz.

Metals constituted another category where data were scarce: only found in 16 water bodies of the following States: Baja California, Sonora, Sinaloa, Nayarit, Colima, Oaxaca, Tamaulipas, Veracruz, Tabasco, Campeche and Yucatan. In most records, local impacts were qualified from 'intense' to 'extreme', since significant concentrations of Cadmium, Copper, Chrome, Lead and Zinc were reported. In the Veracruz lagoons and in Laguna La Cruz (Sonora), impacts reached 'severe' levels whereas in Bahia Magdalena (Baja California), Pabellon-Altata (Sinaloa), Bahia de Manzanillo (Colima) and the neritic zone in Campeche, impacts reached 'extreme' levels for considerable concentrations of Cu, Zn, Ni, Cr, Ba and Al.

Biological parameters: records basically regarded coliform concentrations (faecal and total), whose levels were qualified as 'intense' to 'severe' in most of the 30 water bodies where records exist, especially along the Veracruz and Sinaloa coasts. 'Extreme' levels of impact were recorded in Baja California, Sonora, Guerrero, Colima, Oaxaca (in Salina Cruz alarming concentrations were recorded), Tamaulipas, Campeche and Quintana Roo. Other records concerned heterotroph and hydrocarbonoclastic bacteria.

Practically no records are available for studies performed in organisms or their tissues, even for POC's or hydrocarbons: the few data gathered enabled us to consider the impact as 'moderate' for both parameters. Baja California and Terminos Lagoon (Campeche) were the only sites where data existed for POC's and Veracruz and Oaxaca (Salina Cruz port) were the only ones for hydrocarbons, despite the heavy oil-oriented status of the Tabasco and Campeche coasts which are, at the same time, highly praised for their shrimp, oyster and fish production.

Data on metals recorded from organisms were only found in 15 water bodies, in the coastal regions of Baja California Sur, Sinaloa, Nayarit, Colima, Oaxaca, Tamaulipas, Tabasco and Veracruz. Their impact reached levels from 'moderate' to 'extreme', the latter in the Veracruz lagoons, while Cd, Cu, Cr, Pb, Zn and Fe were found in high concentrations in selected organisms of Tabasco coastal lagoons (Carmen & Machona).

Discussion

From the compiled results and the visits done to the main coastal cities, resorts and industrial centres of the Mexican coasts, we could divide the main activities done in the coastal zone in: Fishing and Aquaculture, Petroleum extraction, Tourism, Port activities, and Urban and Industrial development.

From these, fishing, aquaculture and tourism require a clean environment to survive and flourish, while creating potential damage to it, especially in the case of aquaculture (the by-products of aquaculture can irreversibly damage entire coastal areas) and secondly tourism. The other activities are always in conflict with a healthy environment and considerable efforts have to be made in order to limit the damages. These conflicts are particularly acute in Mexico, because of the especially high economic benefits derived from the first three activities mentioned: the potential and demonstrated fast profits of the short term have to be constantly weighed with the known dangers and real damage in the long term. The conflicts of interests become even more delicate to manage when two or more activities are carried out contemporaneously; to take only one example, see the offshore oil extraction in the continental shelf of Tabasco and Campeche in the richest zone of shrimp fisheries in the country.
With the results obtained from the measured parameters, regional maps were built which showed, for each coastal city or locality studied, the degree of impact of the different parameters on water quality for the different activities performed in the area, as is exemplified in Fig. 5.

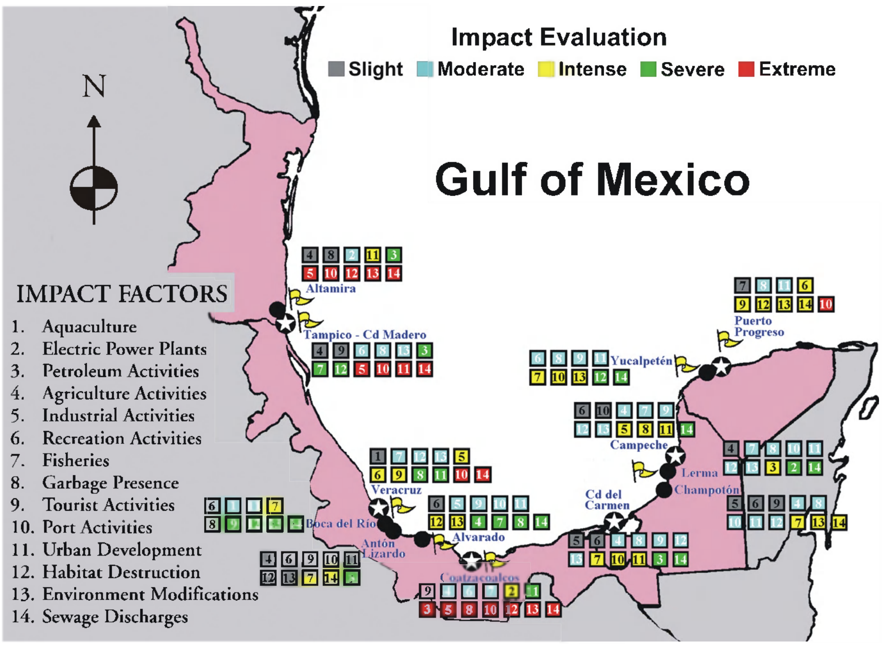


Fig. 5. Example of impacts evaluation in the Gulf of Mexico region (Tamaulipas, Veracruz, Tabasco, Campeche and Yucatan).

The graphic information provided by these regional maps, where impacts are evaluated for each site and each group of parameters, complemented by the analysis and diagnosis of water quality arranged and presented as exemplified in Fig. 3, for each State individually and the information contained in the database complemented by the in situ observations, enables us to present an overview of the situation of the whole Mexican coastal zone as follows:

- Studies about water quality were generally limited in scope and area covered, whatever the parameter or the category under study. More importantly, no time sequences could be observed which means that there is no continuity in the research projects; monitoring is rare, or if carried out, the results are not available to the public.
- The lack of communication between government agencies and public universities resulted in redundant efforts in well known areas (*i.e.* Veracruz) or left uncovered important zones (*i.e.* Yucatan, Chiapas)
- When data are available, pollution by coliforms is always present, be it in coastal zones, rivers, estuaries, bays, lagoons, beaches and sometimes in a large section of the neritic zone. This type of pollution is alarming in the large coastal cities and tourist centres, where in addition, low levels of dissolved oxygen were commonly detected. This problem is certainly due to inefficient or inadequate wastewater treatment.
- Physico-chemical parameters were more often studied than the other categories. Problems were detected close to urban, tourist and industrial centres where high concentrations of Fats and Oils as well as of dissolved and suspended solids and low values of dissolved oxygen were reported. By contrast, nutrients never represented a problem as pollutants, but discontinuity in those studies, poor sampling effort and selection of the sites (by exclusion of some 'hot spots', where information either does not exist or is not available to the public), most probably mean that future (urgently needed) studies will not confirm these results.
- The lack of information on POC's except for selected zones can be considered a serious problem: their presence in sediments and organisms, in the few studies available was alarming, since the toxicity of these commonly used products in agriculture is well known; their effects on the environment, in this case the surrounding coastal zone, should be better documented and monitored.
- In the industrial areas especially where petroleum exploitation or related industries are involved (Veracruz, Tabasco, Campeche, Oaxaca) pollution by compounds derived from those activities was notorious in water, sediments and organisms. However, the situation for the presence of hydrocarbons is similar to that of the POC's: too few records are available. In addition, some industrial areas such as Coatzacoalcos (the largest petrochemical plants in the country) as well as many ports are generally considered out of bounds for the public, so that independent analyses or evaluations can only exceptionally be carried out (this is an international problem).
- Metals are also generally poorly studied, probably due to the high costs involved in the necessary technology used for their determination. However, in selected zones like the shrimp farms areas of the Sonora coasts or the ports and areas used in activities related to the petroleum industry in Tabasco and Campeche, with adequate sampling effort, studies have shown impacts that go from 'severe' to 'extreme', again in water, sediments and organisms.
- Urban, tourist and industrial development has proceeded with no planning or controls to avoid potential damage to the coastal environment. Generally the 'charge capacity' of the aquatic systems is ignored and abuses are frequent. The intrinsic characteristics of each region are not taken into account when thinking about their future development, often

provoking social discomfort and unwanted pressures on the local populations when changes occur (such as new industries, ports or marinas, construction booms for tourism, etc.).

- When measures to protect the environment are considered, mitigation and corrective measures are commonly preferred to prevention and conservation. This was remarked especially regarding the oil industry. In addition, quite often, no measures at all are enforced, or are ineffective for the problem considered. In some cases, we observed for example waste water treatment plants which although installed, had never functioned.
- According to our in situ observations of environmental impacts together with the existing (valued) data, we can say that the areas with greater environmental damage are the big tourist resorts such as Acapulco, Ixtapa-Zihuatanejo and Cancun regarding environment modification, sewage discharges and coliform presence. The industrial ports like Coatzacoalcos, Lazaro Cardenas, Tampico-Madero and Altamira show 'extreme' impacts in port activities, urban development, environment modification and sewage discharges. The less polluted areas were found to be zones like San Felipe, Bahia Kino (Baja California) and in general the coastal zone of Yucatan.

As part of the effort of the government to act in accordance with international trends in environment protection, an increasing number of areas are being declared 'protected areas', with different degrees of protection enforced. They were 26 in the coastal zone when the Database was finished (see internet site and Fig. 3), but since then a few have been added, the latest in the Caribbean sea, protecting the coral reef areas of Cozumel (1999). In 2002, the total protected areas in Mexico, counting coastal and inland were 117 (SEMARNAP/INE, 2000).

Conclusions

The most important contribution of this study was the systematization of the whole set of available information until then dispersed and not contextually evaluated, and make it available to any interested party. Then, with the evaluation and analysis of the data contained in the database, it was possible to make a diagnosis of the water quality at the State level, and have an approximate idea not only of the coastal environment water quality but also to highlight the shortcomings, lacks and/or needs in scientific information, to evidence critical areas that need special attention and to see that corrective measures are now preferred to the more effective protection and prevention. All this will help to organize the needed research and data gathering in a systematic frame which, in addition to scientific results, will help formulate the necessary laws to protect and conserve the natural resources of the coastal zone which are now the richest source of wealth for Mexico, as well as ensure their sustainable exploitation.

The excellent initiative of declaring ever more protected areas should be continued, with all the sectors of society involved in the protection of their environmental patrimony.

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