Rev. Int. Contam. Ambie. 38 (Ambiente y Bioenergía) 191-207, 2023
https://doi.org/10.20937/RICA.54240

TOURISM SUSTAINABILITY, OFFICIAL MEXICAN STANDARDS AND THE FULFILLMENT OF THE HUMAN RIGHT TO A HEALTHY ENVIRONMENT: HYDROCARBONS, PLASTICS, AND BIOREMEDIATION

Sustentabilidad del turismo, NOMS en México y el cumplimiento del derecho humano a un ambiente sano: hidrocarburos, plásticos y biorremediación

Violeta MENDEZCARLO SILVA[1] and Manuel Alejandro LIZARDI-JIMÉNEZ[2]*

[1] Facultad de Derecho, Universidad Autónoma de San Luis Potosí, Cuauhtémoc 170, Col. Moderna, 78270 San Luis Potosí, San Luis Potosí, México.
[2] Maestría en Derechos Humanos, CONACYT-Universidad Autónoma de San Luis Potosí, Sierra Leona 550, Lomas Segunda Sección, 78210 San Luis Potosí, San Luis Potosí, México.

*Author for correspondence: chamarripas@yahoo.com.mx

(Received: February 2021; accepted: May 2021)

Key words: tourism, Official Mexican Standards, human right to a healthy environment, hydrocarbons, plastics.

ABSTRACT

The negative effects of tourism have led to urban, environmental, and social deterioration in various Mexican tourist destinations. Biotechnology can provide some technical alternatives for hydrocarbon and plastic pollution with promising results of bioremediation. However, the scientific approach apparently is insufficient due to the magnitude of environmental concerns regarding these materials. In this work, remediation and prevention are studied. Therefore, Official Mexican Standards that directly address environmental problems, particularly those generated by hydrocarbons and microplastics, are necessary.

Palabras clave: turismo, Normas Oficiales Mexicanas, derecho humano a un ambiente saludable, hidrocarburos, plásticos.

RESUMEN

Los efectos negativos del turismo han provocado el deterioro urbano, ambiental y social de diversos destinos turísticos mexicanos. La biotecnología puede aportar algunas soluciones técnicas para la contaminación por hidrocarburos y plásticos con resultados prometedores de biorremediación. Sin embargo, el enfoque científico aparentemente es insuficiente debido a la magnitud de las preocupaciones ambientales respecto a estos materiales. En este trabajo se estudian la remediación y la prevención. Por lo tanto, las Normas Oficiales Mexicanas que abordan directamente los problemas ambientales, en particular los ocasionados por hidrocarburos y los microplásticos, son necesarias.

INTRODUCTION

The negative effects of tourism have led to urban, environmental, and social deterioration in various Mexican tourist destinations (Gómez-Reyes et al. 2017, Sierra-Cortés et al. 2019), which suffer de consequences of urban disorder, corruption, and government indolence. These conditions manifest, among others, in polluted underwater sinkholes in the state of Quintana Roo; the deterioration of coastal ecosystems in the so-called Integrally Planned Centers, such as Cancun; or the abandonment of traditional destinations such as Veracruz, where important port activities occur, and the Huasteca Potosina in the San Luis Potosí state (Baldenegro et al. 2019).

The coastal and underwater sinkholes of Quintana Roo are a substantial part of the environment in the region and are exposed to contamination by anthropogenic factors (e.g., by hydrocarbons). The presence of pharmaceutical and personal care products in this environment has been documented (Metcalfe et al. 2011), and the presence of hydrocarbons in cenotes has been initially documented by our research group (Lizardi-Jiménez et al. 2015). However, there is insufficient information about compliance with the human right to a healthy environment (HRHE), free from oil pollution, even though a large number of cars circulate and there is an important road network. There is also insufficient information about remediation options. Beaches adjacent to the Veracruz port are part of the Veracruz Reef System National Park, which encompasses the principal coral resources of the Gulf of Mexico and tourist activities take place there. Its proximity to the commercial port of Veracruz generates pollution problems due to human activity (Rodríguez-Gómez et al. 2013). Also, the activities of port extensions and built infrastructure for coastal protection in operation since 2014 (Hayasaka-Ramírez and Ortiz-Lozano 2014). The scarce oil industry of San Luis Potosí would lead one to assume that there would be no risk of oil spills in the region after the Ébano oil field contamination in 2004. However, hydrocarbons and their polluting effects have been documented based on the widespread use of biomass for domestic heating, burning, and cooking, as well as in the brick industry and nearby roads in the Huasteca, an important tourist destination (Martínez-Salinas et al. al. 2010).

The industrial production of plastics is increasing and has become an emerging environmental concern (Meo et al. 2018). The persistence of plastic causes it to contaminate the environment for a long period, in which macroplastics break down into microplastics (Lusher et al. 2014). Hydrocarbon and plastic pollution in water bodies is a serious global concern today. Plastic waste is a threat to the biosphere. Hydrocarbons are also persistent pollutants. Plastics' hydrophobicity and large surface area make them work as a vector for hydrocarbon contamination.

On the other hand, the HRHE is found in Article 4 of the Mexican Constitution: "Any person has the right to a healthy environment for his/her own development and well-being", and laws, regulations, and norms should be established accordingly.

Bioremediation (remediation using microorganisms) is a promising technique for oil pollution in water bodies, and some works that address this issue are well documented (Varjani 2017). Very recently, promising information on microorganisms as an alternative to remedy plastic contamination has emerged (Koshti et al. 2018, Patrício 2020, Lear et al. 2021).

As a fundamental premise, our work points out the need to establish national technical standards (Mexican regulations and official standards) oriented towards the prevention of the effects of such contamination in the sites indicated. The establishment of maximum levels of the above-mentioned contaminants in the ecosystems under study would also allow assigning of responsibilities to the State that would justify the implementation of restrictive or economic instruments to limit these effects and effectively guarantee the right to a clean environment by using remediation mechanisms. Water bodies in tourist coastal zones and reefs of Quintana Roo and Veracruz, rivers and lagoons in Veracruz and the Huasteca Potosina, in addition to sinkholes in Quintana Roo, provide a wide overview of pollution in water bodies along México.

The objective of this work was to review the status of compliance with the HRHE and Official Mexican Standards (NOMs, for their Spanish acronym) in relation to the presence of hydrocarbon and plastics in tourist sites in Mexico and to propose alternatives for remediation using biotechnology.

MATERIALS AND METHODS

Identification of hydrocarbons and plastics

Our study is an interdisciplinary work covering both human rights and environmental biotechnology. We identified recent hydrocarbon and plastic pollution in México using the following methodology:

- Identification of the study area and revision of environmental history, particularly from our research group expertise.

- Assembly of bibliographic and electronic information, and access to databases.
- Review and analysis of recent investigations regarding environmental problems in Quintana Roo, Veracruz, and San Luis Potosí.
- Documentation of the remediation suggestions from biotechnology.

Bioremediation of hydrocarbons and plastics

An oil-degrading microbial consortium composed of *Xanthomonas* sp., *Acinetobacter* bouvetii, *Shewanella* sp., and *Aquamicrobium lusatienses* was used for biodegradation purposes (Narciso-Ortiz 2019). The consortium was isolated from the rhizosphere of *Cyperus laxus*, a hydrocarbon-tolerant herb. The microbial consortium was cultivated with a mineral medium composed of (in g/L): $NaNO^3$, 6.75; K_2HPO_4, 2.15; KCl, 1.13; $MgSO_4.5H_2O$, 0.54, in a bubble column bioreactor (0.08 x 0.40 m) with 2 L of volume operation. Air was sparged by a stainless-steel L-shaped, diffuser of 6.35 mm internal diameter (seven orifices, 1.0 mm diameter), air superficial velocity of 1 cm/s, measured using a rotameter (Cole-Parmer, USA). Diesel was used as a carbon source.

On the other hand, microplastic identification of the remediation proposals from biotechnology was shown, mainly based on our expertise (Narciso-Ortiz et al. 2020).

Mexican standards regarding hydrocarbons and plastics (microplastics) in water bodies for tourist sites

To establish the objectives of this research, the guidelines that comprise the HRHE were initially established. Subsequently, a review was carried out of the standards that regulate the presence of hydrocarbons and plastics in tourist sites, their approach and correspondence with elements of the HRHE, highlighting (in the context described) the omissions found and their consequences in terms of the general obligations and specific duties in the enforcement of this and other related rights, such as water, health, and food. The need for regulatory intervention in this area is also indicated.

It is worth mentioning that the problem of water pollution by contaminants such as hydrocarbons or plastics and microplastics affects the enjoyment of several human rights, especially those that are more interdependent, such as the HRHE and the human right to water and sanitation (HRWS), as well as the right to health and food.

In the specific case of the HRHE, it has become necessary for international research to evolve and specialize in defining its elements more precisely. Currently, there are more than 93 international documents (including treaties, protocols, agreements, initiatives, and conventions), which form a consensus around the elements to which the international community has gradually granted protection. The following topics are part of this consensus:

a. Protection of the biosphere and its natural components, such as biodiversity, ecosystems, and natural resources (protection of flora and fauna, ecological stability, renewable and non-renewable resources, among others).
b. Protection of environmentally relevant areas, aesthetic, tourist and landscape heritage (areas susceptible to protection, regulation of human settlements, land use planning, urban development, and ancestral territories).
c. Assignment of property rights (individual property, common goods and those of collective character, of environmental significance).
d. Equitable access to natural resources (which implies a condition of sustainability and equity within and between generations), forms of exploitation of natural resources, their use and conservation.
e. Social and economic development (regulation of industrial activities associated with poverty and underdevelopment, and commercial treaties).
f. Scientific and technological exchange (technology transfer, environmental impact of the scientific progress and its use to reduce environmental problems).
g. Prevention of environmental degradation (water, air and soil pollution, acid rain, stratospheric ozone depletion, global warming, and climate change).
h. The impact of the degraded environment on human health and safety (resource scarcity, precarious housing, food contamination and the effects of any anthropogenic alterations on ecosystems).
i. The internalization of environmental costs (environmental accounts, mechanisms of internalization, valuation of environmental goods and services).
j. Environmental liability and remediation of environmental damage.
k. Transversal issues (sustainability, access to environmental information and justice, public policy instruments, and social participation).

RESULTS AND DISCUSSION

The problem of water pollution by plastics and hydrocarbons has been addressed from the perspective of various protection aspects, although yet to be explicitly developed. Protection against these issues still requires the integration of several of the referred international instruments, so it may be considered that there is only scattered protection at this level, such as flora and fauna protection through the Convention on Biological Diversity (CBD) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), as well as the protection of water bodies through the Convention on the Protection and Use of Transboundary Watercourses and International Lakes and the International Convention for the Prevention of Pollution from Ships, among others. However, there are no specific provisions at the international level that regulate this problem in a concrete way.

Meanwhile, Article 4 of the Mexican Constitution substantiates this right, and the Ley General del Equilibrio Ecológico y la Protección al Ambiente (General Law of Ecological Balance and Environmental Protection, LGEEPA) lays the foundations to regulate certain aspects subject to NOMs, such as:

a. To function as an instrument to guarantee the HRHE aimed at the development, health, and well-being of people (f. I), although it is necessary to point out that a system of guarantees should not be exhausted in the expression and regulation of a problem at the level of general norms, but rather of technical standardization, a function that as we will see below is fulfilled by the Mexican Official Standards (hereinafter NOMs).
b. The definition of the instruments for its application (f. II), among them the different types of preventive and corrective instruments that allow to properly establish the elements of said guarantee.
c. The preservation, restoration and improvement of the environment (f. III), which implies that the scope of regulation of these instruments will include preventive and corrective emphasis, hence the need for regulations that limit polluting activities (use of technologies and processes that reduce the impact of activities on water), such as those that measure pollution not sanctioned (accumulated levels from low-impact, clandestine activities and those not included in the normative assumptions) by the State and those that establish the maximum tolerable levels of pollutants to develop activities by the population. The co-responsible participation of individuals and collectives will be necessary for the preservation of the ecological balance f. VII).
d. The sustainable use of the soil, water and natural resources in such a way that it is compatible to obtain economic benefits and the activities of the society and also the preservation of the ecosystems (f. III), so that the establishment of maximum limits of emissions or maximum permitted limits must contemplate the existence of activities linked to the access and enjoyment of the ecosystems such as tourism.
e. The prevention and control of air, water, and soil pollution (f. VI).
f. To guarantee the co-responsible participation of individuals and communities in the preservation, restoration of the ecological balance and the protection of the environment (f. VII).
g. Through coordination, induction and agreement mechanisms among all social actors (f. IX).
h. And finally, in the establishment of control and security measures, administrative and criminal sanctions where appropriate (f. X).

These bases made it possible to legislate, regulate and standardize the problem addressed in this research, although in a general (and not specific) manner. According to what was pointed out in Chapter III of the mentioned LGEEPA, called Prevención y control de la contaminación del agua y de los ecosistemas acuáticos (Prevention and control of pollution in water and aquatic ecosystems), it was found that the provisions that regulate contamination by hydrocarbons and plastics (especially microplastics) in aquatic ecosystems are the following:

The LGEEPA includes a section on the prevention and contamination of water, whose objective is to regulate its availability according to its uses and the protection of ecosystems; this implies a double emphasis on the protection of water as an indispensable element of human life and as a natural element interrelated with ecosystems life (article 117). Recognizing the correlative obligation of the State and society in the prevention of water pollution (article 117, fractions II and V), and the treatment of discharges generated by productive activities and of urban origin (article 117, fractions III and IV).

Likewise, the integration of the criteria for the prevention and control of water pollution is carried out from its insertion in the NOMs: agreements for the delivery of water in block, the establishment of regulated areas for closure or reserve, concessions, assignments, permits and any kind of authorizations, hydrology works in national waters, as well as in the classification of receiving bodies of wastewater discharges.

The guarantee of the HRHE through the prevention and control of water pollution corresponds to the different levels of government (which include public agencies that administer water) within the scope of their respective competencies (article 119), especially regarding the control of discharges, monitoring of the NOMs, determining the amounts for water treatment, imposing sanctions, and keeping a record of discharges into drainage systems.

Likewise, to regulate water pollution, the same LGEEPA establishes regulations for discharges of municipal origin for the mixing and infiltration of water into aquifers (article 122). For this purpose, all discharges must comply with the requirements of the NOMs and additionally with the discharge regulations determined by local authorities (article 123), which will condition the granting and renewal of concessions (article 129).

The prevention and control of pollution by discharges to marine waters, regardless of the source, will be carried out by the Secretaría de Medio Ambiente y Recursos Naturales (Ministry of Environment and Natural Resources), the Secretaría de Marina (Navy Ministry), the Secretaría de Salud (Health Ministry), the Secretaría de Turismo (Tourism Ministry) and the Secretaría de Comunicaciones y Transportes (Ministry of Communications and Transportation) in accordance with applicable national and international provisions. The Mexican State is committed to issue NOMs that regulate the exploitation, preservation and administration of the natural, living and abiotic resources of the seabed and subsoil, as well as the waters above it and those that must be observed for the exploration and exploitation activities in the exclusive economic zone (article 131).

It follows that the Mexican State has created a secondary regulatory framework for the prevention and control of water pollution that recognizes the need to be complemented with technical standards which address environmental problems that endanger the availability of water, both for the satisfaction of human consumption and the preservation of aquatic and marine ecosystems.

When we descend to the analysis of operational standards, we must enter the analysis of the NOMs. An Official Mexican Standard is defined as the mandatory technical regulation issued by the competent Standardization Authorities whose essential purpose is to promote quality for economic development and the protection of the legitimate objectives of public interest set forth in this ordinance, through the establishment of rules, denomination, specifications, or characteristics applicable to a good, product, process or service, as well as those related to terminology, marking or labeling and information. As established in the 2020 Ley de Infraestructura de la Calidad (HCDU 2020), the Mexican Official Standards should be considered as technical regulations or sanitary or phytosanitary measures, according to the corresponding definitions set forth in the international treaties to which the Mexican State is a party.

In this work, 28 NOMs regulating aspects related to water were analyzed, which were classified according to their purpose, and whether they introduce an emphasis on pollution prevention or pollution control. At the same time, it was reviewed whether their orientation is focused on guaranteeing the HRWS (a purely anthropocentric approach), or on protecting the right to a healthy environment (an approach with a more holistic component). The results are presented in **Table I**.

It should be noted that NOMs were classified according to their main emphasis or orientation, since it cannot be said that they exclude one particular aspect to guarantee the other. Hence, it was found that they are predominantly oriented towards the protection of the HRWS, especially regarding the establishment of criteria that favor its quality, as well as the specifications of the systems and equipment intended for its public management or individual use. The protection given to the quality of water as an environmental element (beyond human consumption) is notoriously inferior, with only nine NOMs focused on the quality of the wastewater discharged by different players.

We also analyzed the preventive or corrective approach of the NOM. That is, if the regulation focuses on the final use of the resource (mainly human consumption, which is related to the protection of the HRWS) or if it has a corrective emphasis (protection of the HRHE) referred to the return of used water to the hydrological cycle, and to the maximum levels of contaminants that it should contain. Thus, in analyzing these NOMs, we found that 18 of them have an emphasis on prevention and 10 on control, which is consistent with their correlation with protected human rights, with the HRWS prevailing over the HRHs, which may be due to the following factors:

a. The perception is that the HRWS is more immediate to people than the right to a healthy environment (Gutiérrez 2010). However, as it has been explained throughout this study, the

TABLE I. PREDOMINANT APPROACH OF CURRENT NOMS IN RELATION TO REGULATORY EMPHASIS ON POLLUTION AND HUMAN RIGHTS FOCUS.

Official Mexican Standard (NOM)	Emphasis on pollution		Focused Human Right	
	Preventive	Of control	HRWS	HRHE
NOM-001 SEMARNAT-1996 (Maximum permissible limits of pollutants in wastewater discharges into waters and national assets)		X		X
NOM-002-SEMARNAT-1996 (Maximum permissible limits of pollutants in wastewater discharges to urban or municipal sewage systems)		X		X
NOM-003-SEMARNAT-1997 (Establishes the maximum permissible limits of contaminants for treated wastewater that is reused in services to the public)		X		X
NOM-127-SSA1-1994 (reformed in 2000) (Environmental health. Water for human use and consumption. Permissible quality limits and treatments to which the water must be submitted for its purification).	X		X	
NOM-015-CONAGUA-2007 (Artificial water infiltration into aquifers - Characteristics and specifications of the works and water)		X		X
NOM-014-CONAGUA-2003 (Requirements for the artificial recharge of aquifers with treated wastewater)		X		X
NOM-013-CONAGUA-2000 (Drinking water distribution networks - Sealing specifications and test methods)	X		X	
NOM-011-CONAGUA-2000 (Conservation of the water resource. It establishes the specifications and the method for determining the average annual availability of national waters)	X		X	
NOM-010-CONAGUA-2000 (Intake valve and toilet tank discharge valve - specifications and test methods)	X		X	
NOM-009-CONAGUA-2001 (Toilets for sanitary use. Specifications and test methods)		X	X	
NOM-008-CONAGUA-1998 (Showers used in body hygiene - Specifications and test methods)	X		X	
NOM-007-CONAGUA-1997 (Safety requirements for the construction and operation of water tanks)	X		X	
NOM-006-CONAGUA-1997 (Prefabricated septic tanks - Specifications and test methods)		X	X	
NOM-005-CNA-1996 (Fluxmeters - Specifications and test methods)	X		X	
NOM-004-CNA-1996 (Requirements for the protection of aquifers during the maintenance and rehabilitation of water extraction wells and for the closure of wells in general)	X		X	
NOM-003-CNA-1996 (Requirements during construction of water extraction wells to prevent contamination of aquifers)	X		X	
NOM-002-CNA-1995 (Household drinking water supply - Specifications and test methods)	X			X
NOM-001-CONAGUA-1995 (Sanitary sewer systems - Watertightness specifications)		X		X
NOM-201-SSA1-2002 (Products and services. Water and ice for human consumption, packaged and in bulk. Sanitary specifications)	X		X	

TABLE I. PREDOMINANT APPROACH OF CURRENT NOMS IN RELATION TO REGULATORY EMPHASIS ON POLLUTION AND HUMAN RIGHTS FOCUS.

NOM-160-SSA1-1995 (Goods and services. Good practices for the production and sale of purified water)	X		X	
NOM-112-SSA1-1994 (Goods and services. Determination of coliform bacteria. Most probable number technique)	X		X	
NOM-041-SSA1-1993 (Goods and services. Purified bottled water. sanitary specifications)	X		X	
NOM-014-SSA1-1993 (Sanitary procedures for the sampling of water for human use and consumption in public and private water supply systems)	X		X	
NOM-013-SSA1-1993. (Sanitary requirements to be met by the tank of a vehicle for the transport and distribution of water for human use and consumption)	X		X	
NOM-012-SSA1-1993 (Sanitary requirements to be met by public and private water supply systems for human use and consumption)	X		X	
NOM-117-SSA1-1994 (Goods and services. Test method for the determination of cadmium, arsenic, lead, tin, copper, iron, zinc and mercury in food, drinking water and water purified by atomic absorption spectrometry)	X		X	
NOM-014-CONAGUA-2003 (Requirements for the artificial recharge of aquifers with treated wastewater)		X		X
NOM-143-SEMARNAT-2003 (Congenital waters)		X		X
TOTAL	18	10	19	9

Source: Own elaboration according to the text of the revised NOMS.

consequences of a regulation that is not updated in relation to the scientific evidence produced, in the face of the phenomenon of contamination, translates into a lack of progressiveness in the protection of the HRHE (COMDA 2017).

b. The HRWS has a greater development in terms of its elements (sufficiency, health, affordability, and accessibility), and especially its measurement parameters, which have been defined early on. On the other hand, the elements of the HRHE have been difficult to establish due to the multiplicity and lack of knowledge about its impacts and interactions, and it is imperative that the principle of prevention be diligently applied, as well as the principle of precaution, despite the fact that the consequences of the effects of certain pollutants, such as those under study, are not conclusive (Angles 2018).

c. The system of justiciability of human rights in Mexico still does not incorporate or fully recognize the responsibility of the states for violations or faults that have gone unpunished and therefore it is up to the Federal State to make a reparation (when due to failures in primary guarantees such as, e.g., the HRHE legislation, the subject that caused the damage does not assume the reparation), which occurs more frequently in the case of the protection of the HRWS elements, due to the aforementioned complexity of their causal relationships (Vázquez 2004).

Likewise, of the 28 analyzed NOMS, we found that nine are focused on pollution control, establishing maximum limits of different contaminants in the water that can cause damage to ecosystems or people when the water is intended for human consumption. Thus, the pollutants, whose maximums are established in the mentioned NOMs, are those presented in **Table II**.

From what is mentioned in Table II, it is evident that there is no specific protection of ecosystems against contamination caused by microplastics or waste derived from hydrocarbons since it does not

TABLE II. PREDOMINANT APPROACH OF CURRENT NOMS IN RELATION TO REGULATORY EMPHASIS ON POLLUTION AND HUMAN RIGHTS.

Official Mexican Standard (NOM)	Scope	Regulated pollutant
NOM-001-SEMARNAT-1996	It establishes the maximum permissible limits of pollutants in wastewater discharges into waters and national assets, in order to protect their quality and enable their uses, and is mandatory for those responsible for such discharges. It does not apply to water discharges from drains separated from rainwater.	**Basic pollutants:** fats and oils, floating matter, sedimentable solids, total suspended solids, biochemical oxygen demand, total nitrogen, total phosphorus, temperature and pH. **Pathogenic and parasitic pollutants:** fecal coliforms and helminth eggs. **Heavy metals and cyanides:** Arsenic, cadmium, copper, chrome, mercury, nickel, lead, zinc and cyanides.
NOM-002-SEMARNAT-1996	It establishes the maximum permissible limits of pollutants in wastewater discharges into urban or municipal sewage systems in order to prevent and control the pollution of water and national assets, as well as to protect the infrastructure of such systems, and is mandatory for those responsible for such discharges. (...) does not apply to the discharge of domestic, rain, or industrial wastewater, other than process wastewater and conducted by separate drainage.	Fats and oils, sedimentable solids, arsenic, cadmium, cyanide, copper, chromium, mercury, nickel, lead and zinc.
NOM-003-SEMARNAT-1997	It establishes the maximum permissible limits of contaminants for treated wastewater that is reused in services to the public, in order to protect the environment and the health of the population, and is mandatory for public entities responsible for its treatment and reuse.	**Basic pollutants:** fats and oils, floating matter, biochemical oxygen demand and total suspended solids **Pathogenic and parasitic pollutants:** fecal coliforms and helminth eggs
NOM-015-CONAGUA-2007	1.1 Protect the quality of water in aquifers. 1.2 Use rainwater and surface runoff to increase the availability of groundwater through artificial infiltration.	Fats and oils, floating matter, sedimentable solids, suspended solids, nitrogen, phosphorus, fecal coliforms.
NOM-014-CONAGUA-2003	It establishes the requirements to be met: water quality, operation and monitoring used in artificial aquifer recharge systems with treated wastewater.	Pathogenic microorganisms, contaminants regulated by NOM-127-SSA1-1994 and contaminants not regulated by Standard.
NOM-117-SSA1-1994,	It establishes the atomic absorption spectrometry test methods for the determination of cadmium, arsenic, lead, tin, copper, iron, zinc and mercury present in food, beverages, purified water and drinking water.	Cadmium, arsenic, lead, tin, copper, iron, zinc, and mercury.
NOM-014-CONAGUA-2003	It establishes the requirements to be met: water quality, operation and monitoring used in artificial aquifer recharge systems with treated wastewater.	Pathogenic microorganisms, contaminants regulated by standard NOM-127-SSA1-1994 and contaminants not regulated by standard.
NOM-143-SEMARNAT-2003	It establishes the requirements to be met: water quality, operation and monitoring used in artificial aquifer recharge systems with treated wastewater.	Total dissolved solids.

Source: Own elaboration, with information from the Mexican Official Standards.

establish specific parameters for their effects or the manifestations of their degradation in the analyzed NOMs. Although it is true that diverse aspects are analyzed as floating matter (which could account for the presence of microplastics), likewise the particles related to hydrocarbon contamination do not include in an integral manner the different substances that are detached from asphalt (such as polyaromatics hydrocarbons) or from the use of fuels for domestic use.

Hydrocarbons and plastics in tourist sites of Mexico: water bodies

Tables III and **IV** display recent studies about hydrocarbon and plastic pollution in water bodies of tourist sites in Quintana Roo (main pole of tourism development in Mexico), Veracruz (middle tourist importance, with important presence of oil industry), and San Luis Potosí (recent tourist interest due to water bodies).

As we can see in **Table III**, recent studies show that oil pollution is an important environmental concern. Veracruz reefs and rivers (Narciso-Ortiz et al. 2020) exceed the limits for the discharge of waste waters from the oil industry (15 ppm in fresh water and 40 ppm in sea water) (SEMARNAT 2005). This fact is dramatic since the concentration of pollutants in water bodies is expected to be less than 15 ppm. In some sinkholes in Quintana Roo, the concentration of a sole hydrocarbon detected (naphthalene in Cozumel: 10 ppm) is very close to 15 ppm. However, the absence of a regulation regarding hydrocarbons in water bodies (since regulations are only focused on waters at the end of the industrial processes, before being delivered to the water body) could suppose a sub estimation of hydrocarbons. Mexico does not currently have a standard for permissible limits of hydrocarbons in water bodies.

Regarding plastic pollution the scenario is worse: large plastic debris breaks down to form mega, micro, and nano plastics (Alimi et al. 2018, Zhao et al. 2015). However, the scarce studies available show nurdles (small pieces of plastics used in industrial processes) in beaches of Quintana Roo, where no plastics industries are located). Nurdles are being drawn from other regions, so the local problem is a reflection of global problem.

In San Luis Potosí no studies have been carried out about plastic pollution up to nowadays. However, the important presence of the automotive industry, in addition to the common use of plastics in our culture, requires additional research regarding plastic degradation. If plastic pollution is a global problem, there should be a particular study of the San Luis Potosí region. An explanation is about the kind of science that is used. Neoliberal science is focused on mercantile solutions in the short term. Here, it is necessary to think of another kind of science. An important distinction must be made between neoliberal science, which is a paradigm of public policy, and science which can be called normal. Normal science follows the scientific method and considers the observation of all evidence to propose a hypothesis and carry out experiments to reach universally valid conclusions in the state of the art.

In the case of the so-called neoliberal science, which is a public policy paradigm related to the changes that the world has undergone because of the re-concentration of power and the commodification of all spheres of life since the beginning of the neoliberal attack that began during the Ronald Reagan and Margaret Thatcher administrations in the early 1980s, it has had profound effects on the modes and processes of science production in contemporary societies. The scientific-technological paradigm driven by the mercantile logic of neoliberal science is the total denial of ethical responsibility. Neoliberal science has become an extraordinary risk to life (Lander 2008) due to environmental or social concerns that are not in its focus. The neoliberal science key feature is a very small application of science with scarce articulation with social policies aimed at combating poverty, hunger, and social exclusion (Jover 2020). In consequence, it generates many environmental problems for most people due to economic maximum utility obtained by a few people.

Since plastic pollution could originate substantial problems to the vast majority of the population, the precautionary principle (which is used when considerable scientific uncertainties exist) and citizen science (a useful tool for gathering great amounts of data across large spatial scales) could be considered (Tunell et al. 2020). Citizen science is the process through which people in general contribute actively to scientific projects (Cochero 2018). In this process, citizens are volunteers in scientific projects that interest them, for example in relation with environmental problems. Citizen science is relevant in sustainable development goals for the United Nations (Fritz et al. 2019) due to the growing concentration of scientific knowledge in a few groups of power.

The bioaccumulation of hydrocarbons and plastics (two pollutants considered in this work) is

TABLE III. HYDROCARBON POLLUTION IN WATER BODIES OF TOURISTIC SITES: QUINTANA ROO, VERACRUZ, AND SAN LUIS POTOSÍ.

Hydrocarbon pollution			
Year, State	Site	Hydrocarbon	Reference
2015, Quintana Roo	Sinkholes: Cancún City (A, B, C) (21° 11’ 25.5” N, 86° 50’ 14.9” W; 21° 9’ 41.3” N, 86° 51’ 0.81” W; 21° 8’ 19” N, 86° 51’ 39.35” W); Puerto Morelos (D, E) (20° 50’ 15.96” N, 87° 01’ 24.78” W; 20º 50’ 53.7” N, 86º 52’ 33.98” W); Riviera Maya (F, G) (20° 39’ 43.59”, 87° 4’ 7.25” W; 20° 12’ 31.26” N, 87° 28’ 21.81” W); Cozumel (H) (20° 26’ 35” N, 86° 59’ 40” W); Chetumal (I, J) (18° 46’ 2.37” N, 88° 18’ 24.92” W; 18° 30’ 50.98” N, 88° 25’ 27.29” W); Holbox (K) (21° 32’ 16.0” N, 87° 13’ 12.0” W).	**Anthracene** (A: 8 ppm, H: 4.2 ppm). **Benzene** (F: 1 ppm). **Benzo (a), pyrene** (F: 1.3 ppm). **Phenanthrene** (B: 6.2 ppm, J: 1 ppm). **Pyrene** (I: 2.1 ppm), naphthalene (H: 10.3 ppm).	Narciso-Ortiz et al. 2019.
2018, Quintana Roo	Beaches: Puerto Juárez (21° 11’ 2.80” N, 86° 48’ 25.30” W); Puerto Cancún (21° 9’ 41.80” N, 86° 48’ 29.50” W); Perlas (21° 7’ 43.96” N, 86° 44’ 55.77” W); Delfines (21° 03’ 35.4” N, 86° 46’ 44.6” W); Oasis Palm (21° 8’ 38.80” N, 86° 47’ 10.60” W).	**Benzo(a)pyrene** (Puerto Cancun: 1.14 ppm). **Eicosane** (Perlas: 0.32 ppm, Puerto Cancun 1.55 ppm, Delfines: 0.24 ppm). **Heneicosane** (Oasis Palm: 0.58 ppm, Puerto Juarez: 0.34 ppm, Puerto Cancun: 1.11 ppm Perlas: 0.31 ppm).	Sandoval-Herazo, 2020
2018, Veracruz	Reefs and rivers in Veracruz state: Arrecife Sacrificios (19° 10’ 38.233” N, 96° 5’ 32.507” W); Arrecife de en Medio (19° 6’ 24.090” N, 95° 56’ 17.574” W); Arrecife Gallega (19° 13’ 19.235” N, 96° 7’ 37.558” W); Arrecife Punta Gorda (19° 14’ 41.970” N, 96°, 10, 32.942” W); Río Jamapa (19° 05’ 39.0” N, 96° 08’ 04.3” W); Río La Antigua (19° 19’ 08.4” N, 96, 19’ 23.2” W); Río Actopan-Chachalacas (19° 25’ 02.3” N, 96° 19’ 17.7” W); Río Papaloapan (18° 36’ 47.2” N, 95° 39’ 7.64” W).	**Dotriacontane** (Río Actopan-Chachalacas: 51 ppm, Arrecife Gallega: 67 ppm). **Hexatriacontane** (Río Actopan-Chachalacas: 78 ppm, Arrecife Gallega: 66 ppm). **Octatriacontane** (Río Actopan-Chachalacas: 123 ppm). **Tetracontane** (Río Actopan-Chachalacas: 155 ppm). **Tetratriacontane** (Arrecife Punta Gorda: 134 ppm, Río Actopan-Chachalacas: 18 ppm).	Narciso-Ortiz, 2019
2018, Veracruz	Beaches: Regatas (19° 11’ 44.86” N, 96° 7’ 41.74” W); Playón de Hornos (19° 11’ 5.17” N, 96° 7’ 25.88” W); Villa del Mar (19° 10’ 52.15”, N 96° 7’ 25.92” W); Martí (19° 10’ 32.45” N, 96° 7’ 12.04” W); La Bamba (19° 9’ 50.67” N, 96° 6’ 12.48” W).	**Azulene** (Regatas: 3.7 ppm, Martí: 7.8 ppm, Playón de Hornos: 12.7 ppm, La Bamba: 4.6 ppm). **Benzo(a)pirene** (Playón de Hornos: 1.7 ppm, Villa del Mar: 1 ppm)	Sandoval Herazo, 2019

TABLE III. HYDROCARBON POLLUTION IN WATER BODIES OF TOURISTIC SITES: QUINTANA ROO, VERACRUZ, AND SAN LUIS POTOSÍ.

2019, Veracruz	Lagoon: The Sistema Lagunar Alvarado is located between 18° 44’ 00”-18° 52’ 15” N, and 95° 44’ 00”-95° 57’ 00” W. The Sistema Lagunar Mandinga is located between 19° 00’-19° 06’ N and 6° 02’-96° 06’ W.	Regarding its presence, the dominant PAHs are formed by four rings (pyrolytic) such as **chrysene, benzo[a]anthracene, benzo[k]fluoranthene** and **benzo[b] fluoranthene.** (Alvarado: 2 ppm, Mandinga: 5.7 ppm).	Vázquez-Botello et al. (2019) (only total PAH’s are reported in this work)
2019, San Luis Potosí	Rivers and lagoon: Laguna de la Media Luna (21° 51’ 39.5” N, 100° 01’ 37.5” W); Puente de Dios (21° 55’ 50.4” N, 99° 24’ 59.5” W); Río Tampaón (21° 47’ 43.4” N, 99° 08’ 50.9” W).	**Eicosane, pentacosane and octacosane** with concentrations higher than Mexican normative for discharge of produced waters of the oil industry.	Lizardi-Jiménez et al. 2019

A, B, C, D, E, F, G, H, I, J, K are sample points in Quintana Roo.

TABLE IV. PLASTIC POLLUTION IN WATER BODIES OF TOURISTIC SITES: QUINTANA ROO, VERACRUZ AND SAN LUIS POTOSÍ.

Plastic pollution			
Year, State	Site	Type of plastic	Reference
2019, Quintana Roo	Beaches: Xpu Ha (20° 28' 23.95" N, 87° 15' 26.3" W). Xcacel (20° 20' 21.959" N, 87° 20' 49.185"W). Sian Kaan (19° 54' 23.8" N, 87° 25' 55.624" W)	31-100 nurdles collectes in 10 min by citizens. Nurdles can be made of polyethylene, polypropylene, polystyrene, polyvinyl chloride, or other plastic types	Tunnell et al. 2020
2019, Veracruz	Beaches: Boca del Río (19º 06’ 17.60” N, 96º 05’ 55.0” W); Mocambo (19º 07’ 57.5” N, 96º 06’ 2.73” W); Pelícano (19º 08’ 49.6” N, 96º 05’ 43” W); La Bamba (19º 09’ 49.01” N, 96º 14’ 53” W); Martí (19º 10’ 26.96” N, 96º 07’ 10.67” W); Villa del Mar (19º 10’ 55.20” N, 96º 07’ 26.70” W).	Microplastics range 32 to 784 µm. Macroplastics (4 to 8 per m2)	Narciso-Ortiz et al. 2020
2020, San Luis Potosí,	Absence of local diagnosis, despite having one of the main pollution factors: industrial development.	Automotive plastics but no studies carried out until now.	

not included in the normative. That is because of the series of omissions analyzed, the absence of a regulatory framework under the guidance of a water law that recognizes the ecosystemic function of water bodies, i.e., their impact on the HRHE, will significantly limit the issuance of regulations and NOMs that prevent pollution generated by industrial and even tourist activities, which translates into a failure of the Mexican State to establish adequate guarantees. Subsequently, such parameters were contrasted with those established by current regulations and correlated with Article 4 of the

Mexican Constitution, as well as the international instruments that substantiate the HRHE. In that sense, the Comisión Nacional de Derechos Humanos (National Commission for Human Rights), in its general recommendation 32/2018 (Sobre las violaciones a los derechos humanos a la salud [On human rights violations to health]), states that the failure to update the NOMs in accordance with the standards of the World Health Organization (which have been considered by various specialized sources as the most protective) must be considered as a failure to comply with the principle of progressivity related to human rights, especially environmental rights (CNDH 2018).

Bioremediation of hydrocarbons and plastics

Hydrocarbon remediation by microorganisms is a well-studied issue in which our research group has expertise. Residual diesel and suspended solids (SS) that include microbial consortium performance are presented in Figure 1. SS initial concentration was 0.85 g/L and the maximum concentration obtained was 2.9 ± 0.04 g/L after 14 d of culture time. Diesel was reduced from 17. 6 g/L to 0. Then, the consortium growing in this bioreactor could remove the hydrocarbon from several oil pollution sites. Bioremediation (airlift bioreactors as an example) is an environmentally approachable alternative used for the sanitation of water polluted by hydrocarbons, as native microorganisms are capable of converting hydrocarbons into carbon dioxide in aqueous phase. In some cases, these microorganisms work together (known as consortia) in the degradation of pollutants. Some studies have shown that consortia can degrade hydrocarbons more efficiently. Our research group develops bioremediation by means of pneumatic bioreactors using microbial consortia (Lizardi-Jiménez et al. 2015, Castañeda-Chávez et al. 2020, León-Borges et al. 2020, Narciso et al. 2020). The following are examples of consortia that have demonstrated their ability to degrade hydrocarbons: (a) *Xanthomonas* sp., *Acinetobacter bouvetii*, *Shewanella* sp., and *Aquamicrobium lusatiense* (Narciso-Ortiz et al. 2020) are able to degrade hexadecane, triacontane, tetracontane and a diversity of hydrocarbons; (b) *Enterobacter*, *Serratia*, *Escherichia*, *Proteus*, and *Klebsiella* (León-Borges et al. 2020) are able to degrade naphthalene, phenanthrene, benzo(a)pyrene, hexadecane and a diversity of hydrocarbons; (c) *Pseudomonas* sp., *Vibrio diplococcus*, and *Enterobacter* sp. (Lizardi-Jiménez et al. 2015) are able to degrade naphthalene, phenanthrene, benzo(a)pyrene, eicosane, heneicosane and a diversity of hydrocarbons, and (d) *Proteobacteria*

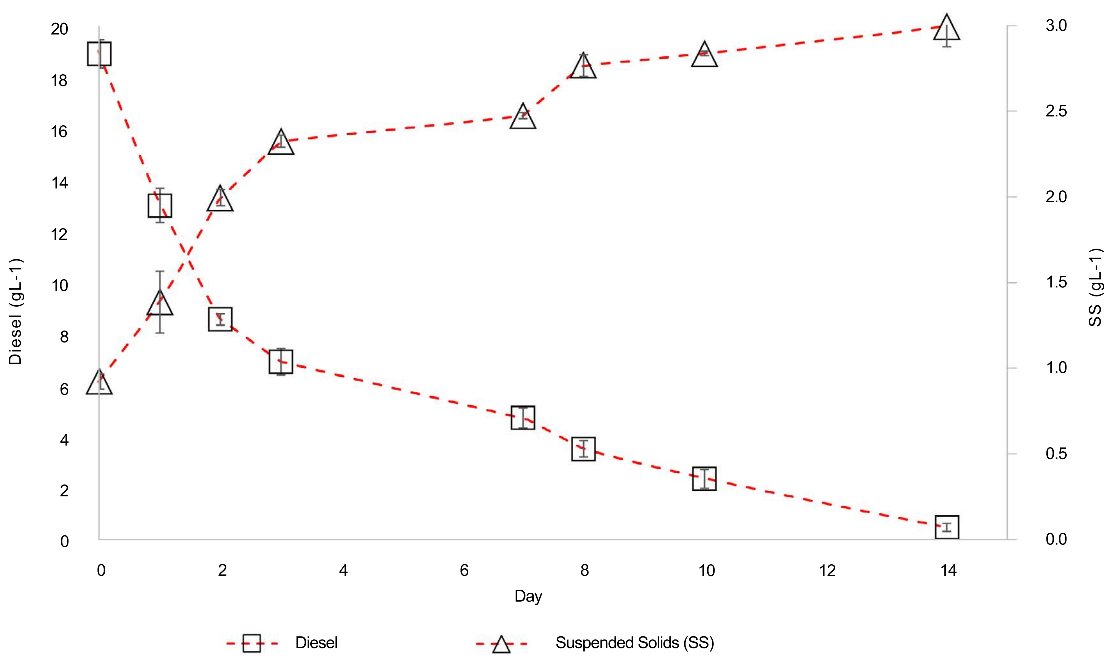

Fig. 1. Diesel uptake by microbial consortium throughout the 14-days culture.

sp., *Planctomycetes* sp., *Actinobacteria* sp., *Bacteroidetes* sp., *Marinobacter* sp., and *Alcanivorax* sp. (Castañeda-Chávez et al. 2020) are able to degrade different types of hydrocarbons such as hexadecane, pyrene, phenanthrene and diesel.

Our group has developed biotechnological proposals such as the degradation of hydrocarbons in concentrations found in tourist areas (such as Quintana Roo, Veracruz and San Luis Potosí) using microbial consortia and various bioreactors capable of carrying out this process.

Other works from our research group and other groups (Khan et al. 2017, Nápoles-Álvarez et al. 2017) have demonstrated that oil pollution could be treated through remediation. However, oil pollution remains a significant environmental concern due to its complexity since it encompasses not only technical aspects. Political factors and stakeholders (citizens) need to be considered through citizen science. In the case of plastic degradation, information is scarce. Some recent studies have shown that microorganisms can degrade plastics in the environment, although it is not very clear to what extent (Danso et al. 2019). In a recent work (Giacomucci et al. 2020) polyvinyl chloride (PVC) films treated with a marine bacterial consortium were able to reduce 11.7 % the plastic's weight in seven months of culture in anaerobic microcosms. *Achromobacter xylosoxidans* affect polyethylene. Similarly, *Anoxybacillus rupiensis* Ir3, isolated from hydrocarbon-polluted soil, has capacity to utilize aromatic compounds as carbon sources followed by their degradation (Ahmed et al. 2018). For plastic degradation, our research group work uses microbiota obtained from soil of the Las Palomas forest (21° 3' 49.55" N, 101° 13' 24.04" W). In our previous work (Narciso et al. 2020), polyethylene terephthalate (PET) showed cracks, cavities, erosion, and pinholes on the surface, which were attributed to degradation by microorganisms (using FTIR spectroscopy). We could identify that the isolated bacterial strain *Bacillus muralis* showed the best degradation ability. Our work is focused on the bioremediation of low-biodegradability plastics. On the other hand, bioplastics such as polyhydroxyalkanoates (PHAs), including polyhydroxy butyrate (PHB) and polylactic acid, could be an essential contribution to the reduction of plastic pollution due to their biodegradability. Biotechnology can provide some promising technical solutions to reduce hydrocarbon and plastic contamination. However, the scientific approach needs to be revised due to the magnitude of the environmental concerns regarding these materials. Therefore, more than remediation and prevention are needed to address this issue, together with NOMs focused on environmental problems, particularly hydrocarbons, and microplastics.

CONCLUSIONS

NOMs are an efficient way for the federal regulatory framework that guarantees the HRHE to qualitatively limit the actions of companies, producers or providers of water-related services. However, these standards do not address the water problem integrally, so this guarantee is partial.

Another aspect that must be balanced is that of prevention, because the NOMs analyzed in this work regulate mainly two aspects: the use of water, seeking its rationing and the reduction of its contamination; and, on the other hand, the control of its contamination, being the latter the least developed aspect. Reduction or prevention of hydrocarbon and plastic pollution in water bodies in México were absent in the regulations studied extensively in our work (**Tables I** and **II**). However, our work shows oil and plastic pollution in the water bodies in Quintana Roo, Veracruz and San Luis Potosí (**Table III**). The type of hydrocarbons and plastics found in our study could be degraded in 14 days and seven months, respectively.

Given the evidence of contamination by microplastics and hydrocarbons, it is necessary to issue specialized NOMs on the matter, since daily practices deteriorate the quality of water and, therefore, health and the availability of it as components of the HRWS.

Likewise, it is important to protect the HRHE by issuing NOMs that limit the presence of contamination by the studied pollutants in water, to properly and progressively apply the elements of this right, especially the precautionary principle, in relation to the damage that this type of pollution can cause to human health and the environment.

LIST OF RELATED OFFICIAL MEXICAN STANDARDS

NOM-143-SEMARNAT-2003. Que establece las especificaciones ambientales para el manejo de agua congénita asociada a hidrocarburos (Environmental specifications for the management of congenital water associated with hydrocarbons). Secretaría de Medio Ambiente y Recursos Naturales (http://dof.gob.mx/nota_to_doc.php?codnota=789183)

NOM-001-SEMARNAT-1996. Que establece los límites máximos permisibles de contaminantes en las descargas de aguas residuales en aguas y bienes nacionales (Maximum permissible limits of pollutants in wastewater discharges into waters and national assets). Secretaría de Medio Ambiente y Recursos Naturales (http://dof.gob.mx/nota_to_doc.php?codnota=789183)

NOM-002-SEMARNAT-1996. Límites máximos permitidos de contaminantes en descargas de aguas residuales a sistemas de alcantarillado urbanos o municipales (Maximum permissible limits of pollutants in wastewater discharges to urban or municipal sewage systems) Secretaría de Medio Ambiente y Recursos Naturales (https://www.dof.gob.mx/nota_detalle.php?codigo=5446671&fecha=03/08/2016)

NOM-003-SEMARNAT-1997. Que establece los límites máximos permisibles de contaminantes para aguas residuales tratadas que se reutilizan en servicios al público (Establishes the maximum permissible limits of contaminants for treated wastewater that is reused in services to the public). Secretaría de Medio Ambiente y Recursos Naturales (https://www.dof.gob.mx/nota_detalle.php?codigo=5446671&fecha=03/08/2016)

NOM-012-SSA1-1993. Requisitos sanitarios que deben cumplir los sistemas públicos y privados de suministro de agua para uso y consumo humano (Sanitary requirements to be met by public and private water supply systems for human use and consumption). Secretaría de Salud (http://www.salud.gob.mx/unidades/cdi/nom/013ssa13.html)

NOM-013-SSA1-1993. Requisitos sanitarios que debe cumplir el depósito de un vehículo de transporte y distribución de agua para uso y consumo humano (Sanitary requirements to be met by the tank of a vehicle for the transport and distribution of water for human use and consumption). Secretaría de Salud (http://www.comapareynosa.gob.mx/resources/other/reglamentos/NOM-013-SSA1-1993.pdf)

NOM 014-SSA1-1993. Procedimientos sanitarios para el muestreo de agua para uso y consumo humano en sistemas públicos y privados de abastecimiento de agua (Sanitary procedures for the sampling of water for human use and consumption in public and private water supply systems). Secretaría de Salud (http://www.salud.gob.mx/unidades/cdi/nom/014ssa13.html)

NOM-001-CONAGUA-1995. Sistemas de alcantarillado sanitario: especificaciones de estanqueidad (Sanitary sewer systems - watertightness specifications) Comisión Nacional del Agua (http://legismex.mty.itesm.mx/normas/cna/cna001.pdf)

NOM-002-CNA-1995. Suministro de agua potable en el hogar: especificaciones y métodos de prueba (Household drinking water supply - specifications and test methods). Secretaría de Medio Ambiente y Recursos Naturales (https://www.ecolex.org/details/legislation/nom-002-cna-1995-especificaciones-de-toma-domiciliaria-para-abastecimiento-de-agua-potable-lex-faoc050671/)

NOM-003-CNA-1996. Requisitos durante la construcción de pozos de extracción de agua para prevenir la contaminación de acuíferos (Requirements during the construction of water extraction wells to prevent contamination of aquifers). Secretaría de Medio Ambiente y Recursos Naturales (http://diariooficial.gob.mx/nota_detalle.php?codigo=4882660&fecha=12/06/1998)

NOM-004-CNA-1996. Requisitos para la protección de acuíferos durante el mantenimiento y rehabilitación de pozos de extracción de agua y para el cierre de pozos en general (Requirements for the protection of aquifers during the maintenance and rehabilitation of water extraction wells and for the closure of wells in general). Secretaría de Medio Ambiente y Recursos Naturales (https://www.gob.mx/cms/uploads/attachment/file/94212/NOM-004-CONAGUA-1996.pdf)

NOM-005-CNA-1996. Fluxímetros, especificaciones y métodos de prueba (Fluxmeters - specifications and test methods). Secretaría de Medio Ambiente y Recursos Naturales (https://www.gob.mx/cms/uploads/attachment/file/94214/NOM-006-CONAGUA-1997.pdf)

NOM-006-CONAGUA-1997. Tanques sépticos prefabricados: especificaciones y métodos de prueba (Prefabricated septic tanks - specifications and test methods). Comisión Nacional del Agua (http://www.ordenjuridico.gob.mx/Documentos/Federal/wo69276.pdf)

NOM-007-CONAGUA-1997. Requisitos de seguridad para la construcción y operación de tanques de agua (Safety requirements for the construction and operation of water tanks). Comisión Nacional del Agua (https://www.dof.gob.mx/nota_detalle.php?codigo=5394025&fecha=28/05/2015)

NOM-008-CONAGUA-1998. Duchas utilizadas en la higiene corporal: especificaciones y métodos de prueba (Showers used in body hygiene - specifications and test methods). Comisión Nacional del Agua (https://www.cclnom.com/pdf/NOM-008-CNA-1998.pdf)

NOM-009-CONAGUA-2001. Inodoros para uso sanitario, especificaciones y métodos de prueba (Toilets for sanitary use - specifications and test methods). Comisión Nacional del Agua (http://dof.gob.mx/nota_detalle.php?codigo=5097702&fecha=03/07/2009&print=true)

NOM-010-CONAGUA-2000. Válvula de admisión y válvula de descarga del tanque del inodoro: especificaciones y métodos de prueba (Intake valve and toilet tank discharge valve - specifications and test methods) Comisión Nacional del Agua (https://dof.gob.mx/nota_detalle.php?codigo=689854&fecha=02/09/2003)

NOM-011-CONAGUA-2000. Conservación del recurso hídrico. Establece las especificaciones y el método para determinar la disponibilidad anual promedio de aguas nacionales (Conservation of the water resource. Establishes the specifications and the method for determining the average annual availability of national waters). Comisión Nacional del Agua (https://www.dof.gob.mx/nota_detalle.php?codigo=5353477&fecha=23/07/2014)

NOM-013-CONAGUA-2000. Redes de distribución de agua potable: especificaciones de sellado y métodos de prueba (Drinking water distribution networks - sealing specifications and test methods). Comisión Nacional del Agua (http://dof.gob.mx/nota_detalle_popup.php?codigo=5105753)

NOM-014-CONAGUA-2003. Requisitos para la recarga artificial de acuíferos con aguas residuales tratadas (Requirements for the artificial recharge of aquifers with treated wastewater) Comisión Nacional del Agua (http://www.conagua.gob.mx/conagua07/contenido/documentos/NOM-014-CONAGUA-2003.pdf)

NOM-014-CONAGUA-2003. Requisitos para la recarga artificial de acuíferos con aguas residuales tratadas (Requirements for the artificial recharge of aquifers with treated wastewater). Comisión Nacional del Agua (http://www.conagua.gob.mx/conagua07/contenido/documentos/NOM-014-CONAGUA-2003.pdf)

NOM-015-CONAGUA-2007. Infiltración de agua artificial en acuíferos: características y especificaciones de las obras y el agua (Artificial water infiltration into aquifers - characteristics and specifications of the works and water). Comisión Nacional del Agua (http://www.dof.gob.mx/normasOficiales/3801/semarnat1/semarnat1.html)

NOM-041-SSA1-1993. Bienes y servicios. Agua embotellada purificada. Especificaciones sanitarias (Goods and services. Purified bottled water. Sanitary specifications). Secretaría de Salud (http://www.salud.gob.mx/unidades/cdi/nom/041ssa13.html)

NOM-112-SSA1-1994. Bienes y servicios. Determinación de bacterias coliformes. Técnica del número más probable (Goods and services. Determination of coliform bacteria. Most probable number technique). Secretaría de Salud (http://www.salud.gob.mx/unidades/cdi/nom/112ssa14.html)

NOM-117-SSA1-1994. Bienes y servicios. Método de prueba para la determinación de cadmio, arsénico, plomo, estaño, cobre, hierro, zinc y mercurio en alimentos, agua potable y agua purificada por espectrometría de absorción atómica (Goods and services. Test method for the determination of cadmium, arsenic, lead, tin, copper, iron, zinc and mercury in food, drinking water and water purified by atomic absorption spectrometry). Secretaría de Salud (http://www.salud.gob.mx/unidades/cdi/nom/117ssa14.html)

NOM-127-SSA1-1994. Salud Ambiental. Agua para uso y consumo humano. Límites de calidad permisibles y tratamientos a los que debe someterse el agua para su depuración (Environmental health. Water for human use and consumption. permissible quality limits and treatments to which the water must be submitted for its purification). Secretaría de Salud (http://www.dof.gob.mx/nota_detalle.php?codigo=2063863&fecha=31/12/1969#)

NOM-143-SEMARNAT-2003. Aguas congénitas (Congenital waters). Secretaría de Medio Ambiente y Recursos Naturales (https://biblioteca.semarnat.gob.mx/janium/Documentos/Ciga/agenda/PPD02/DO561.pdf)

NOM-160-SSA1-1995. Bienes y servicios. Buenas prácticas para la producción y venta de agua purificada (Goods and services. Good practices for the production and sale of purified water). Secretaría de Salud (http://www.salud.gob.mx/unidades/cdi/nom/160ssa15.html)

NOM-201-SSA1-2002. Productos y servicios. Agua y hielo para consumo humano, envasados y a granel. Especificaciones sanitarias (Products and services. Water and ice for human consumption, packaged and in bulk. Sanitary specifications.) Secretaría de Salud (http://www.salud.gob.mx/unidades/cdi/nom/201ssa12.html)

ACKNOWLEDGMENTS

We thank the Consejo Nacional de Ciencia y Tecnología (CONACyT) for the grant Cátedras-CONACYT-

UASLP 466, and the Universidad Autónoma de San Luis Potosí (UASLP) for the grant FAI 2019: C19-FAI-05-49.49. We also acknowledge the CIACYT National Laboratory.

REFERENCES

Ahmed T., Shahid M., Azeem F., Rasul I., Shah A., Noman N., Hammed A. and Muhammad S. (2018). Biodegradation of plastics: Current scenario and future prospects for environmental safety. Environmental Science and Pollution Research 25, 7287-7298. https://doi.org/10.1007/s11356-018-1234-9

Alimi O.S., Farner Budarz J., Hernandez L.M., Tufenkji N. (2018). Microplastics and nanoplastics in aquatic environments: aggregation, deposition, and enhanced contaminant transport. Environmental Science Technology 52(4), 1704-1724. https://doi.org/10.1021/acs.est.7b05559

Angles M. (2018). El principio precautorio en México: plaguicidas, medio ambiente y salud. In: Bioética y bioderecho (Chan S. and Ibarra F., Eds.). Instituto de Investigaciones Jurídicas, Universidad Nacional Autónoma de México, Ciudad de México, 439-459.

Baldenegro M.E.R., Alvarado J.O. and Villa J.M.Q. (2019). Turismo equilibrado. Competividad y sustentabilidad de las ciudades turísticas de México. Pearson, México, 216 pp.

Castañeda-Chávez M.R., Isidoro-Pío A., Lango-Reynoso F., and Lizardi-Jiménez M.A. (2020). Bioreactors for the remediation of hydrocarbon-polluted water of the Bitzal River, a place of environmental emergency due to the death of manatees. Environmental Pollution 266, 115171. https://doi.org/10.1016/j.envpol.2020.115171

Cochero J. (2018). AppEAR: una aplicación móvil de ciencia ciudadana para mapear la calidad de los hábitats acuáticos continentales. Ecología Austral 28(2), 467-479. https://doi.org/10.25260/EA.18.28.2.0.686

COMDA (2017). Informe sobre violaciones a los derechos humanos al agua potable y saneamiento en México. Coalición de Organizaciones Mexicanas por el Derecho al Agua, Ciudad de México, México, 90 pp. [online]. https://www.researchgate.net/profile/Celia-Fernandez-Aller/publication/318259363_La_exigibilidad_de_los_derechos_humanos_al_agua_y_al_saneamiento/links/595f338eaca2728c1146ab83/La-exigibilidad-de-los-derechos-humanos-al-agua-y-al-saneamiento.pdf 05/06/2023.

CNDH (2018). Recomendación General 32/2018 sobre las violaciones a los derechos humanos a la salud, un nivel de vida adecuado, medio ambiente sano, e información pública ocasionadas por la contaminación atmosférica urbana. Comisión Nacional de Derechos Humanos, Ciudad de México, 2018, 24 pp. [online]. https://www.cndh.org.mx/sites/default/files/doc/Recomendaciones/Generales/RecGral_032_Anexo.pdf

Danso D., Chow J. and Streit W. R. (2019). Plastics: Environmental and biotechnological perspectives on microbial degradation. Applied and Environmental Microbiology 85(19), e01095-19. https://doi.org/10.1128/AEM.01095-19

Fritz S., See L., Carlson T., Haklay M. M. Oliver J. L., Fraisl D. and West S. (2019). Citizen science and the United Nations sustainable development goals. Nature Sustainability 2(10), 922-930. https://doi.org/10.1038/s41893-019-0390-3

Giacomucci L., Raddadi N., Soccio M., Lotti N. and Fava F. (2020). Biodegradation of polyvinyl chloride plastic films by enriched anaerobic marine consortia. Marine Environmental Research, 104949. https://doi.org/10.1016/j.marenvres.2020.104949

Gómez-Reyes R., Medina-Moreno S.A., Jiménez-González A. and Lizardi-Jiménez M.A. (2017). Aislamiento y análisis cualitativo de biomasa microbiana fúngica degradadora de hidrocarburos de un cenote de Quintana Roo. Revista Internacional de Contaminación Ambiental 33, 53-61. https://doi.org/10.20937/RICA.2017.33.esp01.05

Gutiérrez R. (2010). El derecho al agua y su relación con el medio ambiente. In: Derechos humanos y medio ambiente (Carmona J.U. and Hori J.M., Eds.). Instituto De Investigaciones Jurídicas, Universidad Nacional Autónoma de México/Secretaría de Medio Ambiente y Recursos Naturales, Ciudad de México, México, 123-143 [online]. https://agua.org.mx/wp-content/uploads/2020/01/El-derecho-al-agua-y-su-relaci%C3%B3n-con-el-medio-ambiente.pdf

Hayasaka-Ramírez S. and Ortiz-Lozano L. (2014). Anthropogenic pressure indicators associated with vessel groundings on coral reefs in a marine protected area. Ciencias Marinas 20, 237-249. https://doi.org/10.1590/S0080-6234201400005000022

Jover J.N. (2020). Pensar la ciencia en tiempos de la COVID-19. Anales de la Academia de Ciencias de Cuba 10(2), 979. http://revistaccuba.sld.cu/index.php/revacc/article/view/797

Khan A.H.A., Tanveer S., Alia S., Anees M., Sultan A., Iqbal M. and Yousaf S. (2017). Role of nutrients in bacterial biosurfactant production and effect of biosurfactant production on petroleum hydrocarbon biodegradation. Ecological Engineering 104, 158-164. https://doi.org/10.1016/j.ecoleng.2017.04.023

Koshti R., Mehta L. and Samarth N. (2018) Biological recycling of polyethylene terephthalate: A mini-review. Journal of Polymer and the Environment 26(8), 3520-3529. https://doi.org/10.1007/s10924-018-1214-7

Lander E. (2008). Neoliberal science. Tabula Rasa (9), 247-284. https://revistas.unicolmayor.edu.co/index.php/tabularasa/article/view/1494

Lear G., Kingsbury J.M. and Franchini S. (2021). Plastics and the microbiome: Impacts and solutions. Environmental Microbiome 16 (2), 1-19. https://doi.org/10.1186/s40793-020-00371-w

León-Borges J.A., Viveros-Jiménez F., Rodríguez-Mata A.E., and Lizardi-Jiménez M.A. (2020). Hydrocarbon contamination patterns in the cenotes of the Mexican Caribbean: The application of principal component analysis. Bulletin of Environmental Contamination and Toxicology 105(5), 758-763. https://doi.org/10.1007/s00128-020-03026-1

HCDU (2020). Ley de Infraestructura de la Calidad. H. Congreso de la Unión, Ciudad de México, México, 63 pp. [online]. https://www.diputados.gob.mx/LeyesBiblio/pdf/LICal_010720.pdf

Lizardi-Jiménez M.A., Leal-Bautista R.M., Ordaz A. and Reyna-Velarde R. (2015). Airlift bioreactors for hydrocarbon water pollution remediation in a tourism development pole. Desalination and Water Treatment 54(1), 44-49. https://doi.org/10.1080/19443994.2013.876670

Lusher A.L., Burke A., O'Connor I. and Officer R. (2014). Microplastic pollution in the Northeast Atlantic Ocean: validated and opportunistic sampling. Marine Pollution Bulletin 88(1-2), 325-333. https://doi.org/10.1016/j.marpolbul.2014.08.023

Martínez-Salinas R.I., Leal M.E., Batres-Esquivel L.E., Domínguez-Cortinas G., Calderón J., Díaz-Barriga F. and I. Pérez-Maldonado N. (2010). Exposure of children to polycyclic aromatic hydrocarbons in Mexico: Assessment of multiple sources. International Archives of Occupational and Environmental Health 83(6), 617-23. https://doi.org/10.1007/s00420-009-0482-x

Meo S.A., AlMutairi F.J., Alasbali M.M., Alqahtani T.B., AlMutairi S.S., Albuhayjan R.A. and Ahmed N. (2018). Men's health in industries: Plastic plant pollution and prevalence of pre-diabetes and type 2 diabetes mellitus. American Journal of Men's Health 12(6), 2167-72. https://doi.org/10.1177/1557988318800203

Metcalfe C.D., Beddows P.A., Bouchot G.G., Metcalfe T.L., Li H. and van Lavieren H. (2011). Contaminants in the coastal karst aquifer system along the Caribbean coast of the Yucatan Peninsula, Mexico. Environmental Pollution 159(4), 991-997. https://doi.org/10.1016/j.envpol.2010.11.031

Nápoles-Álvarez J., Ábalos-Rodríguez A., Rodríguez-Pérez S., Sánchez-Vázquez V. and Gutiérrez-Rojas M. (2017). Airlift bioreactor using a bacterial mixed culture improves hydrocarbon degradation in contaminated salty water. Desalination and Water Treatment 86, 28-34. https://doi.org/10.5004/dwt.2017.21307

Narciso-Ortiz L. (2019). Cuencas y sistemas arrecifales del Golfo de México en el Estado de Veracruz: contaminación por hidrocarburos y biorremediación. M.Sc. thesis. Instituto Tecnológico Superior de Tierra Blanca, Veracruz, México, 75 pp.

Narciso-Ortiz L., Vargas-García K.A., Vázquez-Larios A.L., Quiñones-Muñoz T.A., Hernández-Martínez R. and Lizardi-Jiménez M.A. (2020). Coral reefs and watersheds of the Gulf of Mexico in Veracruz: Hydrocarbon pollution data and bioremediation proposal. Regional Studies in Marine Science 35, 101155. https://doi.org/10.1016/j.rsma.2020.101155

Patricio Silva A.L. (2020). Role of microorganisms in ecoremediation. In: Handbook of microplastics in the environment (Rocha-Santos T., Costa M. and Mouneyrac C., Eds.). Springer Cham, 1-39. https://doi.org/10.1007/978-3-030-10618-8_54-1

Rodríguez-Gómez C.F., Aké-Castillo J.A. and Campos-Bautista G. (2013). Productividad primaria bruta y respiración planctónica en el parque nacional sistema arrecifal veracruzano. Hidrobiologica 23, 143-153.

Sandoval-Herazo J.E. (2019). Biorreactores como alternativa de remediación a la contaminación por hidrocarburos en méxico: costas de Cancún y Veracruz, y la región de la huasteca potosina. M.Sc. thesis. Instituto Tecnológico Superior de Tierra Blanca, Veracruz, México, 70 pp.

SEMARNAT (2005). NOM-143-SEMARNAT-2003. Que establece las especificaciones ambientales para el manejo de agua congénita asociada a hidrocarburos (Environmental specifications for the management of congenital water associated with hydrocarbons). Secretaría de Medio Ambiente y Recursos Naturales. Diario Oficial de la Federación, 3 de marzo.

Sierra-Cortés J. C., Vega y León S., Gutiérrez-Tolentino R., Ortis-Salinas R., Pérez-González J.J. and Escobar-Medina A.C. (2019). Plaguicidas organoclorados en agua de la Laguna Negra de Puerto Marqués, Acapulco, Guerrero, México. Revista internacional de Contaminación Ambiental 35(2), 397-406. https://doi.org/10.20937/RICA.2019.35.02.11

Tunnell J. W., Dunning K.H., Scheef L.P. and Swanson K.M. (2020). Measuring plastic pellet (nurdle) abundance on shorelines throughout the Gulf of Mexico using citizen scientists: Establishing a platform for policy-relevant research. Marine Pollution Bulletin 151, 110794. https://doi.org/10.1016/j.marpolbul.2019.110794

Varjani S.J. (2017) Microbial degradation of petroleum hydrocarbons. Bioresource Technology 223, 277-286. https://doi.org/10.1016/j.biortech.2016.10.037

Vázquez A. (2004). La responsabilidad por daños al ambiente. Gaceta Ecológica 2004(73), 45-62. https://www.redalyc.org/articulo.oa?id=53907305

Zhao S., Zhu L. and Li D. (2015) Characterization of small plastic debris on tourism beaches around the South China Sea. Regional Studies in Marine Science 1, 55-62. https://doi.org/10.1016/j.rsma.2015.04.001