

GREENPEACE

THE PRICE OF PORK:

How Illegal Pig Megafarms Are Destroying Mexico's Underground Springs

2026. OCTOBER

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Abstract

ABSTRACT

The Yucatán Peninsula harbors one of the planet's most fragile freshwater ecosystems, defined by dense tropical rainforest and an interconnected subterranean karst aquifer, known as the *cenotes* (from the Mayan "dzonot"). Today, this global biodiversity hotspot faces severe environmental degradation caused by the rapid expansion of real estate, industrial agriculture including poultry farming and, above all, industrial pig megafarms, over 90% of which operate illegally without Environmental Impact Statements (Greenpeace Mexico, 2020). Yucatán's highly porous karst limestone provides minimal natural filtration between surface runoff and the underlying aquifer, allowing agricultural contaminants to migrate rapidly into the groundwater that sustains millions of people, rendering the aquifer particularly vulnerable to contamination (Alvarado-Zambrano *et al.,* 2026).

To evaluate the impact of industrial livestock operations, Greenpeace México collaborated with affected communities and an accredited independent laboratory in August 2026 to analyze water samples across a number of wells and cenotes in the Yucatán state. A range of chemical and microbiological indicators reveal a complex mosaic of severe, localized organic pollution. Microbiological testing confirmed widespread fecal contamination, with Fecal Enterococci reaching saturation limits of the applied analytical technique (>2400 MPN/100 mL) across multiple sites. Extreme hotspots exhibited coinciding peaks of Chemical Oxygen Demand (up to 795 mg/L), Total Phosphorus (up to 29.1 mg/L), and fecal pathogens, directly indicating pollution from livestock manure slurry or municipal wastewater. A number of samples returned nitrate concentrations above the World Health Organization (WHO) and Mexican guidelines of 48.7mg/L NO_3^- for drinking water[1]. Thanks to community-led water and surface sampling conducted in affected municipalities - including Kinchil, Sitilpech, Chapab, Maxcanú, and Uayalceh - with support from academic partners (Carter et al., 2026), host-specific microbial source tracking successfully identified the swine fecal marker (Pig-2-Bac) in some community water samples. These various studies were conducted in Mayan communities in the municipality of Mérida and its surrounding areas, which have been filing complaints and reports regarding water quality issues, health hazards, and losses to their livelihoods for more than 10 years.

1. NORMA Oficial Mexicana NOM-127-SSA1-2021, Agua para uso y consumo humano. Límites permisibles de la calidad del agua. (Link)

Previous official studies (SEMARNAT, 2023) and research commissioned by the communities themselves (UNAM, 2025), have shown much higher concentrations of hazardous pollutants - including coliform bacteria such as *Escherichia coli,* nitrates, and nitrites - in water bodies (cenotes, lagoons, and shallow wells) located near large-scale pig farms. The current study by Greenpeace Mexico provides further evidence for widespread bacterial and nitrate contamination of water resources in this region.

In that context, it should be noted that recent research links drinking water nitrate to health risks like cancer and pre-term birth at levels far lower than the current WHO guideline.[2]

Because the Great Mayan Aquifer is an already overstressed system, it cannot tolerate additional pollution (Polanco Rodriguez et al., 2018; Alvarado-Zambrano et al., 2026). To protect public health, local Indigenous rights, and the fragile freshwater and forest ecosystems of the Yucatán Peninsula, Greenpeace México demands an immediate moratorium on new industrial livestock operations and expansions, as well as a rigorous regulatory enforcement against illegal facilities.

1

2. The Danish Government recently committed to revising its national drinking water standards in response to a growing body of research linking ingested nitrate to serious health risks, including colorectal cancer and pre-term birth at levels far below the current WHO guideline. Experts advising the Danish government recommended lowering the nitrate limit to 6mg/L NO_3^-. See Halldorsson, T. I., et al. (2025).



Introduction

INTRODUCTION

The Yucatán Peninsula in Mexico hosts the Great Mayan Aquifer, one of the world's largest coastal karst systems, spanning over 165,000 km² (Alvarado-Zambrano et al., 2026). Due to the absence of surface rivers and streams across the low-lying limestone platform (Derrien et al., 2015), groundwater constitutes the sole freshwater source for human consumption, agriculture, and regional ecosystems (Alvarado-Zambrano et al., 2026). The hydrogeological framework is characterized by an extensive network of submerged caves and natural sinkholes (cenotes) that directly link surface activities to the aquifer. However, the extreme porosity and high permeability of the karst limestone facilitate rapid infiltration of surface-derived pollutants, rendering this freshwater reservoir exceptionally vulnerable to severe contamination (Polanco Rodriguez *et al.*, 2018; Alvarado-Zambrano *et al.,* 2026).

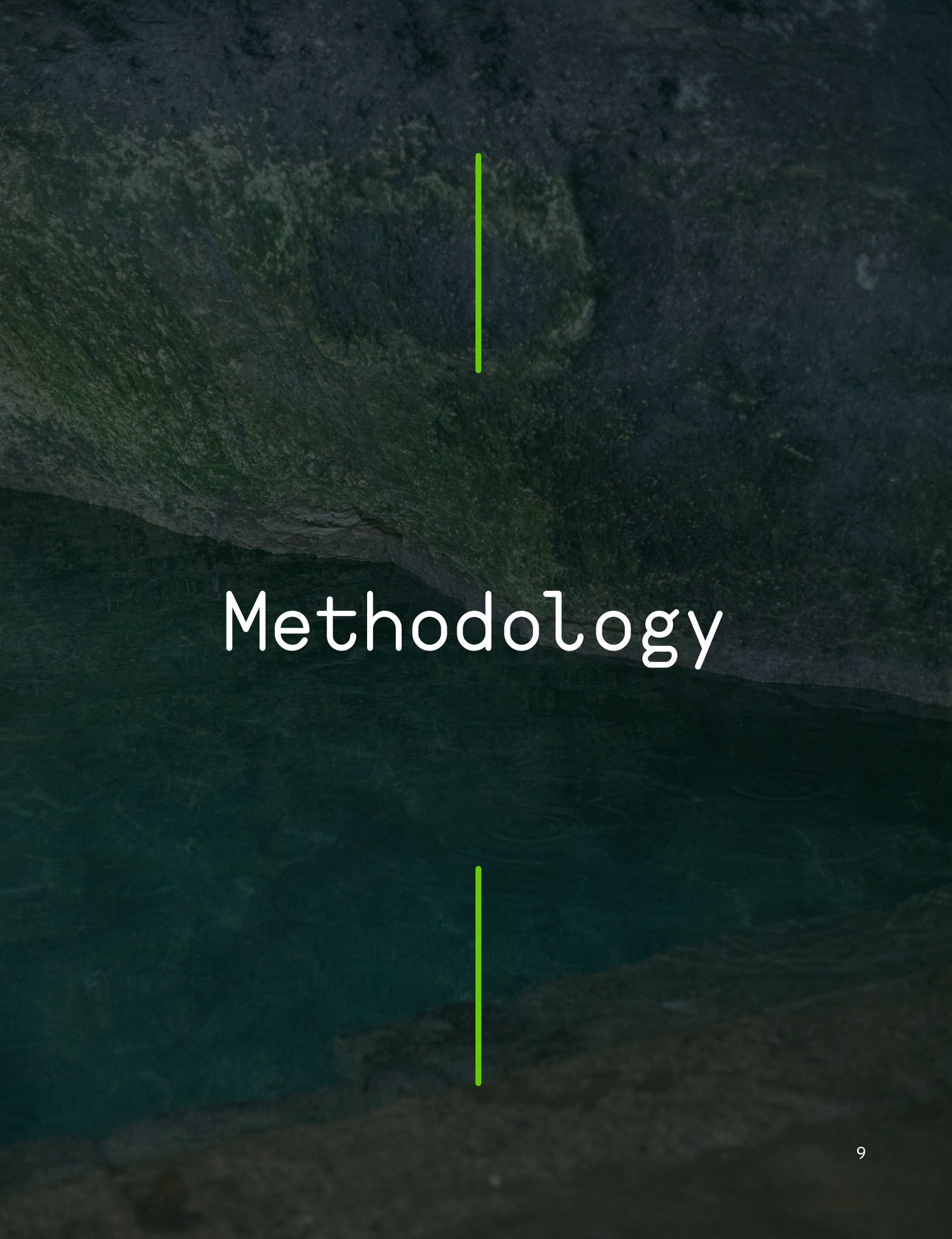
A substantial body of literature identifies agricultural expansion, livestock production, and urban growth as the primary drivers of regional water degradation (Polanco Rodriguez *et al.,* 2018; Alvarado-Zambrano et al., 2026). Inorganic nitrogen compounds, particularly nitrates (NO_3^-), represent a widespread chemical contaminant: intensive fertilizer application in agricultural areas, combined with runoff from poultry, beef cattle and - above all - swine operations, heavily contributes to elevated nitrate levels in groundwater supplies (Aranda-Cirerol *et al.,* 2006; Long *et al.,* 2018). Furthermore, municipal wastewater management infrastructure remains insufficient, with continuous nutrient leaching and contamination across regional aquifers (Aranda-Cirerol *et al.,* 2006; Kopczynski *et al.,* 2025).

Environmental studies highlight an alarming expansion of pollution threats beyond traditional nutrients, extending to pathogenic biological agents, for example, high densities of fecal indicator bacteria, such as *Escherichia coli* (Hernández-Terrones *et al.,* 2011; Kopczynski *et al.*, 2025). This is consistent with the sampling conducted by the affected communities living near the large-scale pig farms (UNAM, 2025; Carter *et al.,* 2026). Crucially, the detection of multidrug-resistant *E. coli* strains within open cenote systems underscores a critical public health hazard (Kopczynski *et al.,* 2025). These environmental pressures are further amplified by ongoing land-use transformations, including deforestation and large-scale infrastructure developments such as the Mayan Train megaproject, which accelerate soil erosion and nutrient mobilization into neighboring aquatic channels (Kopczynski et al., 2025).

The temporal and spatial distribution of water contaminants across the Yucatán Peninsula is strongly dictated by seasonal precipitation cycles (Derrien *et al.,* 2015). While heavy rainfall during the wet season causes dilution of nitrate concentrations in deeper wells, enhanced surface runoff simultaneously could elevate contaminant loads in exposed cenotes (Long *et al.,* 2018). As this polluted groundwater flows toward the coast, high nutrient fluxes discharge into coastal habitats, threatening sensitive ecosystems such as mangroves and coral reefs (Hernández-Terrones et al., 2011). Given that approximately 30% of the local population relies on drinking water drawn directly from vulnerable wells and sinkholes (Polanco Rodriguez *et al.,* 2018), continuous monitoring and effective management strategies are urgently required. Within this context, the present study investigates current water quality metrics to provide an updated empirical assessment of anthropogenic impacts on the Great Mayan Aquifer.

According to an earlier Greenpeace México report documenting the pork industry's impact on the Maya forest, 45% of swine farming in the region takes place directly within tropical forests, driving the deforestation of an estimated 11,000 hectares of forest. Data from the landmark Greenpeace México report *La carne que está consumiendo al Planeta (The Meat That Is Consuming the Planet)* identified 257 pig farms across the Peninsula; remarkably, only 22 possessed an Environmental Impact Statement, revealing that over 90% were operating illegally.[3] Furthermore, 43 facilities were located inside Protected Natural Areas (ANPs) and 122 in priority sites for biodiversity conservation, while systematically violating the ancestral rights of Indigenous Maya communities without free prior, informed consent (Greenpeace Mexico, 2020). Just a few years after the 2020 Greenpeace México report, the situation has worsened. An official assessment conducted by SEMARNAT in 2023 reported the existence of 507 pig farms - nearly double the previous figure. A 2025 report by the international NGO Mercy for Animals indicated that these could now exceed 800 (Mercy for Animals, 2025).

3. Under Mexican federal law (Ley General del Equilibrio Ecológico y la Protección al Ambiente – LGEEPA, Art. 28), a Federal Environmental Impact Statement (Manifestación de Impacto Ambiental – MIA) is legally mandatory prior to construction for industrial livestock projects involving forest land-use changes, federally designated Protected Natural Areas, coastal ecosystems, or wetlands of international importance (Ramsar Sites) or harm to species or ecosystems regardless of farm capacity. Other livestock activities, including pig farms that do not fall under the federal jurisdiction established in Art. 28, generally fall under state jurisdiction and are subject to the applicable state environmental legislation which may require a state-level Environmental Impact Statement.



Methodology

METHODOLOGY

The project had a twofold methodological approach, combining 1) Community-based monitoring, identifying sampling sites by local residents, documenting local observations regarding odors, water quality, flies, health concerns, and agricultural impacts and 2) Laboratory analysis, using accredited analytical methods and chain-of-custody documentation. The sampling sites focus on shallow, surface water bodies (including cenotes) in Mayan communities that rely on these sources and are located near large-scale pig farms identified as potential pollution sources.

1) Greenpeace México conducted an initial first phase of community-based water monitoring in several communities across in Yucatán in July 2026, using pocket devices fit for citizens' science (Horiba LAQUAtwin Nitrate Ion NO_3^-) to identify wells and cenotes with elevated levels of nitrate content in water.

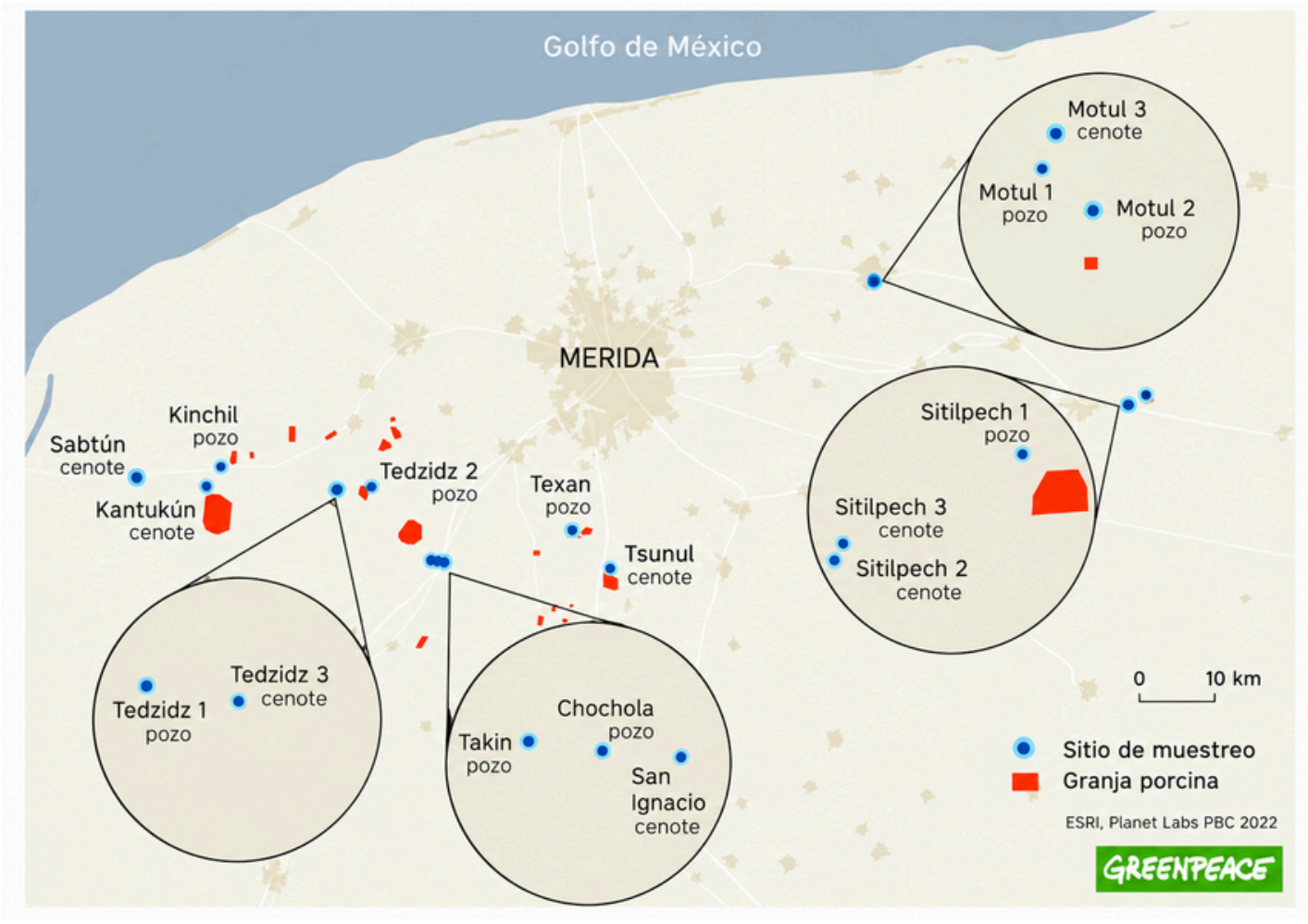
2) To have scientifically robust information on groundwater quality, Greenpeace México commissioned an accredited laboratory, Laboratorio de Análisis de Aguas Q.F.B. Manuel A. Comas Bolio (Laboratorio H2O), Mérida, Yucatán, Mexico. An EMA (Entidad Mexicana de Acreditación) accredited laboratory for water analysis; Accreditation No. AG-038-009/11 (Water Testing Branch), approved by CONAGUA (Mexico's National Water Commission). The laboratory performed sampling and analysis under accredited methodologies and maintained chain-of-custody procedures for all samples.

The geographical scope of the research was the Yucatán peninsula's North-West tip, in the Yucatán state, around Merida, in the following communities: Kinchil, Sitilpech, Motul, Chocholá, San Antonio Tetzitz, Molas. A total of 17 sampling sites were part of this research, including domestic wells, community water supply points, agricultural wells and cenotes.





YUCATÁN WATER MONITORING
AUGUST 2026



THE 17 SAMPLING SITES WERE THE FOLLOWING

Sample code	Location	Type of water	Coordinates
2720-AN	Motul 1	well	21°04'48.2"N 89°17'03.9"W
2721-AN	Motul 2	well	21°04'31.8"N, 89°16'45.8"W
2722-AN	Motul 3	cenote	21°05'01.8"N 89°16'58.0"W
2723-AN	Sitilpech 1	well	20°57'00.0"N 88°56'10.7"W
2724-AN	Sitilpech 2	cenote	20°56'17.8"N 88°57'30.5"W
2725-AN	Sitilpech 3	cenote	20°56'23.9"N 88°57'28.3"W
2737-AN	Kantukún	cenote	20°50'22.6"N 90°08'33.0"W
2738-AN	Sabtún	cenote	20°51'00.9"N 90°14'08.4"W
2739-AN	Kinchil	well	20°51'52.9"N 90°07'26.0"W
2740-AN	Takín	well	20°45'07.6"N 89°51'08.8"W
2741-AN	Chochola	well	20°45'03.9"N 89°50'36.1"W
2742-AN	San Ignacio	cenote	20°45'00.7"N 89°50'03.4"W
2757-AN	Tsunul	cenote	20°44'25.6"N 89°37'20.1"W
2758-AN	Texan	well	20°47'17.3"N 89°40'07.0"W
2759-AN	Tedzidz 1	well	20°50'05.9"N 89°58'27.3"W
2760-AN	Tedzidz 2	well	20°50'23.0"N 89°55'49.1"W
2761-AN	Tedzidz 3	cenote	20°50'04.6"N 89°58'16.5"W

PARAMETERS INCLUDED IN THE WATER TESTING:

Nutrient and Organic Pollution Indicators:

- Chemical Oxygen Demand (COD)
- Total Kjeldahl Nitrogen (TKN)
- Nitrate (NO_3^-)
- Total Phosphorus (TP)

Microbiological Indicators:

- Total Coliforms (TC)
- Fecal Coliforms (FC)
- Fecal Enterococci (FE)

Physical Parameters:

- Total Suspended Solids (TSS)







Results and interpretation of data

RESULTS AND INTERPRETATION OF DATA

Location	COD (mg/L)	TKN (mg/L)	NO3- (mg/L)	TP (mg P/L)	TSS (mg/L)	FC (MPN/100ml)	TC (MPN/100 ml)	FE (MPN/100 ml)
Motul 1	<30	<2.3	20.1	1.2	<4	11	92	1
Motul 2	329	<2.3	100.9	14	76	>1800	>1800	>2420
Motul 3	<30	<2.3	21.2	16.1	<4	>1800	>1800	32
Sitilpech 1	<30	<2.3	38.3	6.2	4	18	>1800	2
Sitilpech 2	63	<2.3	25.8	15.1	1724	>1800	>1800	>2420
Sitilpech 3	<30	<2.3	11.4	19.6	12	>1800	>1800	54
Kantukún	54	11	1.3	7.2	4	92	>1800	5
Sabtún	<30	21	<0.4	10.4	<4	>1800	>1800	105
Kinchil	<30	<2.3	1.1	9.5	5	>1800	>1800	>2420
Takín	<30	<2.3	39	17.1	<4	54	>1800	921
Chochola	<30	<2.3	53.1	1.1	14	>1800	>1800	179
San Ignacio	<30	<2.3	25.3	9.1	<4	>1800	>1800	11
Tsunul	<30	<2.3	18.8	4.2	<4	>1800	>1800	66
Texan	795	49	3	29.1	1932	>1800	>1800	>2420
Tedzidz 1	<30	<2.3	22.8	8.6	45	>1800	>1800	687
Tedzidz 2	243	10	<0.4	6.8	500	>1800	>1800	50
Tedzidz 3	<30	<2.3	20.6	<0.3	6	>1800	>1800	687

Nitrate contamination was widespread across the tested sites (reaching up to 38 mg/L in several locations) and culminated in two samples (Chocholá and Motul 2) that exceeded the WHO 50 mg/L NO_3- drinking-water limit (WHO, 2024). The majority of samples exceed nitrate levels that have been linked to increased risk of cancer and pre-term birth (Halldorsson et al., 2025). These nitrate levels are broadly consistent with historic seasonal baselines recorded in the region roughly 30 years ago (N.D.–59.4 mg/L; Pacheco et al., 2001), but alongside broader chemical and microbiological indicators, they reveal a clear though complex picture of localized contamination across this region of the Yucatán Peninsula.

Chemical Indicators

Chemical parameters across the dataset confirm heavy pollutant loading from organic matter and nutrients:

- **Nitrate (NO_3^-):** Concentrations exceeding the 50 mg/L WHO guideline were identified in Sample 2 (101 mg/L) and Sample 11 (53 mg/L). Nitrate levels at 6 of the 8 cenotes and 6 of the 9 wells sampled exceeded the lower threshold of 6 mg/L recommended by an expert panel appointed by the Danish government to protect against long-term health risks from consumption of nitrates in drinking water.

- **Total Kjeldahl Nitrogen (TKN):** Elevated organic nitrogen and ammonia levels were recorded, particularly in Sample 14 (49 mg/L) and Sample 8 (21 mg/L), confirming that organic material is entering the system faster than it can naturally oxidize.

- **Total Suspended Solids (TSS):** High TSS amounts in Samples 14, 16, and 5 highlight major insoluble contamination. While these values reflect physical loading, they may also originate from natural sediment resuspension or sampling disturbance, meaning they should not be overinterpreted regarding source origin, but should be considered in context with other measured parameters.

- **Chemical Oxygen Demand (COD):** High COD values across multiple samples—peaking at Sample 14 (795 mg/L), Sample 2 (329 mg/L), and Sample 16 (243 mg/L)—demonstrate heavy organic loading that rapidly consumes dissolved oxygen.

- **Total Phosphorus (TP):** Found in all but one sample, with concentrations ranging from 1.1 mg/L to 29.1 mg/L. Because background surface water levels globally are typically expected to remain well below 1.0 mg/L (Poikane et al., 2019), these readings indicate widespread influxes of municipal wastewater, livestock manure, or synthetic detergents.

Microbiological Indicators of Fecal Contamination

Microbiological testing confirms that water contamination across the target area stems from warm-blooded animal fecal sources:

- **Total Coliforms (TC):** 16 of the 17 samples reached the laboratory upper limit of quantification (>1800 MPN/100 mL), demonstrating widespread environmental microbial contamination across the region.
- **Fecal Coliforms (FC):** Current laboratory analysis revealed that 13 out of 17 samples hit the method's saturation limit (>1800 MPN/100 mL), demonstrating heavy microbiological pollution indicative of inputs of animal wastes.
- **Fecal Enterococci (FE):** Bacteria specifically inhabiting the digestive tracts of warm-blooded animals reached the upper quantification limit (>2420 MPN/100 mL) in Samples 2, 5, 9, and 14.

Taken together, the FC and FE data provide direct evidence of untreated or poorly treated fecal contamination (e.g., sewage or livestock manure slurry). While the current data cannot distinguish between human and animal origins, it confirms substantial contamination with potentially harmful fecal bacteria. However, host-specific molecular testing conducted by researchers at Johns Hopkins University confirmed the presence of the swine-specific Pig-2-Bac marker in some community water samples, linking local water pollution to swine mega-farms (Carter *et al.,* 2026).

Integrated contamination analysis

Considering the dataset as a whole, chemical pollution spikes show some alignment with peak concentrations of fecal pathogens, though every sample shows some degree of contamination likely related to fecal origin.

Most notably, Sample 14 exhibits extreme contamination, combining the highest recorded levels of COD (795 mg/L), Total Phosphorus (29.1 mg/L), Total Suspended Solids (1932 mg/L), and Fecal Enterococci (>2420 MPN/100 mL) hitting the method's saturation limit. The presence of multi-milligram Total Phosphorus alongside elevated TKN and Enterococci strongly indicates a gut- or waste-derived source, such as manure lagoons, or direct livestock runoff etc.

Although the overall pattern is complex, the dataset nonetheless confirms significant contamination across several sampling sites, with a number of chemical indicators providing evidence of pollution while microbiological analyses suggest its type of origin. Several tested wells and cenotes appear severely degraded by direct influxes of human sewage and/or animal manure, posing serious public health and environmental risks. Although not the only possible source, these findings nonetheless raise critical accountability questions regarding the potential contribution of nearby megafarms (located between 300 and 2,000 meters from residential areas) to local water degradation.





Conclusions

CONCLUSIONS

The dataset from the analysis of water samples in the current study reveals a complex mosaic of contamination across the sampled region of the Yucatán Peninsula, providing further evidence that water degradation in local wells and cenotes is likely driven by a combination of point and diffuse sources. This is interacting with variable local geology, soil structures, and groundwater recharge dynamics. While the interconnected nature of the subterranean karst network makes isolating and apportioning exact pollution sources challenging at every site, the evidence demonstrates an aquifer already severely stressed by pollution of organic waste and nutrient overload.

The region's porous karst limestone provides minimal natural filtration between surface runoff and the underlying aquifer, allowing agricultural contaminants to migrate rapidly into subterranean drinking water supplies, leaving the ecosystem with limited capacity to absorb additional pollution. Although the natural self-flushing and recharge capacity of the karst cenote system offers a window of opportunity for water quality to recover if pollutant inputs cease, the ecosystem might face critical tipping points beyond which recovery would become challenging. Scientific monitoring demonstrates a significant, long-term decline in water quality across the Yucatán Peninsula over the last decade (Hernández-Hernández et al., 2026). However, scientific monitoring alone cannot determine how close the Great Mayan Aquifer currently is to such irreversible ecological thresholds, and this should prompt decision makers to take a precautionary approach and address the current situation with responsibility and seriousness.

These environmental risks are exacerbated by widespread regulatory failure: prior data indicates that over 90% of regional pig megafarms operate illegally without the required Environmental Impact Statements (Greenpeace Mexico, 2020), while official assessments confirm widespread permit non-compliance and widespread encroachment on Protected Natural Areas (SEMARNAT, 2023), violating the ancestral rights of Indigenous Maya communities. In light of these findings, the regional and national decision makers should not tolerate additional industrial livestock operations, nor the expansion of existing megafarms.

To safeguard public health, protect human rights, and prevent the ecosystem from crossing irreversible tipping points, the following measures are urgently required:

- **Immediate moratorium on industrial livestock production facilities (megafarms):** Enforce a complete ban on new or expanded factory farm facilities across the Yucatán Peninsula, as the stressed aquifer cannot accommodate further pollution loads.

- **Enforcement of regulatory mandates and continuous water monitoring:** Relevant authorities (including National Water Commission (CONAGUA)) must implement comprehensive water monitoring networks, in dialogue with the affected communities, regularly inspect active livestock operations, and prosecute illegal facilities operating without environmental permits. The results of these monitoring activities must be made public immediately.

- **Guarantee the fundamental human rights of communities:** The Mexican government must uphold the right to clean water and a healthy environment, while fully respecting the self-determination of local communities and the Peninsular Maya people, their territorial rights, and their right to free, prior, and informed consultation that is culturally appropriate (FPIC).

- **Prioritize the comprehensive protection of the Selva Maya:** State environmental national policies must explicitly protect the Selva Maya, the communities within it, its biodiversity, and its aquifer from pollution from all sources, including megafarms, prioritizing the survival of the ecosystem and community ways of life over corporate profits.

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