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"Environmental Pollution and Challenges of Environmental Sustainability"

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Oil pollution, its occurrence, origin on the Libyan coast, and its impact on the marine environment

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Abstract: Ship accidents occasionally lead to oil spills, posing a significant threat to the marine environment and causing detrimental impacts on coastal ecosystems. This issue is particularly concerning in the Mediterranean Sea, which is regarded as one of the world's most ecologically and economically valuable marine regions, encompassing a wide array of coastal and marine ecosystems. Libya hosts three offshore oil production platforms situated along the continental shelf of its western coastline. In addition to offshore operations, significant oil and gas industrial activities are concentrated along the coast, particularly around the Zawiya Oil Refining Port and the Mellitah Oil Terminal. These facilities collectively represent considerable environmental pressure on Libya's marine and coastal ecosystems. Ecologically, Libya encompasses three of the thirteen recognized marine biodiversity hotspots in the Mediterranean region. Among these, the western Libyan coast stands out as a particularly sensitive area, distinguished by its rich marine and coastal biodiversity. The occurrence of oil spills in such areas can lead to a broad spectrum of adverse impacts, including substantial degradation of marine habitats, disruption of ecological balance, and harm to the livelihoods of coastal communities. In addition to environmental damage, oil pollution often imposes long-term social and economic stress on populations residing near contaminated shorelines, thereby compromising their overall quality of life.

This study conducted a scientific review of sources and documents related to oil spills off the Libyan coast, and analysed CleanSeaNet reports data to determine the number of reports of oil spills off the Libyan coast. This was done to determine the frequency of these incidents and to predict their potential negative impacts on the marine environment.

By reviewing the available information on oil spills in Libya, it was noted that the most common incidents involved leaks, and in larger quantities, from fuel storage tanks, such as those used in power plants and oil supply lines on offshore platforms. This has resulted in the contamination of numerous sites on the coast, as it was found that the oil spills in Libya are widespread across many areas along the coastline, and some have occurred near sites considered important for Libya's biodiversity. Therefore, we recommend implementing an integrated survey and monitoring program covering all important areas in Libya, to assess the extent to which the marine environment is affected by oil pollution incidents.

1. Introduction

Global trade particularly the transport of oil products by marine transportation has increased rapidly since the industrial revolution (Naz et al., 2021). Sometimes ship accidents occur resulting in an oil spill, which is a threat the marine environment and affects the coastal ecosystem (Liu et al., 2019), especially in the Mediterranean Sea which is one of the most highly valued seas in the world and comprises a vast set of coastal and marine ecosystems (UNEP/MAP, 2012). Recently, the Mediterranean coastal ecosystem has been considered highly sensitive to oil spills (Daffonchio et al., 2013), and the United Nations Environment Program reports that approximately 55,000 MT of crude oil was spilled in the areas near Malta, Tunisia, Italy, and Libya (UNEP/MAP, 2012). Nowadays, the scale of oil spill accidents is greater than ever due to the deployment of a series of offshore installations across the Mediterranean Sea. According to findings by the Mediterranean Oil Industry Group (MOIG), the Mediterranean Sea hosts around 100 facilities involved in oil-related activities, comprising 40% refineries, 24% ports, 26% oil terminals, and 10% offshore platforms, highlighting the region's intensive hydrocarbon infrastructure (Plan Bleu, 2014). These offshore facilities/installations pose a great risk to the sea and coastal environment, and the consequences of oil spill incident can be devastating not only at a local but also at a regional level, hence, affecting the economies of many countries in the Mediterranean Basin. Compared to other regions, the Mediterranean Sea can be considered a relatively small producer of offshore oil and natural gas. Today, the main offshore oil producers in the Mediterranean are Egypt and Libya (REMPEC, 2021).

Libya hosts three offshore oil production platforms located along the continental shelf of its western coastline: Al-Bouri, Bahr Essalam, and Al Jurf oil fields. Among these, the Al-Bouri platform is recognized as the largest and most productive in the Mediterranean region, with an average daily output of approximately 60,000 barrels of crude oil. It holds an estimated 4.5 billion barrels of proven crude oil reserves and 3.5 trillion cubic feet (TCF) of natural gas (Offshore Technology, 2020; Egypt Oil & Gas, 2020). In addition to offshore production, Libya’s coastline is home to significant oil and gas industrial activities, particularly around the Zawiya refinery port and Mellitah oil terminal. These installations collectively pose substantial risks to the surrounding marine environment.

Furthermore, Libya is home to three of the thirteen critical marine biodiversity hotspots identified in the Mediterranean basin (IUCN, 2011; UNEP/MAP, 2020). One such hotspot lies along the western coast, stretching from the west of Tripoli to encompass the Gulf of Gabes. This region is distinguished by its rich marine and coastal biodiversity, exemplified by ecologically sensitive areas such as Farwa Island, which require urgent protection measures (UNEP/MAP, 2020; IUCN-MedMis, 2021). Oil spills in such areas can inflict severe ecological damage, disrupting marine habitats and threatening biodiversity. Additionally, they can negatively affect the livelihoods and well-being of coastal populations by contaminating essential resources and degrading the overall quality of life (ITOPF, 2011).

2. Oil Spills

An oil spill refers to the accidental or deliberate release of petroleum hydrocarbons onto the surface of water bodies, forming a distinct floating mass that is transported by wind, currents, and tidal forces. Although partial containment of oil spills can be achieved through chemical dispersants, in-situ burning, mechanical barriers, and adsorption techniques, such events often result in significant environmental harm. Oil spills are not limited to aquatic environments; they can also occur inland from tanks and pipelines, contaminating soil, infiltrating sewer systems, and threatening groundwater reserves, in addition to causing extensive damage to coastal ecosystems (United Nations, 1997).

According to the International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC, 1990), an “oil pollution incident” is defined as a single occurrence or a series of related occurrences originating from the same source that results, or is likely to result, in the discharge of oil—thus posing a threat to the marine and coastal environment, or the interests of one or more states, and requiring immediate emergency action. In essence, oil spills constitute a form of marine environmental pollution resulting from the release of liquid petroleum hydrocarbons due to human activities. This term is predominantly associated with marine oil spills involving crude oil, refined petroleum products, or oily waste discharged into oceans, seas, or coastal waters. The economic and environmental costs associated with oil spill clean-up are substantial, often requiring months or even years to fully remediate the affected areas. According to the trends in energy usage, oil production and consumption are not likely to decrease much in the future. Spills occur anywhere around the world during oil production, transportation, storing, or consumption. The majority of spills are relatively small. while, the large spill incidents get the most public attention owing to their greater impact and visibility. Though, spill size is not a direct measure of damage, location and the oil type are extremely important in determining the degree of environmental and socio-economic damage (Mehanna et al., 2013). Furthermore, there are many potential sources of environmental pollution, not only from accidents but also from operations in the field of maritime navigation. For example, the dirty water contaminated with even small amounts of oil in the engine room space causes pollution of the marine environment when it is pumped into the sea. Furthermore, the oil leaking from fuel oil bunkering into the sea in highly sensitive areas has a high impact on the marine environment (Al Fartoosi, 2013).

Oil spills exert significant adverse effects on coastal ecosystems and economically important sectors, including fisheries and tourism (Mendelssohn et al., 2012). Crude oil and refined petroleum products consist of numerous hazardous compounds, among which Polycyclic Aromatic Hydrocarbons (PAHs) are of particular concern due to their high toxicity. These substances are known to possess carcinogenic, mutagenic, and teratogenic properties, posing risks to both human health and marine organisms (Grant et al., 2002). When oil slicks reach coastal areas, their direct impact often involves the physical smothering of benthic fauna by obstructing oxygen exchange, which can be fatal for invertebrates inhabiting the seabed. Furthermore, oil contamination can severely impair the insulation and buoyancy of animals with feathers or fur, such as seabirds and marine mammals, thus compromising their survival.

Toxic effects can occur in the short or long term from oil ingestion or inhalation to external exposure by absorption through the skin. The effects of spilled oil on organisms may be either acute or chronic (Morales-Caselles et al., 2007) and depend on the type of oil released and releasing location. For example, benthic organisms are usually not impacted by oil in the emulsion form, however, may be affected by oil residues (tar balls) which are likely to settle on the sea bottom. Moreover, oil spills near corals, seagrass, salt marshes, or mangrove areas will be greater impacts. Some studies reported that there are significant long-term impacts on various organisms in coastal areas which heavily impacted by oil spills. These impacts were continued many years after the disappearance of the visual signs of oil pollution (Joydas et al., 2011).

Over the last decades, large-scale oil spills have occurred worldwide, causing significant marine and coastal environmental risks and socio-economic losses (Li et al., 2016; Chen et al., 2019). The petroleum industry, which includes the processes of exploration, extraction, refining, and transport by oil tankers and pipelines, is a major contributor to marine oil pollution, and a single event can be release large volumes of oil. For example, the 2010 Deepwater Horizon oil spill in the Gulf of Mexico released approximately 5 million barrels of oil into the ocean during a period of three months (NRC, 2013). Table (1) shows the 10 largest oil spills that have occurred from 2002 to 2020 in many parts of the world, and most of them have been caused by collisions and striking of a reef in the course of crude oil transportation by the sea (Li et al., 2018; ITOPF, 2020).

Over the past few decades, there has been a marked decline in the frequency of large-scale oil spills, defined as incidents involving discharges exceeding 700 tons. In 2010, the annual average number of such spills was recorded at 1.8, representing a reduction of over 90% compared to the average in 1970. Notably, no large spills were reported in the year 2020. In parallel with this trend, the total volume of oil released from tanker incidents has also significantly decreased. For instance, in 2010, approximately 164,000 tons of oil were lost from tanker spills involving quantities of seven tons or more—reflecting a 95% reduction relative to figures reported in 1970 (ITOPF, 2020).

Table (1). The worldwide largest oil spills incidents from 2002 to 2020 (Li et al., 2018; ITOPF, 2020).

No.	Ship or location involved	Date	Cause	Leakage amount
1	“Prestige” Spain	2002.11.13	Storm	25,000 tons
2	United States Gulf of Mexico	2010.04.20	Drilling facility breakdown underwater	7950-9350 barrels of crude oil
3	“Sanchi” China	2018.01.06	Collision	11.13 million tones
4	Panama “modern promotion”	2004.12.07	Collision	More than 1200 tons
5	Panama “Saint Di”	2009.09.15	Striking a reef	30 tons
6	“Qingdao” China	2013.11.22	Oil depot explosion	600 tons
7	Penglai 19-3 Platform-China	2011.06.11	Too much pressure on water injection	6200 square kilometers which are polluted
8	Dalian's Xingang Harbor-China	2010.07.16	Fire due to explosion	1500 tons
9	Hong Kong	2018.01.06	Collision	9000 tons
10	“Hebei Spirit” - South Korea	2007.12.07	Collision	11000 tons

3. Libyan Oil Industry

Libya, a member of the Organization of the Petroleum Exporting Countries (OPEC), holds the largest proven crude oil reserves in Africa and ranks fifth in terms of proven natural gas reserves on the continent (OPEC, 2020). The majority of Libya's crude oil exports are directed to European markets, with Italy being the primary recipient. Although the United States resumed crude oil imports from Libya in 2004 following the lifting of sanctions, the volume imported remains relatively limited. Similar to the oil sector, Libya's natural gas industry began to recover in 2012; however, production levels have continued to fall short of those recorded prior to the conflict. In contrast to its prominent position in the oil industry, Libya's role in natural gas production and reserves is comparatively modest. Notably, around 50% of Libya's natural gas output is exported to Italy via the Greenstream pipeline (EIA, 2015). Over 90% of the crude oil shipped from the Mediterranean region originates from North African ports located in Libya, Algeria, Tunisia, and Egypt. Approximately 80% of Libya's crude oil exports are transported via oil tankers and pipelines connected to a network of refineries, pipeline terminals, and both offshore and coastal platforms along the Libyan coastline (UNEP, 2008; EIA, 2015). The primary oil and gas production zones, along with key oil terminal locations, are distributed across three main segments of the Libyan coast: (1) the western coastal zone, which constitutes the study area; (2) the coastline of the Gulf of Sidra; and (3) the eastern coastal region near Tobruk in the Cyrenaica area, as illustrated in Figure (1) (EIA, 2015). Additionally, Libya operates three offshore oil production platforms situated off the western coastline in the Gulf of Gabes. Among them, the Bouri oil field stands out as the largest in the Mediterranean, containing an estimated 4.5 billion barrels of proven crude oil reserves and 3.5 trillion cubic feet of natural gas (Egypt Oil & Gas, 2021; Offshore Technology, 2021).

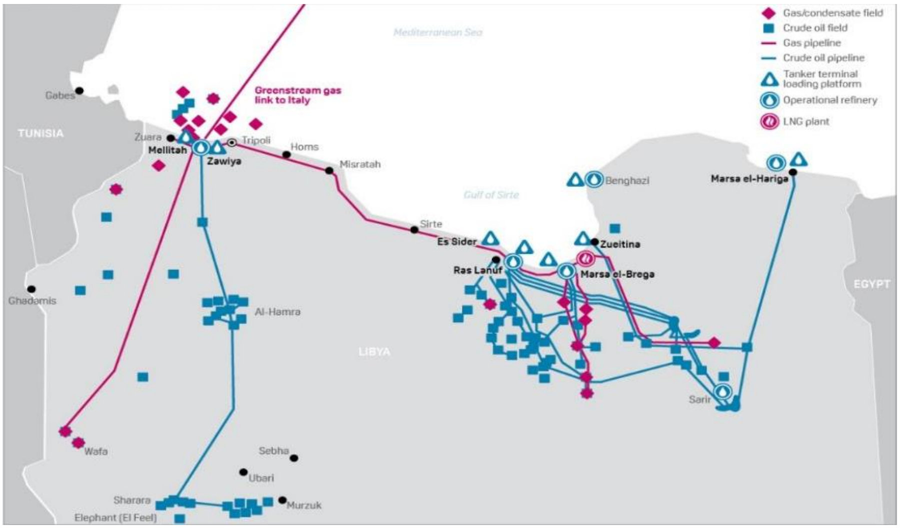

Figure (1). Oil and gas natural production sites of the Libyan coast.(source: SGP Global Platts)

4. Accidents of Oil Spill in Libya

The risk of oil spill incidents is significantly elevated—by as much as 90%—in coastal zones, ports, and areas with concentrated oil infrastructure due to the high density of maritime traffic in such regions (Chen et al., 2019). Human error accounts for approximately 84% to 88% of oil spill accidents (Al-Shammari et al., 2018). Statistical evidence suggests that the Libyan coastline is particularly vulnerable to oil pollution, owing to the diversity and intensity of existing risk factors. Libyan coastal areas are already subject to various forms of marine pollution originating from oil tankers, terminals, and offshore pipelines (IUCN, 2011; Eljabri & Gallagher, 2012; Bonsignore et al., 2018). Furthermore, the likelihood of accidental oil spills in Libyan waters is expected to rise in the future due to multiple factors, including increased maritime traffic in the region, expanded offshore oil exploration and production—particularly along the western coast—and Libya's positioning along key international oil tanker routes that link its ports to the Western Basin of the Mediterranean Sea (Maitig et al., 2018; Bonsignore et al., 2018). The absence of reliable historical records on past spills, combined with limited monitoring capacity and insufficient response mechanisms, further exacerbates the potential impact of oil pollution on Libya's coastal ecosystems and biodiversity.

As a country with a substantial oil and gas sector that constitutes a primary source of national income, Libya also faces considerable environmental risks. Oil spills and other pollution-related incidents associated with this industry pose serious threats to marine and coastal habitats. Over the years, several spill incidents have been reported in Libyan waters, most of which have stemmed from tanker accidents or damage to oil infrastructure during periods of conflict. Notable examples include:

1. **Abdul Rahman Incident (1997):** On November 20, 1997, the Egyptian cargo vessel *Abdul Rahman* ran aground near Benghazi, sustaining significant damage. The accident resulted in the discharge of bunker fuel oil and part of its cargo—including 1,500 tons of ammonium nitrate, 500 tons of ferrosilicon, 100 tons of caustic soda, and 100 tons of black honey—into the sea. While the pollution was monitored, no dedicated response measures were implemented. *(Source: CEDRE)*
2. **Captain Takis Incident (2006):** A minor spill occurred at Misurata Port from the tanker *Captain Takis*, releasing approximately 150 tons of intermediate fuel oil (IFO 360). The fuel quickly solidified upon contact with water, allowing for an efficient recovery operation (ITOPF, 2021).
3. **Tobruk Corniche Incident (2021):** On April 30, 2021, a substantial fuel oil leak occurred from the steam power plant tanks in Tobruk, resulting in marine pollution along the city's shoreline (Figure 2). Reports indicate that around 18,000 liters of diesel were withdrawn from the affected area. *(Source: Libyan Express)*

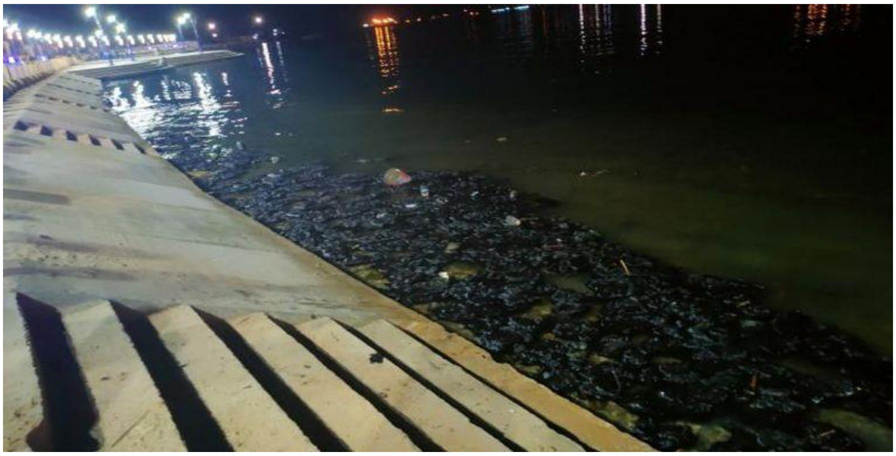

Figure (2): Photo of oil spill in Tobruk Corniche

4. **Derna Oil Spill (2021):** On June 14, 2021, the first official report of an oil spill off the coast of Derna, Libya, was issued by the Libyan non-governmental organization *Alhayat Organization for Protection of Wildlife and Marine Organisms (AOPWMO)*. The incident gained public attention following the release of aerial photographs showing oil slicks along the coastline (Figure 3), which were subsequently circulated by national media outlets. These images were obtained during a helicopter survey conducted by the local branch of the governmental *Environment General Authority (EGA)*, which also prepared a technical report on the event. According to the report, the oil slick was located between 1.1 and 2.1 kilometers offshore, with a thickness ranging from 1 to 4 centimeters. The spill extended over a length of 25 to 260 meters and a width of 10 to 25 meters. Further investigation using satellite imagery revealed the presence of three separate oil slicks in the waters surrounding Derna. Notably, the first slick was detected on June 8, 2021, and was only visible for a single day (Figure 4).

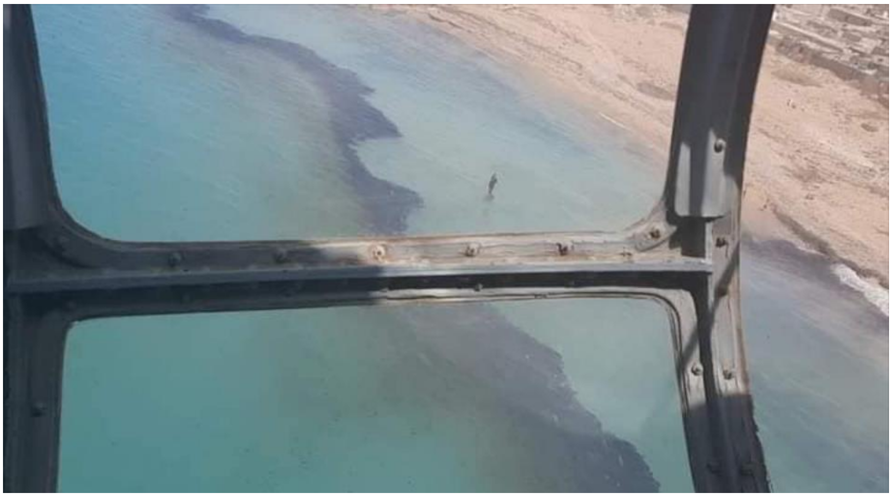

Figure (3): Photo of oil spills near Derna observed from a helicopter. Credit: Alhayat Organization for Protection of Wildlife and Marine Organisms

Figure (4): Incident 1, 8 June 2021. Image courtesy of Planet Labs, Inc

A second oil discharge was observed beginning on June 22, 2021, and remained visible along the Derna coastline until June 25. Satellite imagery revealed that this slick extended more than 25 kilometers eastward from the suspected source near the power plant (Figure 5). A third discharge occurred on July 1, 2021, although it was only partially captured by high-resolution satellite sensors and persisted for a single day. Nevertheless, based on corroborating aerial photographs, social media footage, and official reports from the Environment General Authority, it is reasonable to attribute the event to an oil spill. To assess the frequency of such discharges, archived Sentinel-2 satellite data dating back to January 2018 were analyzed. Two similar oil slicks were detected in May and June 2018, coinciding with the peak of military operations in Derna. However, no comparable incidents were recorded again until June 2021, suggesting that these discharges are not continuous but rather intermittent in nature. Continued satellite monitoring is recommended to determine whether this recent spate of spills persists. [Source: https://ceobs.org/oil-spills-from-libyas-derna-power-and-desalination-plant/].

A report issued by the local branch of the Environment General Authority identified the likely source of the spill as damaged drainage pipes connected to fuel storage tanks at the Derna thermal power plant. These tanks contain stagnant oily water that has reportedly remained unaddressed for over two years. Although the power plant itself has not been operational, the fuel tanks have been leased to the neighboring desalination facility. Due to ongoing conflict, maintenance responsibilities assigned to a third-party contractor have not been fulfilled. The facility is operated by the state-owned General Electricity Company of Libya (GECOL, 2017).

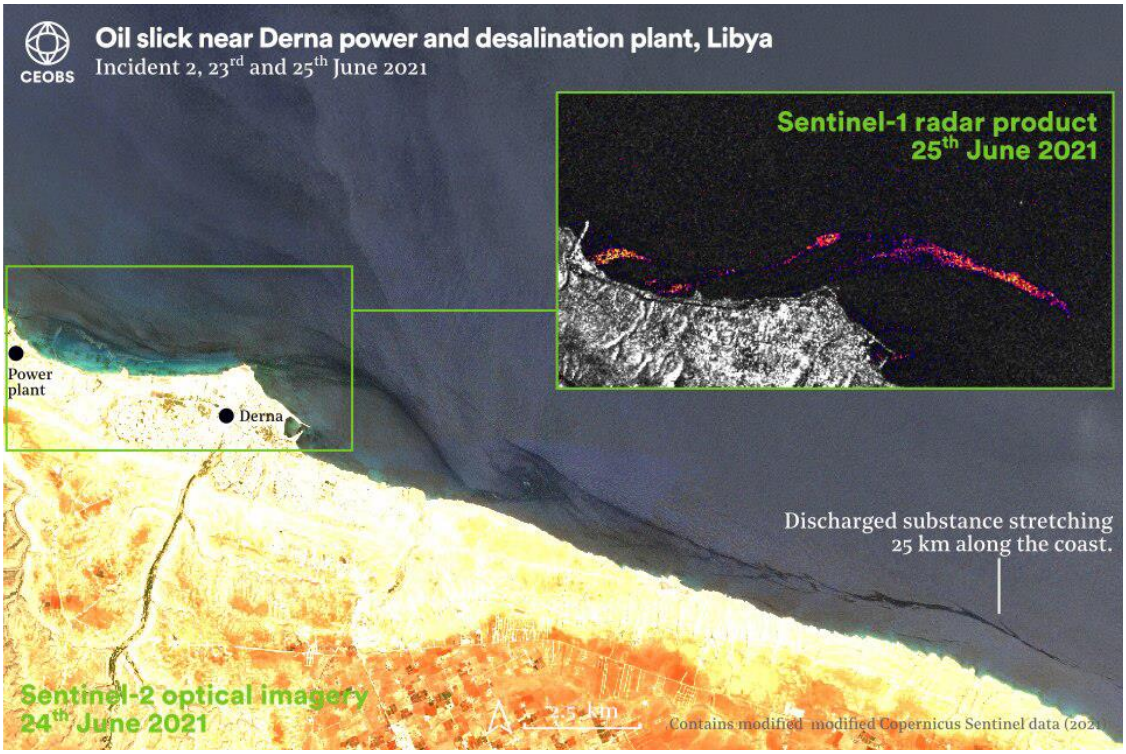

Figure (5): Second oil spill incident observed on June 24–25, 2021. The primary imagery was acquired from Sentinel-2 satellite data, while the inset image was derived from Sentinel-1 using the TIZNEGAR custom script specifically developed for oil slick detection. The original Sentinel-1 analysis was conducted by @Libya_OSINT. The figure includes modified data from the Copernicus Sentinel mission (2021).

5. **VOS APHRODITE Oil Spill (October 2021):** On October 8, 2021, an oil spill involving approximately 1,600 barrels of crude oil occurred during offloading operations from the vessel VOS APHRODITE near the Farwa Floating Production Storage and Offloading (FPSO) platform at the Al-Jurf oil field. This offshore facility is located roughly 130 kilometers northwest of Tripoli and approximately 86 kilometers from the Libyan-Tunisian maritime border, at coordinates 33° 51′ 42″ N, 12° 03′ 34″ E.
   According to the Libyan National Oil Corporation (NOC), the spill was swiftly contained and treated, and it was initially reported that no adverse effects on Libyan coastal areas were expected. However, subsequent analysis of satellite imagery indicated that the oil slick was likely to reach coastal zones between Zuwara and Sabratha (Figure 6). Indeed, large volumes of oil were eventually observed along parts of the western Libyan coast—including Zuwara, Sabratha, and Tripoli—causing measurable environmental harm to marine ecosystems (Figure 7). [Source: https://ceobs.org/libyan-offshore-oil-spill-worse-than-claimed/].

6. Al-Zawiya Oil Refinery Incident (October 2021): On October 26, 2021, the Al-Zawiya Oil Refining Company reported substantial operational and material losses resulting from armed clashes that occurred on the night of October 25 in the vicinity of the Zawiya oil

complex. According to an official statement published on the company's website, the confrontations, which persisted for several hours, caused significant damage to infrastructure within the facility. Specifically, eight storage tanks used for crude oil and petroleum products within the oil movement area were affected. Additionally, five tanks designated for base oils and chemical additives at the mineral oil blending and filling plant sustained damage. The incident led to a substantial leak from Tank No. T9, which contained SN150 base oil. The report further noted that an electrical transformer supplying power to the main station of the blending and filling facility was directly hit, resulting in severe damage. Structural damage was also observed in the ceilings of the production halls associated with the blending and filling lines, further impacting the plant's operational capacity.

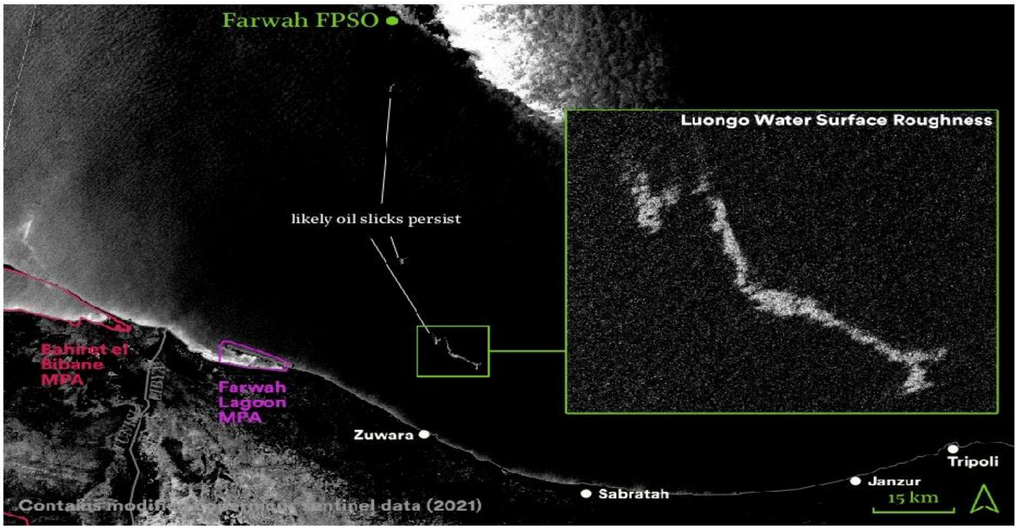

Figure (6): Satellite imagery capturing the movement of an oil spill originating from the Floating Production Storage and Offloading (FPSO) unit, drifting toward the coastal areas between Zuwara and Sabratha along the Libyan shoreline (CEOBS, 2021).

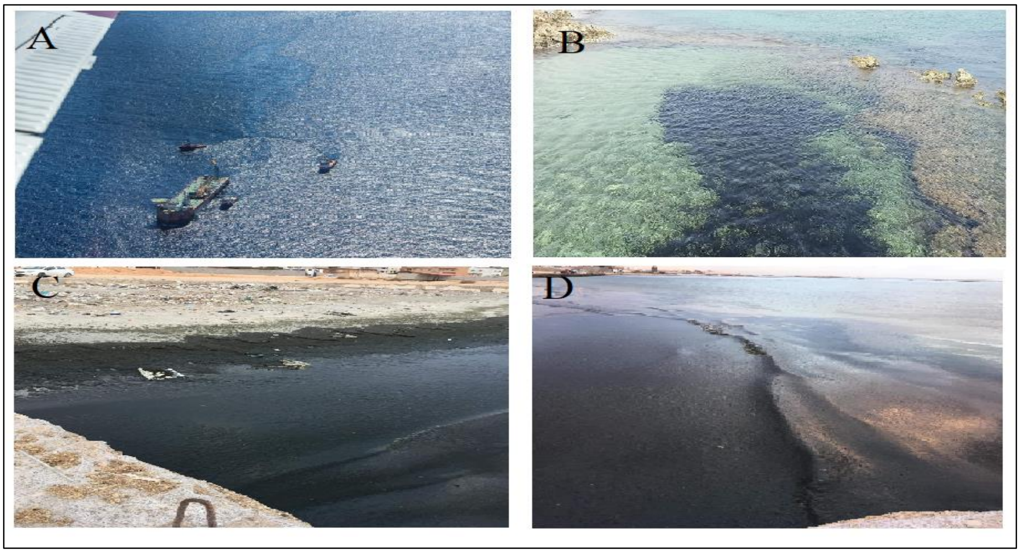

Figure (7): (A) Geographic location of the oil spill incident associated with the Farwa offshore platform; (B) Visual evidence of oil traces along the Sabratha coastline following the spill; (C) and (D) Satellite imagery depicting the spatial extent of the oil slick off the coast of Tripoli. (Sources: CEOBS, 2021; Faculty of Engineering, Sabratha – Libya, 2021).

7. **Janzour power station /** Recently, on 27 October 2022, a collapse occurred in one of the heavy fuel tanks at the Janzour power station, west of Tripoli. According to the report of the Attorney General in Libya, it is certain that 8 million liters of heavy fuel have leaked into the soil and sea water from the tanks of the Janzour power station from the tanks of the Janzour power station. https://libyaalhadath.net/?p=127260. According to an unpublished report of the General Electricity Company's management regarding the oil leakage incident from the fuel tank at West Tripoli station (Janzour), the amount of fuel leaked is much less than what was mentioned in the report of the Ministry of Environment on which the Public Prosecutor relied, because the amount of fuel that was in the tank did not leak completely However, large quantities of it were withdrawn using fuel trucks, in addition to the leaked quantity not reaching the sea completely. The report also indicated that the area of pollution spots amounted to 1,500 square meters, and that the oil leak was dealt with according to the national plan for oil spills in Libya, which was recently approved by the Libyan government on June 16, 2022, where a number of dirt barriers were established to stop fuel leakage and prevent it from reaching the marine environment, and by using barriers and suction pumps, twenty thousand liters were withdrawn. From the fuel leaking into the sea from 9 oil slicks spread in the area extending from the port of Sidi Bilal to the east of the station, and that 10 thousand cubic meters of polluted soil on the beach were removed and preserved for the purpose of disposing of it in environmentally safe ways. The team attempted to conduct a field survey and collect samples from the contaminated area from the east of the Janzour power station to the port of Sidi Bilal (fig. 8), but we were not able to carry out this survey nor collect samples because the targeted area is a prohibited military zone.

Figure (8): Photos for contaminated area from the east of the Janzour power station to the port of Sidi Bilal

The oil spills that have occurred from in many parts of Libya are summarized in the table (2), it is noted from him that most of the accidents in recent years were caused by fuel tanks in power stations and oil supply pipelines in offshore platforms.

Table (2). The largest oil spills incidents on Libya coast.

Source of spill	Date	Site	Leakage amount	Type of spill
Egyptian cargo vessel Abdul Rahman	1997.11.20	Benghazi	2200 tonnes	1,500 tonnes of ammonium nitrate, 500 tonnes of ferrosilicon, 100 tonnes of caustic soda, 100 tonnes of black honey
The incident of the delinquency of the tanker Al-Safa	10/2/2003	Ras Hilal	300 tonnes	Water contaminated with various materials and fuel
Captain Takis oil tanker	2006	Misurata	150 tonnes	intermediate fuel oil
The Arrevo tanker incident	28/12/2006	Misurata	Unspecified	heavy fuel

Tobruk power plant	2021.4.30	Tobruk Corniche	18,000 liters	diesel fuel
Derna power plant fuel storage tanks	2021.6.08 2021.6.22 2021.7.01	Beaches of Derna	Unspecified	diesel spills
VOS APHRODITE locomotive	2021.10.08	the Al-Jurf site	1,600 barrels	crude oil
Al-Zawiya Oil Refining	2021.10.26	Al-Zawiya	Unspecified	oil products and crude oil
Fuel leakage Zawiya oil port	19/8/2022	Al-Zawiya	Unspecified	diesel spills
Janzour power station	2022.10. 6	west of Tripoli	8 million liters	heavy fuel
Tobruk power plant	29/12/2022	Tobruk	Unspecified	diesel fuel

5. CleanSeaNet Reports

The European Maritime Safety Agency (EMSA) launched the CleanSeaNet (CSN) service in April 2007 as a pan-European satellite-based system for monitoring oil spills across maritime regions. Following the revision of EMSA's founding regulation in 2013, the scope of CSN was expanded to include the surveillance of oil discharges from offshore installations. As an operational service, CSN provides participating member states with support in three main areas:

- Detection of oil pollution on the sea surface and assistance in identifying potential polluters.
- Monitoring of accidental pollution events during emergencies.
- Support for oil spill surveillance operations and simulation exercises.

The system relies on Synthetic Aperture Radar (SAR) satellite imagery, which offers global maritime coverage regardless of weather conditions, time of day, fog, or cloud cover. The collected satellite data are processed into imagery and analyzed to detect oil spills, maritime vessels, and relevant meteorological variables. The analytical output includes key parameters such as spill location, surface area, length, detection confidence levels, and contextual information regarding possible pollution sources, including vessels or offshore platforms. Optical satellite imagery can also be acquired upon request, particularly for large-scale spill events or when enhanced visual analysis is needed.

According to EMSA, detections made by the CleanSeaNet system may not always indicate mineral oil contamination. In some cases, they may correspond to other pollutants, such as sewage or garbage, or natural phenomena like algal blooms or zones of oceanic upwelling. Furthermore, not all detected spills are considered illegal under international regulations; for instance, permitted discharges located over 50 nautical miles from the shore, with oil concentrations below 15 parts per million (ppm), fall within legal thresholds. Similarly, authorized discharges of produced water from offshore oil and gas installations may result in surface oil sheens under certain sea conditions. Consequently, all CSN detections require subsequent validation and enforcement by national authorities.

In the Libyan context, data from EMSA reports received by the Environmental Reporting Room of the Emergency Department (ERRED) within the Libyan Ministry of Environment indicate that in 2022, a total of 44 suspected oil spill events were detected off the Libyan coast. Of these, two were confirmed to involve mineral oil, three were ruled out, and the remainder remained unverified. Similarly, 43 suspected incidents were reported in 2021, of which two were confirmed and four were denied, while others lacked validation. The number of detections reported in the preceding years were 52 in 2020, 22 in 2019, and 12 in 2018, respectively (see Table 3).

Table (3): CleanSeaNet possible pollution detected off the Libyan coast: 2018 – 2022

Year	Detections	Confirmed as mineral oil		Nothing observed	Not verified
		Number	Total area (m^2)		
2022	**44**	**2**	4009725.9	**3**	**39**
2021	**43**	**2**	677558.8	**1**	**40**
2020	**52**	**1**	472996.4	**8**	**41**
2019	**22**	**0**	0	**1**	**21**
2018	**12**	**1**	112153.1	**1**	**10**

6. Conclusions and recommendations

i. By reviewing the available information on oil spills in Libya, it was noted that the most common incidents involved leaks, and in larger quantities, from fuel storage tanks, such as those used in power plants and oil supply lines on offshore platforms. This has resulted in the contamination of numerous sites on the coast; therefore, it is suggested that this observation be taken into account when developing, reviewing, or modifying future oil pollution monitoring and prevention plans.

ii. Oil spills in Libya are widespread across many areas along the coastline, and some have occurred near sites considered important for Libya's biodiversity. Therefore, we recommend implementing an integrated survey and monitoring program covering all important areas in Libya, to assess the extent to which the marine environment is affected by oil pollution incidents.

iii. Through visual observations, indications of ancient oil pollution from earlier periods have been observed at Tripoli sites. However, to achieve a more comprehensive understanding of the sources of oil pollution and its potential impacts, it is proposed to implement a continuous monitoring program for the next few years.

iv. The results of the field survey of Tripoli's beach showed that the most prominent evidence of oil pollution on the beach was the presence of tar balls and lumps. Therefore, it is recommended to examine the tar and add this issue to the monitoring program to help determine its source and date of occurrence.

Conflict of Interest: The authors declare that there are no conflicts of interest.

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