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Contents

• Spills

Major spill of palm oil following ship collision (*Global Apollon*, China)
On 3rd August 2017 in the southern part of the Pearl River Delta (South China), a collision of unspecified cause occurred between the container ship *Kota Ganteng* and the Japanese chemical tanker *Global Apollon*, causing a breach in the starboard tank (capacity 1,000 tonnes) of the latter vessel, which was transporting approximately 9,000 tonnes of palm oil (or more precisely palm stearin). The tanker was anchored at Guishan in the Wanshan Archipelago (Guangdong Province of China, on the border with Hong Kong), but not before losing a substantial part of the contents of its ruptured tank. The Government of Hong Kong was not notified by the Chinese authorities until two days after the incident. The figure of 1,000 tonnes, i.e. the entire tank capacity, was reported in the press (which cited various sources, notably the authorities as well as several associations), but we currently have no knowledge of any official confirmation of this estimate. Whatever the extent of the spill, solidified palm oil started to wash up on a massive scale from 6th August onwards along the shoreline and in the port areas of several of the numerous islands that make up the territory of Hong Kong. These strandings took the form of more or less large clusters (chunks, tarballs, etc.) depending on their level of fragmentation and weathering. The authorities of Guangdong Province dispatched nine vessels (types not detailed in our information sources) to perform surveys and to recover the floating palm oil in the inshore waters. It appears that the solidified oil was recovered from the water using nets (scoop nets, etc.), while clean-up operations along the shoreline mainly involved manual recovery by volunteers. Selective mechanised systems such as beach cleaners were reportedly deployed for the clean-up of sandy beaches. However, both on the water as well as along the shoreline, and particularly in port areas, press reports suggested that recovery operations were complicated by the presence of large quantities of litter. According to the Chinese authorities, 205 tonnes of solidified palm oil had been recovered by 17th August, i.e. 20% of the supposed volume spilt.[1] In Hong Kong, the Environmental Protection Department and the Leisure and Cultural Services Department promptly issued statements on the non-toxic nature of the spilt product. It would appear that the main impact of this pollution consisted in the temporary closing of a little more than a dozen tourist beaches, which were reopened to the public a week after the spill. The Agriculture, Fisheries and Conservation Department did not report any negative impact on aquaculture or the environment, despite fears expressed by certain NGOs concerning depleted oxygen levels related to the degradation of the palm oil.[2]

Marine and coastal pollution by crude oil (Al-Khafji offshore oil field, Kuwait)
On 10th August 2017, an incident of an unspecified nature and cause occurred on the Al-Khafji offshore oil field (off the coast of Ras Al-Zour[3] in Kuwait), operated by Khafji Joint Operations (KJO).[4] In a press release from Kuwait Petroleum Corporation (KPC), the Kuwaiti authorities confirmed that this incident had caused a spill of crude oil requiring the implementation of containment and recovery operations at sea. However, and to the best of our knowledge, the resources deployed and the outcome of these operations were not detailed. While experts put forward the hypothesis (covered in the national media) that this spill was due to an ageing subsea pipeline, no official confirmation was issued by the Kuwaiti government.

[1] By way of comparison, the response operations following the *Allegra* spill (Channel, 1997) resulted in the recovery of 4% of the palm kernel oil spilt due to the submersion of the margarine-like balls (formed within a few hours due to their weathering process). See **Bucas G., Le Floch S., & Guyomarch J., 2002.** Vegetable oils Vs. heavy oils: similarities and differences in weathering at sea and recovery constraints. Two case studies: Allegra and Erika Spills. Proceedings of the 3rd R&D Forum on High-density Oil Spill Response/IMO, Brest, France, 5-7 March, 149-158.

[2] A risk that needs to be put into perspective, however, this environment being in all likelihood already quite degraded due to the chronic pollution of the Pearl River Delta (an established fact).

[3] Site selected by Kuwait National Petroleum Co. (KNPC) for the creation (in progress) of what is to be the largest refinery in this emirate, and in the Near East in general.

[4] Joint venture between the Kuwait Gulf Oil Company (KGOC, a subsidiary of the state-owned Kuwait Petroleum Corporation, KPC) and the Saudi Aramco Gulf Operations Company (AGOC).

Oil slick drift in coastal waters and pollution of the shoreline to the south of Ras Al-Zour (source: Kuwait Environment Public Authority)

According to the press (citing various experts on site), an estimated 35,000 barrels of crude oil was spilt, representing a total volume of approximately 5,700 m^3, but again the Kuwaiti government did not officially confirm these figures.

The figures given by the non-profit organisation SkyTruth, however, were very different, estimating that "at least 34,590 gallons" were spilt, i.e. approximately 160 m^3, based on its analysis of satellite images taken on 10th August (by Sentinel-1 and Sentinel-2 of the European Space Agency), assigning a thickness of "at least 1 µm" to the area interpreted as crude oil slicks. It is worth noting that the photographs and various videos taken from aerial observations on the same date and showing the presence of true colour slicks imply a much greater thickness.

Whatever the figures, the volumes spilt were sufficient to cause strandings of oil on the shoreline of the Ras Al-Zour region, prompting clean-up operations and interventions to protect water intakes at a desalination plant and a power plant in the area.

A few days later, a new slick (approximately one nautical mile long) was observed in the same sector. Believed to be a second separate event, no further details on its origin or causes are available.

Ship collision and subsequent marine pollution by bunker fuel (*Sinica Graeca*, Malaysia)

On 17th August, a collision of unspecified cause occurred between the chemical tanker *Chemroad Mega* (Panama-flagged, 30,000 DWT) and the bulk carrier *Sinica Graeca* (Marshall Islands-flagged, 63,270 DWT), 6 km off the coast of Pengerang (Kota Tinggi district, State of Johor, Malaysia). The collision damaged the hull of the *Sinica Graeca*, causing a breach in the starboard side and releasing an unspecified quantity of bunker fuel into the sea, as evidenced by several photographs taken by the Marine Department of Malaysia.

The latter coordinated the response operations at sea and announced the deployment of (unspecified) resources for the implementation of "strategies approved" by the Malaysian authorities, namely dispersant application and the containment and mechanical recovery of slicks.

Discharge of bunker fuel from the bulk carrier Sinica Graeca (source: Marine Department of Malaysia)

While the actual duration of the operations at sea is unknown, they are believed to have lasted several days. Following the incident, and with ongoing investigations by the Malaysian authorities into its causes (the conclusions of which are not known to us), the Ministry of Transport called for the detention of the two vessels concerned and instructed the owners to post a bond of some US$1.16 million.

Several spills following Hurricane Harvey (various oil facilities, US)

In the wake of Hurricane Harvey at the end of August 2017, a number of industrial facilities in the Gulf of Mexico (United States), and particularly in Texas, experienced varying degrees of damage. Among these facilities, the flooding of certain petrochemical sites and the subsequent receding water resulted in several oil and chemical spills from storage facilities, particularly in the estuarine waters of the Houston Ship Channel. Without providing further details, the U.S. Coast Guard (USCG) indicated that it had dealt with more than a dozen spills totalling around 1,750 m^3 of different types of oil as the floodwaters receded.

Coastal pollution by heavy fuel oil: sinking of the bunker tanker *Agia Zoni II* (Saronic Gulf, Greece)

On 10th September in the anchorage area of the port of Piraeus (Greece), and while it was waiting to carry out bunkering operations, the coastal tanker *Agia Zoni II* developed a list for an unspecified reason before sinking in waters 20 m deep.

The tanker contained approximately 2,200 tonnes of bunker fuel (including some 2,000 tonnes of IFO 380 and 200 tonnes of IFO 180), as well as 380 tonnes of marine diesel.

In the days following the sinking, an undisclosed quantity of oil began to spill into the sea, forming drifting slicks that rapidly caused oil to wash up on the coastline. The main areas affected were Salamis Island (approximately 4 km of shoreline) and around Piraeus and its northern boundaries (some 20 km).

The response operations primarily focused on containing the spill as close as possible to the source by laying containment booms around the tanker, and on stopping the leak by plugging the outlets (hatches, vents, etc.) through the intervention of divers.

The leak was stopped two days after the sinking, which enabled the lightering operations of the tanks and bunkers of the *Agia Zoni II* (with recourse to hot tapping procedures) to be performed while recovery operations at sea continued. These salvage and recovery operations mobilised resources and personnel from the Hellenic Coast Guard (HCG) and from specialised companies commissioned by the shipowner. Between 1,600 and 2,000 m^3 of oil were recovered from the tanker after approximately 20 days of operations. The outcome of the recovery operations on the water, which were completed by the end of September given the increasing scarcity of recoverable quantities of floating oil, are unknown to us. The volume of bunker fuel spilt in the coastal waters was estimated at around 700 m^3 by the IOPC Funds.[5]

Five specialised vessels from the HCG and six from private oil spill response organisations (in particular the Greek company EPE[6]) were deployed for oil slick recovery operations. Three days after the spill, the Greek authorities requested the mobilisation of the tanker *Aktea*[7] chartered by the EMSA[8], which was operating in the Aegean Sea (with its storage capacity of 3,000 m^3 in addition to its containment and recovery equipment).

Several hundred responders were assigned to clean up the oiled shorelines using various techniques depending on the sectors (substrates, priority areas, etc.). These included manual recovery (sometimes involving the use of sorbents), the rinsing and recovery of effluents, the use of pressure washers on hard surfaces, the cleaning of pebbles in concrete mixers, etc. On certain sites, clean-up operations involved the removal of polluted sediment. This led the technical advisers of the 1992 Fund to recommend the use of in situ rinsing in order to limit the potentially excessive removal of sediment and debris (both clean and oiled) in certain municipalities.

*D+1 month, Salamis Island: low-pressure rinsing of fuel oil accumulations on rocks along the coastline and recovery using an oleophilic skimmer (**Left**); high-pressure cleaning of riprap with recovery of effluents using sorbents (**Centre**); manual recovery of submerged clusters on the foreshore (depth of approximately 1 m) (**Right**) (source: Cedre)*

The operations on the coastline notably included the recovery of sunken clusters along foreshores and in shallow water areas (depth of around 10-15 m) due to the weathering of the product (seawater content due to emulsification and sediment content). Faced with uncertainty as to how to

[5] International Oil Pollution Compensation Funds.
[6] Environmental Protection Engineering, which notably deployed its *Aktaia* recovery barges.
[7] Belonging to the Greek company EPE, and also commissioned by the owner of the *Agia Zoni II* for the spill response operations.
[8] European Maritime Safety Agency.

treat this buried/submerged oil, the Greek authorities launched a call for international expertise on 29th September. Within this context, REMPEC[9] proposed the mobilisation of a Mediterranean Assistance Unit comprising two experts, one French (from Cedre) and the other Italian (from ISPRA[10]). The European Union's Emergency Response Coordination Centre (ERCC) also sent an expert (again from ISPRA). These expert missions took place simultaneously approximately one month after the sinking of the *Agia Zoni II* and lasted several days.

The recovery of sunken clusters required visual surveys by divers and/or drones[11] (the latter operations being facilitated by the clarity of the water but nevertheless requiring confirmation by divers), and manual recovery (also by diving, or on foot for clusters in shallower waters).

The last shoreline clean-up operations were completed in January 2018 after surveys during storms verified the absence of any new strandings related to the remobilisation of possibly still submerged clusters.

At the end of September, the tanker owner was ordered by the Greek authorities to remove the wreck. It was raised on 30th November and towed to a shipyard on Salamis Island. This operation caused more oil spills and required localised clean-up operations along the Piraeus coastline.

A Claims Submission Office was set up in Piraeus by the IOPC Funds to deal with claims arising from the pollution damage caused by the *Agia Zoni II*. The scale of the pollution and the associated clean-up operations led the Administrator to conclude that the shipowner's fund had been exceeded, which resulted in the 1992 Fund having to pay out compensation. In April 2018, the IOPC Funds reported having received 82 claims totalling €65.6 million and US$175,000, and that the amount of €103,846 had been paid out in respect of four claims (the remaining claims being under assessment at that time).

Spill of micro-plastic pellets from falling containers (*Susanna*, South Africa)

On 10th October, in the port of Durban (South Africa), two 40-foot containers, which had been unlashed in accordance with standard procedures while awaiting unloading, fell off the container ship *Susanna* during a storm.[12] Each of the containers was transporting 990 x 25 kg bags of polyethylene pellets, totalling almost 50 tonnes. Before they could be retrieved, 24 hours after the incident, most of the pellets had been dispersed in the water. The South African Department of Environmental Affairs later reported the loss of 49 tonnes of pellets. Divers were commissioned by the Transnet National Ports Authority (TNPA) the day following the incident to recover intact bags drifting submerged in the port waters. Millions of micro-plastic pellets were nevertheless soon dispersed in the water from the numerous torn bags and were carried out to sea driven the winds and currents.

MSC (Mediterranean Shipping Company), the owner of the *Susanna*, announced that it would pay the costs of the clean-up operations entrusted by the South African Maritime Safety Authority (SAMSA) to the company Drizit Environmental. MSC also contracted the services of Resolve Marine Group to conduct shoreline surveys (from boats, by divers, on foot, etc.) and to recover the washed-up pellets using vacuum suction systems, semi-mechanised methods (beach cleaners) or manual equipment (screens).

Reiterated on several occasions as the plastic pellets drifted at sea under the action of the winds and currents, these operations were continued over a long period of time. According to MSC, recovery operations were still in progress on 25th February 2018, i.e. more than four months after the spill. Mobilising hundreds of responders on a daily basis, these operations had accumulated approximately 250,000 hours of operations by this date over some 1,000 kilometres of coastline, often treated by the manual raking or sifting of sandy beaches. At this point, 12.5 tonnes of pellets had been recovered from the coastline.

It is worth noting that various press sources reported criticism of the port authorities, accused of having delayed announcing the extent of the spill and of having committed technical errors that potentially aggravated the situation (notably the unprotected storage of the leaking container placed

9 Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea.

10 *Istituto Superiore per la Protezione e la Ricerca Ambientale*, the Italian Institute for Environmental Protection and Research of the Italian Ministry for Environment, Land and Sea Protection.

11 The drone surveys were carried out by a local specialist company.

12 This storm was responsible for a collision between the *Susanna* and another vessel.

on the quay after it was recovered from the water).

Spill of nickel ore following cargo liquefaction (*Emerald Star*, Philippine Sea)

On 13th October, the Hong Kong bulk carrier *Emerald Star*, en route from Indonesia to China, sank some 280 km east of the northern coast of the Philippines. The sinking was attributed to the liquefaction of its cargo of nickel ore, this phenomenon suspected of having caused the vessel to lose stability, list, and finally sink.

While three ships in the area were able to rescue 15 members of the crew, 11 others were reported lost at sea according to the Japan Coast Guard, which had received the distress call from the *Emerald Star*.

This incident illustrates why nickel ore is classified as a high-risk cargo according to the International Maritime Solid Bulk Cargoes Code (IMSBC Code),[13] as it is highly susceptible to liquefaction under conditions of excessive humidity, a factor that can compromise ship stability at any time.

It is a well-known fact that the transporting of nickel ore from Indonesia to China is particularly risky. Indeed, this liquefaction phenomenon is believed to have been responsible for at least four ship incidents and the death of 66 sailors between October 2010 and December 2011. In 2013, the sinking of the *Trans Summer* off the coast of Hong Kong, along with its cargo of 57,000 tonnes of nickel ore loaded in Indonesia, was also attributed to this phenomenon. A ban on the exporting of nickel and bauxite ore from Indonesia imposed in 2014 helped limit the occurrence of such incidents. Following the relaxation of this ban in early 2017, INTERCARGO issued a statement to its members reminding them of the risks associated with the transport of nickel ore, potentially with a high moisture content.

Leak from a deep offshore jumper pipe: natural dissipation (LLOG Exploration, US)

On 13th October, approximately 60 km off the coast of Louisiana (US), the rupture of a jumper pipe leading from an offshore well operated by LLOG Exploration in the deep sea (in Mississippi Canyon Block 209) caused an estimated leak of 2,500 tonnes of crude oil in depths greater than 1,300 m. Following detection of the leak and the shutdown of the facility in order to stop the release of oil, operations focused on locating and repairing the breach using remotely operated vehicles (ROVs).

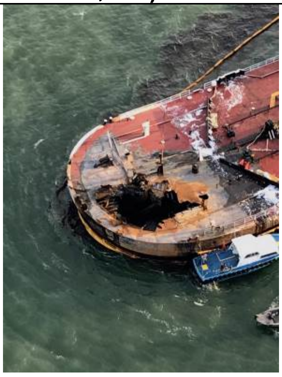
According to the U.S. Coast Guard, working in conjunction with LLOG Exploration and the relevant federal agencies (BSEE and NOAA[14]) to assess the appropriate response actions, only sheen was visible on the surface during reconnaissance flights, indicating the absence of any significant upwellings of crude oil. These upwellings dissipated naturally into the water, notably thanks to the small diameter of the breach, the high outlet pressure (> 3,000 psi[15]), and the depth of the leak. It is worth noting, however, that specialised vessels (from Clean Gulf Associates and Marine Spill Response Corporation) were placed on stand-by, while the NOAA was asked to model the trajectory of possible upwellings.

[13] And “one of the most dangerous in the world” according to the International Association of Dry Cargo Shipowners (INTERCARGO).
[14] Bureau of Safety and Environmental Enforcement and the National Oceanic and Atmospheric Administration.
[15] Over 20,700 kPa.

Crude oil spill following a fire on board a tanker barge (*B255*, Port Aransas, US)

On 20th October, a fire of unspecified cause on board a tanker barge (*Bouchard B255*), in tow and transporting a total of 21,800 m^3 of crude oil, caused breaches to two tanks and the subsequent leakage of some 320 m^3 of oil into the Gulf of Mexico, at a distance of approximately 5 km from Port Aransas (Texas, US).

Two people were killed[16] during the incident and the resulting priority fire-fighting operations before the tank lightering operations could be initiated. These were performed alongside the spill response actions coordinated by the U.S. Coast Guard (within a Unified Command including, in particular, the Texas General Land Office and the owner of the tanker) and involving aerial surveys, boom laying, and the preventive protection of sensitive coastal sites (shipping channels).



Crude oil leaking from the damaged tanks on the bow of the barge B255 *(source: USCG)*

Oil recovery operations on sandy beaches (Mustang Island and North Padre Island) (source: Maritime Executive)

Two days after the spill, scattered strandings of oil on the sandy beaches of Mustang Island and North Padre Island were reported.

The manual clean-up operations undertaken by a large number of responders (up to 120 people) resulted in the recovery of almost 40 m^3 of solid waste. This constitutes a large quantity given the apparent low intensity of the strandings.

• Review of spills having occurred worldwide in 2017

This review is based on the spills recorded by Cedre in 2017 involving volumes greater than or equal to 10 tonnes and for which sufficient information was available for statistical analysis. For a certain number of incidents, however, the volumes spilt are unknown or were not specified in our information sources, although the data available shows that they were clearly in excess of the 10-tonne figure. These knowledge gaps and lack of precise information undoubtedly limit the accuracy of interpretation of the results presented below.

Oil and HNS spills, all origins (Cedre analysis)

• Quantities spilt

In 2017, Cedre recorded 33 spills involving volumes greater than or equal to 10 m^3, for which sufficient information was available for statistical analysis. More than half of these spills occurred at sea (representing around 58% of incidents), followed by inshore and port waters (approximately 18% and 15% of cases, respectively). Just under 10% of the spills occurred in estuaries (Fig. 1).

The number of incidents recorded in 2017 is slightly higher than the annual median expressed for the previous 13 years (29 annual incidents for the years 2004-2016), and is in line with the median calculated for the 2010s. However, the total volume of oils and other hazardous substances spilt, around 15,400 tonnes, is significantly lower than the median estimated using the same method for the previous 13-year period (around 30,600 tonnes; Fig. 3). The year 2017 was punctuated by spills distributed around a median of some 78 tonnes (calculated on the basis of the volumes specified), i.e. a relatively low value, and would appear to fit with the overall downward trend in estimated annual volumes of spills reported over this decade[17] (Fig. 3).

[16] One crew member died in the incident while another was reported lost at sea at the end of search and rescue operations.

[17] This interpretation should however be balanced against the lack of data or lack of precise information concerning the quantities spilt, which inevitably leads to a certain underestimation of the annual volumes.

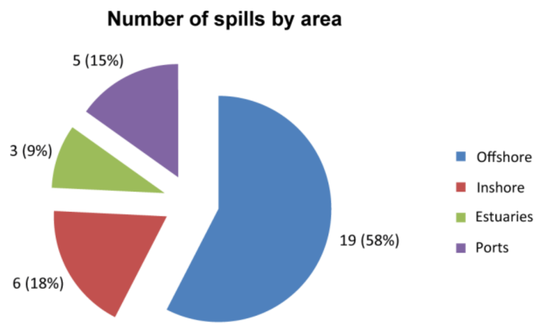


Figure 1

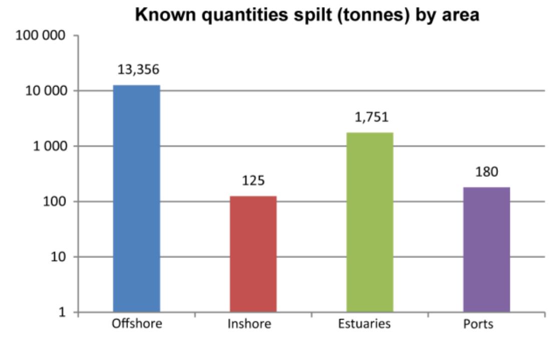


Figure 2

The quantities spilt in 2017 were mainly released at sea (Fig. 2), and were largely due to the loss of a cargo of magnesium oxide in the Channel (see LTML n°45), the rupture of a jumper pipe leading from an offshore well in the United States in October (see above), and the sinking of an oil tanker in the Gulf of Aden in June.[18]

The remaining quantities spilt in estuarine waters were primarily related to the flooding of oil facilities along the Houston Ship Channel during the passage of Hurricane Harvey over the state of Texas at the end of August (see above).

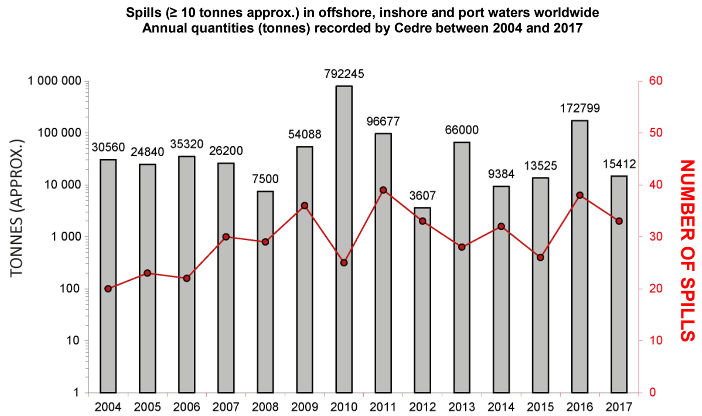


Figure 3

By comparison, ports and inshore areas were less affected by the recorded quantities spilt in 2017 (quantities which it is important to remember, as for previous years, are probably underestimated due to sometimes inaccurate information).

[18] Following a fire, the *Rama 2* (1989; 99 m long; Panama-flagged) sank approximately 390 km off Yemen, in poor weather conditions (force 8; 5 m waves), with a cargo of approximately 5,500 tonnes of diesel. The precise cause of this sinking is not specified in our information sources, nor do we have any data concerning the spill response actions implemented.

• Spill locations

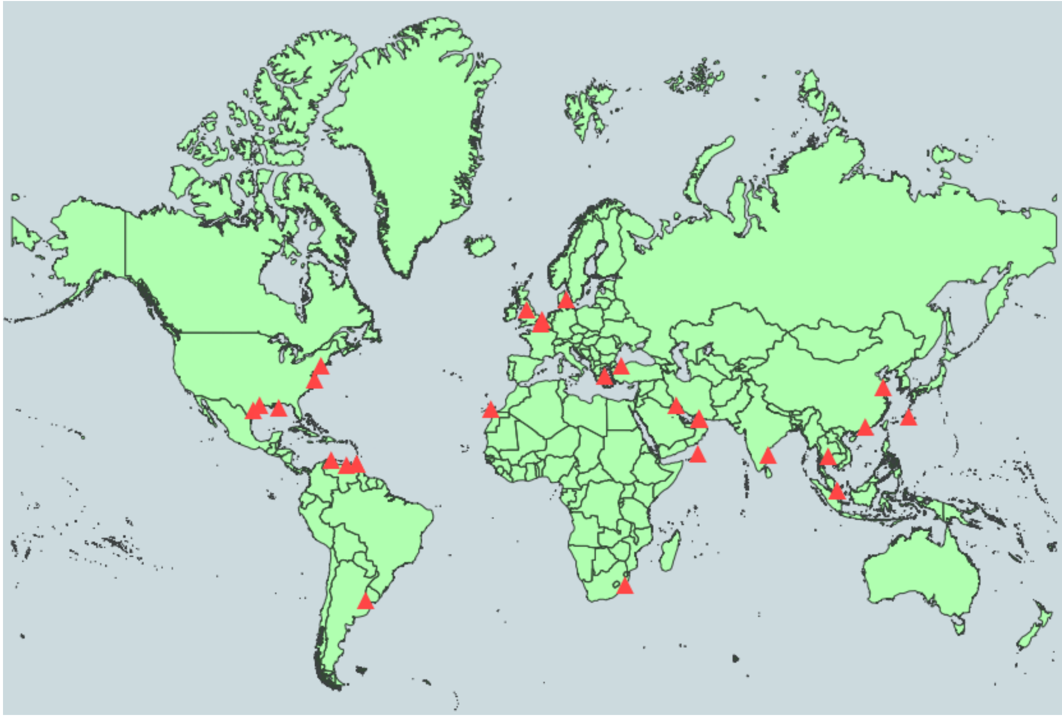


Figure 4 *Locations of the main oil and HNS spills offshore and inshore in 2017 (recorded by Cedre).*

• Events having caused spills

The majority (around 60%) of the spills identified in 2017 were due to **breaches or ruptures** in various structures:

- In terms of spill frequency, approximately one third of these incidents were the result of **ship collisions** (Fig. 5), representing around 4% of the total volume spilt in 2017 (Fig. 6). The data identified concerning the magnitudes of the spills highlight the incidents in January involving the container ship *APL Denver* and the tanker *Dawn Kanchipuram* in Malaysia and India, respectively (see LTML n°45).
- Spills resulting from the **sinking of ships** at sea with their cargoes show a similar frequency but a much higher share of the total volume spilt in 2017 (approximately 65%; Fig. 6). These figures notably include the spills resulting from the sinking of the bulk carrier *Fluvius Tamar* in the Channel with its cargo of around 3,800 tonnes of magnesium oxide, of the oil tanker *Rama 2* with its cargo in the Arabian Sea in June, and of the *Agia Zoni II* in the Aegean Sea (see above).
- Spills associated with **structure rupture** occurred less frequently (12%; Fig. 5), representing a share of approximately 2,600 tonnes (around 20%) in the annual total, and mainly concerned the rupture that occurred in a jumper pipe leading from an offshore well off the coast of Louisiana (US) (see above).

In 15% of the cases recorded in 2017, the incident having caused the spill was not described (**unspecified or undetermined**; Fig. 5). This category represents slightly more than 10% of the total volume spilt over the year (Fig. 6). A few cases (12%) fall into the category of **mystery spills**, the cause of which (accidental or otherwise) was not clearly established. These notably include the episodes of strandings of oil on the coastline of Fujairah (United Arab Emirates), which occurred several times in the spring of 2017. Suspected to have originated from oil tankers, these oilings were significant enough to have required the implementation of clean-up operations.

Based on the information available to us, none of the other types of incidents stood out in the 2017 analysis, either in terms of frequency or of their share in the overall total (Fig. 5 and 6).

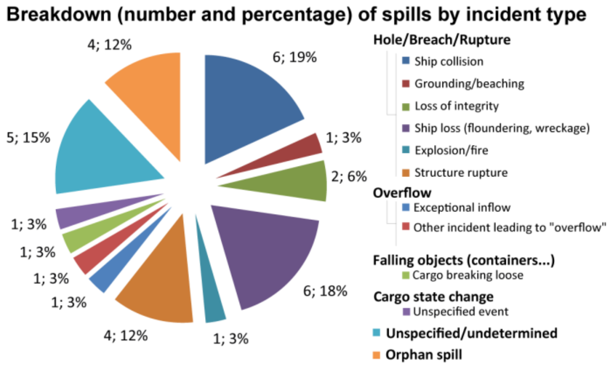


Figure 5

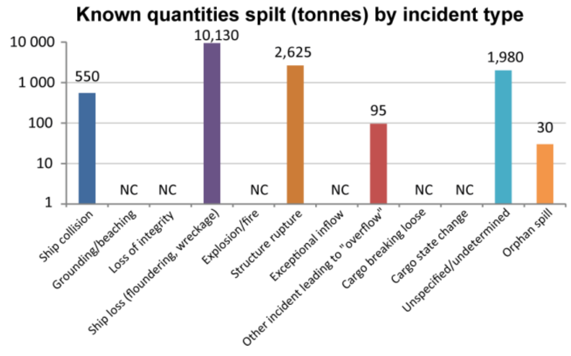


Figure 6

• Spill causes

The analysis of causes shows that they are **undetermined or unspecified** in our information sources for the majority (approximately 70%) of incidents identified (Fig. 7). In terms of volume, these incidents represent around 50% of the quantities spilt in 2017 (Fig. 8), and include significant spills associated with the sinking of the bulk carrier *Fluvius Tamar* (with its cargo of magnesium oxide),[19] and the spill of crude oil following the rupture of a jumper pipe leading from an offshore well in the United States (see above).

As an indication, among the cases for which the causes are mentioned in our information sources, the year 2017 saw a greater prevalence of **natural causes**, notably linked to the passage of Hurricane Harvey in the United States at the end of August. This led to the flooding of petrochemical sites along the Texas coastline and largely explains the estimated share in the annual total (Fig. 8). Although only one incident was recorded, the volume of spills triggered by **fires or explosions** was relatively high, and concerned the tanker that sank off the coast of Yemen in the Gulf of Aden with its cargo of over 5,000 tonnes of oil.

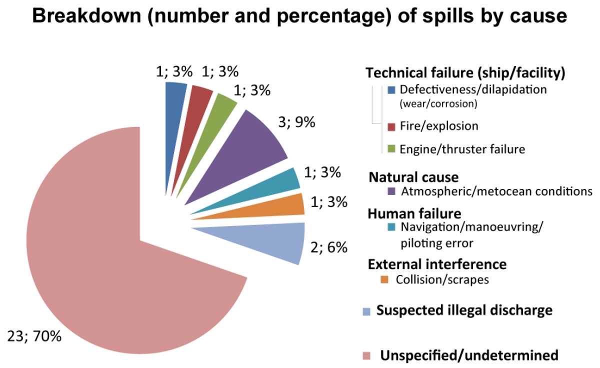


Figure 7

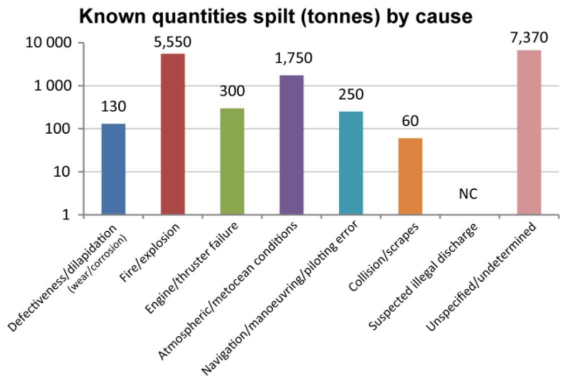


Figure 8

• Substances spilt

The vast majority of significant spills in 2017 involved oil (over 80% of the incidents recorded; Fig. 9), particularly refined products (approximately 50% of cases), followed by crude oil (around 20%) and, finally, unspecified types of oil (around 12%).

In the refined products category, we note the prevalence of **heavy/intermediate** products of unspecified IFO grades (21% of cases), followed by **light refined products** (15% of incidents, most often involving diesel). Spills of **intermediate** and **heavy refined products** accounted for 6% and 3%, respectively, of the cases recorded (Fig. 9).

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[19] See LTML n°45.

Similarly, oils largely dominate the cumulative volumes recorded in 2017, accounting for approximately 75% of the annual total. The main contributors here were refined products (around 45%), followed by crude oils (around 17%) and, finally, unspecified types of oil (around 11%; Fig. 10). We note that the share of refined products is largely attributed to **light products** (80%), with the remainder being mainly **heavy/intermediate** products of unspecified IFO grades (16%).

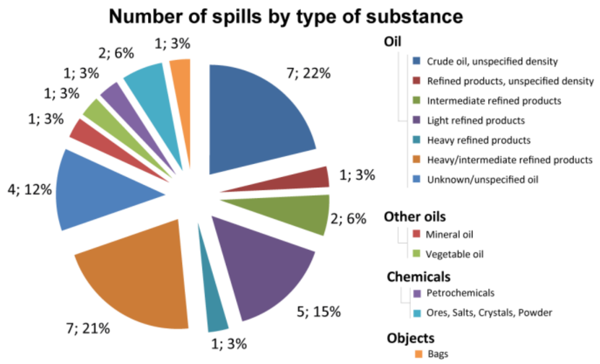


Figure 9

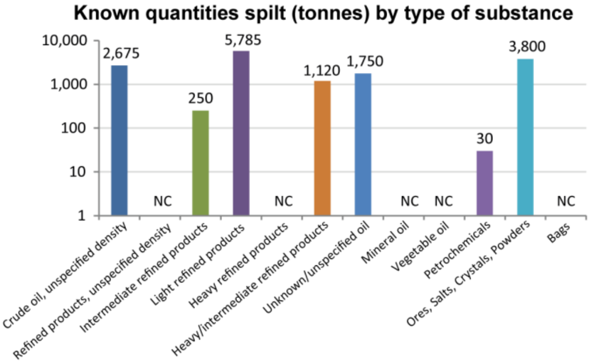


Figure 10

It should be noted that the **vegetable oil** category is underestimated in the annual total. Indeed, although press sources reported a spill of nearly 1,000 tonnes of palm oil following the *Global Apollon* incident (see above), we have not yet been able to gather sufficient data to confirm this figure.

Significant spills of chemical substances were infrequent with only three cases identified, including one in the category of **ores, salts, crystals and powders** (their relatively high share in the annual total being essentially attributed to the loss at sea of a cargo of magnesium oxide following the sinking of a bulk carrier; see LTML n°45), and another in the **petrochemicals** category (Fig. 9).

• Statistics

Ship-source oil spills in 2017: ITOPF statistics

At the end of 2017, the analysis by the International Tanker Owners Pollution Federation (ITOPF) on ship-source oil spills once again confirmed the downward trend of major spills from ships observed since the 1970s.

In 2017, ITOPF reported two large spills (over 700 tonnes according to ITOPF's terminology),[20] in line with the annual average observed by the Federation since 2010 and, above all, the downward trend observed since the 1970s (a decade during which there were on average some 25 large spills per year). These two incidents accounted for the majority of the estimated 7,000 tonnes spilt from oil tankers in 2017. ITOPF also reported four medium-sized spills (7-700 tonnes category) during the year.

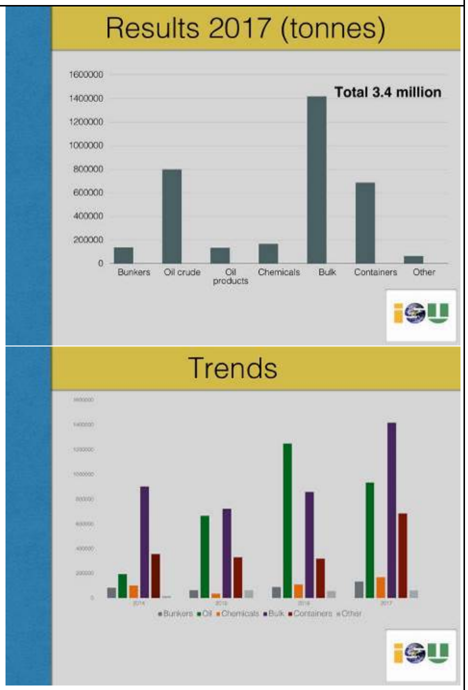
For further information:
http://www.itopf.com

[20] Presumably the sinking of the *Rama 2* in the Gulf of Aden and the *Agia Zoni II* in the Aegean Sea.

International Salvage Union Annual Review 2017

Members of the International Salvage Union (ISU) reported 252 salvage operations in 2017, involving vessels with a combined cargo of 3,405,477 tonnes of potentially polluting substances. These figures represent a significant increase compared with those recorded for 2016. The ISU emphasises the importance of its members' actions in preventing potentially imminent spills into the marine environment, while indicating the influence of the increasing number of services provided for bulk cargoes. These cargoes include various pollutants (ammonium nitrate, coal, scrap steel, grains, soya, cement, etc.), along with substances that are not considered as potential pollutants but that represent a substantial tonnage (845,976 tonnes of non-hazardous dry bulk – mainly ores). The 2017 figures also show a significant increase in the number of containers involved in salvage cases (rising from 21,244 TEU in 2016 to 45,655 TEU in 2017), a trend that reflects the size of modern container ships.

In terms of bunker fuel, the increased number of interventions in 2017 led to the removal of 135,995 tonnes, a figure that is also up in comparison with 2016 (89,492 tonnes).



Source: http://www.marine-salvage.com

According to the ISU, the results of its annual survey – which also provides interesting findings in terms of trends (at least since 2014, following the updating of the statistical methodology used) – show how the services of its members contribute significantly to preventing the occurrence of spills that could potentially impact the marine environment.

For further information:
http://www.marine-salvage.com/media-information/our-latest-news/international-salvage-union-members-operations-in-2017/

• Response preparedness/(inter)national strategies

Preparedness activities in the Netherlands: large-scale exercise in coastal shallow waters; optimisation of oiled wildlife response strategies

In September 2017, the Dutch public agency Rijkswaterstaat, the authority responsible for preparedness and response, organised the largest oil spill response exercise to date in the Wadden Sea. The aim of this exercise was to test the recently adopted response contingency plan for this particular area, which benefits from several specific protection statuses due to its shallow sediments.[21] This contingency plan is thus the result of extensive collaboration between the competent authorities and the parties managing these protected areas, including local municipalities, NGOs, and nature protection associations.

The main risk identified being that of a spill from a ship in the North Sea, the strategy consisted in ensuring the capability to respond effectively in the deepest parts of the Wadden Sea in order to prevent the spill from reaching intertidal areas where the shallow depths would make it practically impossible to deploy specialised vessels.

Based on a spill of 3,000 tonnes of IFO 180, the scenario involved the mobilisation of the *Arca* (a specialised Dutch vessel) off the coast, as well as the deployment of various shallow-draft spill response vessels in the deeper waters of the Wadden Sea. What we note from this exercise is the search for specific response methods for use in shallower waters, in particular through the deployment of an amphibious vehicle (*Wadcrawler*, manufactured by Bouwmeester B.V.) used here

[21] Two-thirds of the Wadden Sea are a UNESCO World Heritage Site, jointly managed by Germany, Denmark and the Netherlands, as well as a Dutch conservation area.

with a small FORU skimmer (see LTML n°45) for the recovery of floating products.[22] Moreover, this vehicle was also intended to be used as a platform for pumping accumulations deposited on the foreshore, but this could not be implemented due to the insufficient area of exposed foreshore, due to the weather conditions at the time of the exercise.

***Left**: volunteer integration exercise for manual clean-up in the Wadden Sea; **Right**: use of the amphibious vehicle Wadcrawler with a FORU skimmer (source: Rijkswaterstaat)*

Intervention in this type of shallow tidal environment represents a real challenge that, in the Dutch plan and in this exercise, included the deployment of volunteers to perform manual clean-up operations as well as the construction of protection systems in front of sensitive sites (sand berms).

This exercise also included a specific component concerning the implementation of oiled wildlife response operations. On this subject, Rijkswaterstaat tasked the Sea Alarm Foundation at the end of 2017 with the management of a programme aimed at optimising national preparedness for oiled wildlife response strategies. This five-year project will run until the end of 2022. It is based on industry recommendations in this area, namely the documents published by IPIECA (see below), as well as the results of the EUROWA project (European Oiled Wildlife Response Assistance Module) co-financed by the European Union within the framework of the Financial Instrument for Civil Protection and also coordinated by Sea Alarm.[23] This project, carried out between 2015 and 2016, aimed to develop an international "module" comprising a team of wildlife care experts, a stockpile of equipment that could be rapidly mobilised by member countries in the event of a spill, as well as a standard operating procedure (SOP) and several training modules. All of the above are intended to be integrated into exercises.

For Rijkswaterstaat, it is therefore a question of inscribing and adapting the current international recommendations in terms of response to oiled wildlife within a national framework and at various levels of preparedness, including contingency planning, training and exercises. The underlying motivation largely concerns the functional importance of the coastal habitats of the Netherlands (notably the Wadden Sea, for example) with respect to the very abundant coastal bird populations.

For further information:
https://www.sea-alarm.org
about the EUROWA project: http://www.oiledwildlife.eu/eurowa

New summary documents by IPIECA and IOGP: oiled wildlife; dispersant storage and maintenance

In December 2017, IPIECA published a new document entitled "Key principles for the protection, care and rehabilitation of oiled wildlife". This document was developed within the framework of the GOWRS (Global Oiled Wildlife Response System) project, under the coordination of the Dutch foundation Sea Alarm contracted for this purpose as part of the Oil Spill Response-Joint Industry Project (OSR-JIP) funded by the International Association of Oil & Gas Producers (IOGP).

The document is intended for crisis managers and the various stakeholders potentially concerned by this issue, and details the principles of the different aspects involved, accompanied by recommendations. These aspects notably include the health and safety of responders, animal handling arrangements (triage, euthanasia, etc.), the logistics (construction/layout of facilities) and organisational aspects, and the chain of actions required (surveys, protective measures including scaring systems and capture/collection, first aid, animal monitoring, release, etc.).

This document complements the 2014 revised edition of the "Wildlife response preparedness" volume of IPIECA's Good Practice Guidelines series on preparing/planning for the care of oiled wildlife.

[22] As a corollary to recovery operations, the issue of the technical aspects of slick containment in such shallow areas with rough waters due to currents and winds is worth being raised.

[23] And developed in conjunction with the Wildlife Rescue Centre Oostende (WRCO), the Royal Society for the Prevention of Cruelty to Animals (RSPCA), WWF Finland, Pro-Bird, the Estonian Fund for Nature, and the Centre Vétérinaire de la Faune Sauvage et des Ecosystèmes des Pays de la Loire (CVFSE).

In addition, IPIECA published a document entitled "Dispersant storage, maintenance, transport and testing" that complements the IOGP recommendations on the application of surface and subsea application of chemical dispersants, presented in two publications in the Good Practice Guidance series, updated in 2015 and 2016.

This summary document stems from the dual observation of, firstly, larger stockpiles of dispersants in recent years linked to the increased integration of this strategy into response options (application to underwater blowouts, for example, following the lessons learned from the *Deepwater Horizon* spill) and, secondly, a global trend indicating a decrease in the frequency of major spills. This also increases the likelihood that dispersant stockpiles will be left unused for long periods of time, hence the need to establish procedures to ensure that they are correctly maintained and that their effectiveness is monitored.

The document addresses various relevant aspects such as the optimum types of materials and storage conditions for prolonging the usability of dispersants, the development of procedures for monitoring their effectiveness (and, where necessary, for the disposal of products that are non-compliant with the specifications), insights into the United Nations' Globally Harmonised System of Classification and Labelling of Chemicals (GHS) as applied to dispersants, etc.

For further information:
http://www.ipieca.org/resources/awareness-briefing/key-principles-for-the-protection-care-and-rehabilitation-of-oiled-wildlife/
http://www.ipieca.org/resources/awareness-briefing/dispersant-storage-maintenance-transport-and-testing/

EMSA: spill response capacity in the Black Sea

The European Maritime Safety Agency (EMSA) has strengthened its offshore response capacity in the Black Sea region through the chartering followed by the entry into operational service in 2017 of a new response vessel, the bunker tanker *Galaxy Eco* from Bulgarian company Cosmos Shipping.

Based out of the port of Varna, the *Galaxy Eco* has a storage capacity of practically 3,000 m^3 of liquid waste and has been outfitted to operate with petroleum products with a flash point below 60°C. It also features a Miros floating slick detection system, and various offshore oil containment and recovery equipment: Lamor LSS15 Stiff Sweep Arms (with interchangeable brush oil recovery or weir skimmer modules), two 250 m sections of Lamor HDB 2000 offshore heavy duty boom, and a Lamor LWS 1300 high flow weir skimmer.

Bunker tanker Galaxy Eco *(90 m) (source: EMSA)*

Within the framework of a technical assistance project funded by the European Neighbourhood Instrument (ENI), the EMSA launched a survey in Ukraine, Azerbaijan, Georgia and Turkey with a view to identifying possible specific needs in terms of maritime safety, traffic surveillance and marine environmental protection in this region on the borders of Europe, the Caucasus and Anatolia. To date, the EMSA has identified one expression of interest in its RuleCheck and MaKCs tools, as well as in the CleanSeaNet service.

For further information:
http://www.emsa.europa.eu/opr-documents/item/3076-galaxy-eco.html

IMO: In-Situ Burning Guidelines

The International Maritime Organisation (IMO) has released a new publication entitled "In-Situ Burning Guidelines", which contains information on the principle of in-situ burning and recommendations for application (i) in the offshore environment, here understood to be at a distance of at least 5 km from the coast, and (ii) in ice-infested waters.

The IMO has also published the 2018 edition of the "Manual on Oil Pollution, Section II - Contingency Planning", a guide intended to assist national authorities or private entities in drawing up or revising their contingency plans.

For further information:
http://www.imo.org/en/Publications/Pages/CurrentPublications.aspx

• Containment

Chemical containment boom

Danish manufacturer DESMI recently developed a containment boom called ChemBoom, designed for use with chemicals.

This permanent flat boom has a fence of a height of 60 cm made of a chemically resistant fluoroelastomer, the Viton® fluorocarbon rubber from DuPont/Chemours Company and a synthetic MPD-I fibre,[24] here Nomex® (a registered trademark of the same manufacturer), ensuring low combustibility and improving the tensile strength of the boom.

The boom's buoyancy is ensured by stainless steel floats, with the weights and connectors of the ChemBoom sections (available in lengths of 10 or 25 m) also made of stainless steel.

View of a section of the DESMI ChemBoom (source: DESMI)

According to DESMI, the ChemBoom provides good chemical resistance against mineral and vegetable oils, a wide range of inorganic acids (with the exception of concentrated solutions of some of these products), and sodium hypochlorite or calcium hypochlorite solutions, for example. However, it would appear that it is not recommended for use with amides, ketones or aldehydes, and is considered as suitable to variable extents for certain other products (e.g. alcohols, phenols or glycols).

Rapid deployment system for the lightweight HARBO T-Fence boom

Dutch auxiliary boats manufacturer Tideman Boats, a specialist in high-density polyethylene (HDPE) hulls, has developed a dedicated oil spill response craft (OSRC) in partnership with HEBO Maritiemservice.

It would appear that the craft is more specifically intended for the deployment of disposable containment booms of the T-Fence type (designed by Israeli company HARBO Technologies) in sheltered waters (especially harbours). Following the development and testing of its fence concept,[25] the company had announced that it was working on developing the means necessary for its rapid deployment (see LTML n°44).

Prototype of the OSRC (developed by Tideman Boats) with HARBO disposable boom deployment chute (source: http://www.harbo-technologies.com)

View of a "cartridge" containing 25 m of lightweight HARBO T-Fence boom (source: Cedre)

HARBO presented its now marketed product at the Interspill 2018 exhibition (London, 13th-15th March 2018).

According to the manufacturer, this deployment chute for cartridges (size = 40 x 75 x 65 cm), each containing 25 m of lightweight boom (draught of 20 cm and freeboard of 12 cm), is deployed in a manner similar to that used for inflatable life rafts. The removable carrier cartridge is relatively small (1 x 1.3 x 0.2 m).

For further information:
http://www.harbo-technologies.com/product/
http://www.harbo-technologies.com/wp-content/uploads/2018/03/HARBO-spec.pdf
https://www.youtube.com/watch?v=dy6g6sQrugs&feature=youtu.be

[24] Poly(m-phenyleneisophthalamide).
[25] This lightweight, disposable boom is designed to be pre-positioned at high risk sites (oil facilities, ports, etc.) and is intended not as a substitute for conventional booms but rather as an initial emergency measure, pending the mobilisation and deployment of more substantial equipment.

Boom towing: small auxiliary boats from Seismic Workboats

Portuguese company Seismic Workboats (SWB), based in Peniche, developed an oil spill response craft in conjunction with Portuguese, English, American and Norwegian engineers. The boat was tested and validated by the National Maritime Authority in Portimão at the end of 2017 following its participation in a response exercise concerning an oil spill in the marine environment. Particularly appreciated aspects of its design include the stability of the vessel and its ability to tow at low speeds (due to a variable pitch propeller).

Seismic Workboats craft for containment boom deployment (source: SWB)

For further information:
http://www.swb.pt/

• Marine litter

Offshore floating litter: test phase for the prototype developed by The Ocean Cleanup

At the end of summer 2017, the Dutch non-profit The Ocean Cleanup tested a first segment of its new boom prototype for the recovery of floating litter in the North Sea, prior to further tests of the system's deployment in spring 2018 in California (US).

Following the failure of the earlier concept of bottom-anchored sections of inflatable offshore booms (DESMI, in this case), the non-profit opted for a free-floating system with a more rigid structure comprising high-density polyethylene (HDPE) tubes with a skirt to retain and concentrate floating objects. The purpose of the 2017 tests was to compare the effectiveness of different attachment systems between the float and the skirt (with a draught that gradually increases from the distal ends of the boom to reach a maximum of 3 m).

In May 2018, a towing test of a 120-metre section of the system was conducted in the Pacific Ocean, approximately 100 km from San Francisco Bay, over a period of two weeks. This test concerned the in-situ analysis of the behaviour and durability of the float and skirt under different configurations (towing speed, positioning with respect to waves and currents, etc.), with a view to assembling (reportedly soon afterwards) a first recovery system (length 600 m) intended to be implemented for accumulations of floating litter in the North Pacific.

View of the prototype float: HDPE tubes (source: *The Ocean Cleanup*)

According to The Ocean Cleanup, the prototype displayed satisfactory behaviour (floatation and buoyancy) and resistance to the ocean weather conditions encountered, confirming the hopes of the designers based on tests conducted in the North Sea and the results obtained on scale models or from numerical modelling. The construction of a complete 480 m boom was to begin shortly afterwards, with deployment planned for summer 2018 in the area known as the Great Pacific Garbage Patch, the idea being to install the boom here in a U-shaped configuration attached to an anti-drift (deep) sea anchor.

View of the skirt (draught of 3 m) (source: *The Ocean Cleanup*)

For further information:
https://www.theoceancleanup.com/

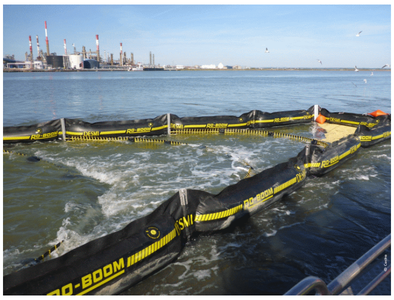
• Recovery at sea

Containment in fast flowing rivers and estuaries: testing the Speed Sweep (DESMI) and MOS 15 (Lamor/Egersund) systems

At the request of two public partners (Maritime Affairs Directorate and Cerema[26]) and an industrial partner (Total), Cedre carried out an assessment in 2017 in the Loire estuary of the in-situ performance of containment and recovery systems designed for areas with strong currents. These assessments benefited from the logistical support of the Port of Nantes Saint-Nazaire, the Sea Invest group, the “Phares et Balises” (lighthouses and beacons) subdivision of Saint-Nazaire, Total’s FOST,[27] as well as the provision of equipment and experts by the companies DESMI, Lamor and Egersund.

Following on from the NOFI system trials in 2013 and 2015 (Current Buster® 4 and Current Buster® 2, respectively), the aim in 2017 was to test various ways of deploying the Speed Sweep (DESMI)[28] and MOS 15 (Lamor/Egersund Group)[29] recovery booms: in dynamic mode (towed behind two vessels, or one vessel working with a paravane), and in static mode (mooring to a fixed point in dock and opening by a paravane; reversal when the tide turns).

The tests determined the manoeuvrability and effectiveness of the booms in recovering floating pollution (represented by oranges and popcorn) in these different configurations and at current speeds exceeding 3 knots. The tests also provided valuable information in terms of the additional resources required to implement these systems (handling, towing, etc.). Characterised by strong currents and sudden changes in the tide, the test site also made it possible to apply the rapid repositioning procedure for these systems in static mode (at slack water), as defined during the 2013 tests.



Attenuation of the surface current by successive Kevlar screens integrated in the Speed Sweep (source: Cedre)

View of the MOS 15 with its deflectors concentrating the pollution towards the recovery channel and collector pool (source: Cedre)

Positioning of the Speed Sweep in static configuration and used with the Ro-Kite (source: Cedre)

The results were satisfactory for both systems in terms of current attenuation in the collector pool, with containment of the simulated pollution at currents of up to 3 knots at the inlet of the systems, the different tests showing a decrease in effectiveness beyond this value. When deployed by a single vessel, the systems were opened sufficiently by the paravanes in currents of between 0.7 knots (DESMI Ro-Kite 1500) and 1 knot (Egersund Seafoil 15; see below). It is worth noting, however, that the deployment of the DESMI system requires the use of vessels with sufficient power.

The static mode tests also validated the technical feasibility of continuous pumping from the dockside (maximum height tested of around 5 m), and identified the need for additional resources (e.g. lifting equipment) of some of the systems for turning manoeuvres at slack water.

In conclusion, these booms do indeed push the envelope where the effectiveness of traditional booms is concerned, from around 0.7 knots in frontal current to around 3 knots (frequent in rivers or estuaries). However, their implementation requires (i) the use of appropriate nautical means (e.g. for opening the booms, the size of the paravanes, etc.) and (ii) a certain level of technical skill, highlighting the importance of regular training and exercises for the operators performing these

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26 Centre for Studies and Expertise on Risks, the Environment, Mobility and Urban Planning.
27 Fast Oil Spill Team.
28 See LTML n°41
29 See LTML n°36

operations.

Egersund Group paravanes: Seafoils 15 and 25

Norwegian firm Egersund Group is now marketing its own paravane designed to deploy booms towed by a single vessel. With its vertical wing-shaped structure topped by a float, the Seafoil comes in two sizes: Seafoil 15 (height 1.70 m) and Seafoil 25 (height 2.20 m) designed for use in conjunction with the MOS 15 and MOS 25 recovery booms, respectively.[30]

From our discussions with the manufacturer, it would appear that a MOS River model and its associated paravane (River Paravane) are currently being developed for use in shallow waters.

For further information:
http://www.egersundgroup.no/oilspill/paravane
http://www.egersundgroup.no/oilspill/mos-sweeper-

Seafoil 15 (left) and Seafoil 25 (right) (source: Egersund Group)

• Sorbents

Möbius hydrophobic sorbent manufactured from recycled tyres

Ukrainian company Möbius Group LLC offers a bulk sorbent product consisting of black granules made from a mixture of cellulose and carbon black – the latter obtained from recycled used tyres. Chemically treated to give it hydrophobic properties, the low density of this product ensures its floatability.

The results of tests conducted in accordance with the AFNOR NFT90-360 standard show that it has an absorption capacity of four times its weight and good hydrophobic properties (water retention capacity/oil retention capacity less than 0.25).

Möbius Group LLC offers its product either in bulk or as sorbent booms consisting of a polymer net (3 m long with a diameter of 13 cm).

For further information:
http://mobius-sorbents.com/

Sorbent made from treated cellulose granulate and carbon black, packaged in nets/booms (source: Möbius)

• In-situ detection/monitoring

Demonstration of marine drones

Organised by Pôle Mer Bretagne (PMB), a demonstration of marine drones was held at the naval academy in Lanvéoc Poulmic (Finistère department) at the end of September 2017. A total of 120 people (industrialists, military personnel, academics and representatives of associations) attended a morning of conferences followed by demonstrations of surface and underwater drones, as well as an exhibition of various equipment and systems.

After the opening address by the base commander, PMB presented a few ongoing drone projects. This was followed by a first round table focusing on the safety, responsibility and regulatory perspectives of the use of marine drones. While regulations for the use of aerial drones are well established, this is not the case for the marine environment. Legal uncertainty still exists regarding the use of marine drones and the liability for any damage they may cause in the event of a collision with a boat, for example. This issue is the subject of numerous meetings, particularly at the IMO, which is having to deal with a very significant boom in this sector and the appearance on the market

[30] For the spacing of the arms of the MOS 50, the largest model of boom manufactured by Egersund Group, the associated paravane is the *Ocean Boomvane* from Swedish company ORC.

of more and more drones, ranging from models measuring a few centimetres to projects for autonomous electrically propelled container ships (developments of which are planned in Norway, for example).

During a second round table entitled “Market access through services”, the French companies Texys Marine and Kopadia presented their services before discussing the state of the current market and its evolution over the years to come. Compared to ROVs, which cost around €100,000 per day to rent, marine drones offer much more financially affordable and technically feasible solutions for measurements at sea. With such a promising market, and without stricter legislation in this field, it therefore seems certain that their development will continue.

The demonstration focused more specifically on the drones and less on sensors, whether existing or under development.

Demonstrations of a surface drone and two underwater drones (source: Texys Marine)

Service provider Kopadia offers solutions for implementing fleets of underwater drones that can be used to map the seabed or to monitor offshore installations in the oil, oilfield services and offshore wind sectors. The company Texys Marine manufactures its own surface drones equipped with sensors (mainly oceanographic). The various demonstrations throughout the day showed how easy it is both to implement the use of drones (thanks to their low weight) and to guide them either using conventional remote control systems or by defining a route on a mapping application such as Google Maps, for example.

In terms of use for oil spill response, these marine drones could be included in the range of tools deployed within the context of spills. Where equipped with appropriate sensors, they could be used to dispel any doubts concerning the presence of gaseous or dissolved pollutants, for example in the vicinity of chemical tankers in distress or of wrecks. Underwater drones could also be used in the detection of submerged oil slicks.

Finally, this day also provided the opportunity to discover the Sea Test Base, a platform located in the roadstead of Brest dedicated to the testing of marine drones. This site boasts a 12-metre boat, an ROV, a workshop, and access to the maritime environment for carrying out experiments on different types of drones and for validating sensors under real-life conditions.

POLLUPROOF project

The end of 2017 saw the completion of the ANR research project POLLUPROOF (PROOF of POLLUtion), launched in 2014. The objective of this project was to improve the collection of evidence of spills at sea of noxious liquid substances (Annex II of the MARPOL Convention) via the use of airborne optical and radar remote sensing systems. The stakeholders involved (ONERA[31], Cedre, French Customs, AGENIUM, AvDEF[32], CEPPOL[33] and DRDC[34]) assessed the performance of several sensors in the detection and characterisation of six noxious liquid substances selected on the basis of experimental work comprising two stages: the calibration of optical sensors in a test tank, and the assessment of airborne optical sensors and radars under real-life conditions at sea.

For the optical sensors, the approach was based on a comparison of the spectral luminances obtained during measurements at sea with the signatures of the pollutants obtained during calibration in the test tank (reference database). Certain pollutants with high evaporation rates (e.g. heptane and methanol) were not observed, while slicks of other substances, such as xylene and rapeseed oil, were detected. The identification of the detected substances was performed by spectral correlation.

Where microwave remote sensing was concerned, the work carried out at sea on radar imagery (SAR and SLAR) enabled the identification of various liquid substances: two out of six detected by SLAR, and three out of six by SAR. In addition to this essential work at the heart of the POLLUPROOF issue, the project also explored the extent to which radar imagery can provide the data necessary for characterising and quantifying surface pollutants. Two methodologies based on

[31] The French national aerospace research centre.
[32] Aviation Defense Service.
[33] Centre of Practical Expertise in Pollution Response.
[34] Defence Research and Development Canada.

the use of radar data acquired in dual polarisation (HH and VV images) thus demonstrated the advantages of airborne or satellite radar imagery for:

- measuring, in relative terms, the quantity of pollutant present in a slick;
- characterising the behaviour of a pollutant on the surface of the sea (distinction between a film on the surface and a mixture in the water column).

The results obtained pave the way for new and innovative means that are better suited than current systems to investigate marine pollution by noxious liquid substances.

For further information:
http://w3.onera.fr/polluproof/

Acoustic measurement by ROVs and gliders of oil slick thickness and underwater leaks

In 2015, as part of its Oil Spill Response Research (OSRR) programme, the Bureau of Safety and Environmental Enforcement (BSEE) funded the development of a prototype ROV (remotely operated vehicle) fitted with inexpensive acoustic sensors, capable of measuring the thickness of an oil slick from below (from 500 µm to over 3 cm; see LTML n°41).[35] Within this context, Applied Research Associates (ARA) and the Virginia Institute of Marine Science (VIMS) designed an ROV equipped with four acoustic transducers, as well as two video cameras and a thermometer, capable of detecting and mapping oil thicknesses from underneath.

Running along rails installed on the bottom of test tanks, this prototype had been delivered to Ohmsett with a view to further enhancements in terms of estimating the volumes of oil released from an underwater source. This work notably involved integrating (i) the results of previous work conducted by the VIMS,[36] which had also evaluated the contribution of these acoustic methods to the measurement of droplets dispersed by deep-sea leaks, and (ii) the technique of acoustic backscattering for the measurement of gas bubble sizes.

A new BSEE-funded project, the results of which were published in 2017, thus assessed the feasibility of transferring the ad hoc acoustic sensors to platforms that, unlike the existing prototype, could move freely through the water, thereby enabling the in-situ deployment of this technology at the sources of underwater oil leaks and beneath surface slicks.

ARA and the VIMS were once again contracted for the management of this project.

Two different vehicles were assessed in the Ohmsett test tanks: the SeaBotix LBV150 ROV, and a glider developed by Teledyne Slocum.

Left: ROV measuring methane bubbles and crude oil droplets; **Right**: glider measuring the thickness of a floating crude oil slick (source: ARA / VIMS)

The ROV correctly measured both the thickness of the surface slicks and the size distribution of the gas bubbles and oil droplets. The glider was used to measure the thickness of the surface slicks, and proved effective in both calm and choppy waters. Certain limitations were nevertheless noted, associated with the mounting of the acoustic transducers on the ROV and glider chassis, as well as the need to physically connect them to the data processing systems, which affected the mobility and stability of the vehicles. These issues mainly concerned the ROV, although to varying degrees depending on the missions. The impact of the sensors and cables required for the thickness measurements was offset by the use of ballast weights and a revised installation of the sensors, which ensured that the ROV could be correctly controlled and guided (within certain current and wave limits). However, the dynamics of the vehicle were significantly affected by the relatively large and heavy transducers and receivers required to measure the size of the bubbles and oil droplets. For deployment and use in the natural environment, a much larger ROV would therefore be

[35] Also: **Panetta, P., McElhone, D., Carr, L., & Winfield, K. (2015)**. Acoustic Tool to Measure Oil Slick Thickness at Ohmsett. Bureau of Safety and Environmental Enforcement. Sterling, VA. Final Report for U.S. Department of the Interior & Bureau of Safety and Environmental Enforcement (BSEE), Herndon, VA. Project #1028. 55 pp.

[36] Conducted as part of an earlier BSEE project in 2014 to develop tools to measure the effectiveness of underwater dispersion.

necessary.

These results[37] are nevertheless promising as they demonstrate the potential of acoustic backscatter to measure the size distribution of gas bubbles, as well as the capacity of this technology to be integrated with the various acoustic sensors carried on board a single mobile platform.

For further information:

Panetta P.D., Argo T., Du H., Gong D., Ferris L.N. & Kidwell J., 2017. Development of acoustic methods to measure oil droplet size and slick thickness on ROV and AUV platforms. Final Report for U.S. Department of the Interior & Bureau of Safety and Environmental Enforcement (BSEE), Sterling, VA. Project # 1065. 80 pp.

• In-situ burning

Research into technologies for the reduction of soot and unburnt residues

Within the framework of a project funded by the Bureau of Safety and Environmental Enforcement (BSEE), a team of fire safety engineering researchers from Worcester Polytechnic Institute (WPI) developed and tested a new in-situ burning (ISB) technology at the Joint Maritime Test Facility (JMTF) located on Little Sand Island (Mobile Bay, Alabama), and operated by the U.S. Coast Guard Research & Development Center (USCG RDC) and the Naval Research Laboratory (NRL).[38]

After a development and assessment phase in the laboratory, the project gave rise to the creation of a prototype called Flame Refluxer®. This concept comprises a heat return system that was expected to improve combustion efficiency and thus reduce the atmospheric emissions (notably soot plumes) generated by ISB operations.

Incidentally, the prototype was also found to have the potential to retain unburnt residues that would otherwise sink in the water.

According to the WPI description, the Flame Refluxer® consists of 48 metal coils connected to a circular plate measuring approximately 1.5 m in diameter, itself consisting of a layer of copper wool arranged between two copper meshes. The system is designed to be placed on top of the previously concentrated oil from slick trawling operations.

Under the experimental conditions implemented at the JMTF, the layer of crude oil was kept at a thickness of about 1 cm throughout the duration of the burns (between 10 and 20 minutes).

Flame Refluxer® prototype being tested at the JTMF on Little Sand Island (source: WPI)

The tests conducted in 2017 involved the measurement of a number of parameters, including the temperatures above the fire, the emissions produced (carbon dioxide, carbon monoxide, nitrogen dioxide, sulphur dioxide, particulate matter, etc.), with the copper wool plate being weighed before and after each burn.

From the results obtained, it was concluded that, following ignition of the oil slick, the metal coils and copper structure transferred the heat produced by the fire to the floating oil, increasing both the speed (the quantity burnt per minute being four to five times greater than without Flame Refluxer®) and efficiency of combustion. This leads to a significant reduction in the atmospheric emissions of soot (visible to the naked eye according to the WPI), and in unburnt semi-solid residues, which are retained by the copper wool.

[37] Leading to the Technology Readiness Level (TRL) of this concept being raised to level 6.

[38] Since the 1990s (with a break between 2005 and 2015 in the wake of the damage caused by Hurricane Katrina), the NRL has notably conducted assessments of the effectiveness of fireproof booms using a shallow tank dedicated to the implementation of experimental ISB operations.

***Left**: installation of the prototype in the JMTF tank by WPI engineers (note the use of an Elastec American Fireboom); **Centre**: view of the soot plumes (relatively sparse and of a greyish colour) generated by the ISB operations using Flame Refluxer®; **Right**: view of the prototype at the end of slick burning (source: WPI)*

Pending the publication of a report detailing the results of this project, the WPI researchers announced that the design of the Flame Refluxer® technology should allow this equipment to be produced in larger sizes at a relatively low cost, as well as for other applications, notably the disposal of hazardous waste.

For further information:
https://www.wpi.edu/news/wpi-bureau-safety-and-environmental-enforcement-and-us-coast-guard-successfully-test-novel-oil

• Past spills

The *Exxon Valdez* spill, 28 years later: status of lingering oil and outlook

Numerous scientific studies[39] published since the *Exxon Valdez* oil spill (1989, Gulf of Alaska), address the lingering subsurface oil in the geologically complex coastal sediments characterising the polluted area. These findings concern localised pockets where the recovery of all of the oil was not possible, this oil lingering beyond the first few years following the spill in the form of a pasty emulsion and in conditions that penalise rapid biodegradation by bacteria.

Supported by the Exxon Valdez Oil Spill Trustee Council (EVOSTC), the consultancy firm Research Planning, Inc. recently published a paper on this lingering subsurface oil. This paper provides a new synthesis of the available literature on the causal physical and geomorphic mechanisms explaining the lingering of oil in the intertidal subsurface sediments of Prince William Sound and the Gulf of Alaska.

The paper also summarises the various modelling approaches deployed to date with a view to assessing the spatial extent and quantities of residual oil, taking additional data into account to further refine the conclusions.

On the basis of the accumulated body of knowledge, and 28 years after the spill, it consolidates the following findings:

- In 1989, approximately 17,750 tonnes of oil washed up on the affected coastlines, with only 2% of this quantity acknowledged as remaining some 3.5 years later.
- This 2% consists of residues of a thickness of between 5 and 20 cm, trapped under 10 to 20 cm of clean substrate comprising mainly heterogeneous sediments composed of fine sand and gravel. These are often topped by a layer of angular rocks forming a type of “armoured beach”, typical of the surface of impacted foreshores. The sub-surface layers here are protected from hydrodynamics, and also marked by the low circulation of interstitial water and limited porosity. All these factors promote the lingering of oil residues, directly related to the intensity of the initial pollution.
- The residual pollution of the foreshores currently covers a total area of 30 hectares and a length of just over 10 km. It reportedly represents approximately 227 tonnes, i.e. 0.6% of the total volume spilt.

[39] See for example:
BOEHM P.D., NEFF J.M., and PAGE D.S., 2007. Assessment of polycyclic aromatic hydrocarbon exposure in the waters of Prince William Sound after the *Exxon Valdez* oil spill: 1989-2005. *Marine Pollution Bulletin* **54** (3): 339-367.
SHORT, J. W., G. V. IRVINE, D. H. MANN, J. M. MASELKO, J. J. PELLA, M. R. LINDEBERG, J. R. PAYNE, W. B. DRISKELL, and S. D. RICE, 2007. Slightly weathered *Exxon Valdez* oil persists in Gulf of Alaska beach sediments after 16 years. *Environ. Sci. Technol.* **41**:1245-1250.

Finally, the conclusions of the compiled analytical results of the *Exxon Valdez* crude oil are twofold: (i) it has low bioavailability, and (ii) given its state of weathering and therefore extremely low rate of degradation, it will certainly linger for several more decades.

In the same issue of the academic journal Deep-Sea Research, scientists from the National Oceanic and Atmospheric Administration (NOAA) and from the National Marine Fisheries Service (NMFS) published an article presenting the results of samples taken during the summer of 2015 at previously monitored sites identified as containing residual oil. According to this study, residual oil was found at eight of the nine sites concerned, and no significant changes had been noted in either its quality (degree of weathering, spatial distribution) or its quantity over the period 2001-2015. Overall, this new study supports the conclusions from the above-mentioned paper, the new data it provides highlighting the negligible nature of the biodegradation of the oil trapped in the sediments due to the prevailing conditions in the area (protection from the physical action of the environment, oxygenation levels unfavourable to biodegradation, etc.).

For further information:

Nixon Z. & Michel J., 2018. A Review of distribution and quantity of lingering subsurface oil from the *Exxon Valdez* Oil Spill. *Deep Sea Research Part II: Topical Studies in Oceanography*, **147**, pp 20-26. https://doi.org/10.1016/j.dsr2.2017.07.009

Lindeberg M.R., Maselko J., Heintz R.A., Fugate C.J., & Holland L., 2018. Conditions of persistent oil on beaches in Prince William Sound 26 years after the *Exxon Valdez* spill. *Deep Sea Research Part II: Topical Studies in Oceanography*, **147**, pp 9-19. https://doi.org/10.1016/j.dsr2.2017.07.011

• Wrecks

Potentially hazardous wrecks: "isolation" by mineral sedimentation?

A recently published paper presents a new method for managing potentially polluting tanker wrecks. The authors of this paper include experts from Spain (Institute of Marine Sciences,[40] the Research Centre for Energy, Environment and Technology,[41] and departments of the Ministry of Economy and Finance[42]) and the United States (Pennsylvania State University). This method consists in burying the wreck to be "neutralised", considered a potential source of leaks, under layers of minerals in order to "isolate" it from the marine environment.

The paper presents the results of a study covering such subjects as particle size, sedimentation properties, and the modelling of the behaviour of mineral deposits (slope, consolidation/settlement, etc.).

Based on the results of their work and taking into account local environmental conditions (e.g. depth, stratification of water masses, vertical current velocity profiles, etc.), the authors essentially suggest that a layer of sepiolite (a soft, white clay) of a thickness of 2.5 m could be used to cover a submerged wreck, thus providing an effective barrier against the upwelling of oil (or other fluids with a density less than that of sea water).

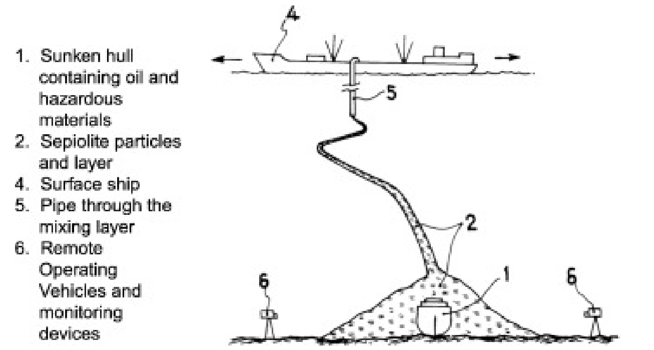

Diagram illustrating the covering of a potentially polluting wreck by a "dune" of sepiolite (source: García-Olivares et al., 2017)

Basing their calculations on the fact that currents and hydrodynamic forcing are generally much weaker on the seabed, judged to be three orders of magnitude less than the values required for the erosion of sepiolite particles of a diameter of 6 mm, the authors estimate that these mineral deposits would remain effective for about 100 years.

This concept is suggested here as an alternative to the extraction of polluting fluids from wrecks in the marine environment, an operation that is often logistically complex, costly, and sometimes

[40] Instituto de Ciencias del Mar.
[41] Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas.
[42] MINECO.

difficult to carry out successfully.

For further information:

García-Olivares A., Agüero A., Haupt B.J., Marcos M.J., Villar M.V. & dePablos J.L., 2017. A system of containment to prevent oil spills from sunken tankers. *Science of The Total Environment*, **593–594**, 242-252. https://doi.org/10.1016/j.scitotenv.2017.03.152

• Environmental impact

Deepwater Horizon spill and the macrobenthos of the Louisiana tidal marshes

A recent scientific article published in the Marine Ecology - Progress Series presented the results of a meta-analysis of more than five years of published and unpublished data on the study of populations of marsh periwinkles *Littoraria irrorata* in the Louisiana marshes, at least on the edges (15 m at the widest point) polluted following the *Deepwater Horizon* spill in April 2010.

Compared to data sampled on control sites, the authors of this study conclude that, five years after the incident and within the most affected areas, there was a significant decrease in both population densities and the size of adult individuals. These results suggest that the local restoration of this species, very representative of this coastal habitat, is still incomplete.

Initially reduced by 73% in the seaward marsh edge where the oiling in 2010 was typically heaviest (band of a maximum width of 6 m from the shore), the densities of the nearshore populations experienced a significant restoration process until 2013. They then plateaued below the levels of the reference sites and those that had been polluted to a lesser degree in 2010, which were fully restored by 2012 (marsh interior within the main oiling band, between 6 and 15 m from the shoreline).

At the most polluted sites, the average shell length decreased in 2011, returned to normal values in 2012, and then decreased again between 2012 and 2015. In comparison, in areas that had experienced little or no oiling, no effect on size was observed. The authors attribute these differences in the size distribution of the populations to a relatively long-term alteration in the recruitment of this mollusc[43] at the most polluted sites in 2010.

In conclusion, the study suggests that the restoration of populations of these coastal marsh periwinkles will take several years at the local level, i.e. in the sectors most affected by the spill in 2010. In all likelihood resulting from a combination of factors (e.g. presence of residual oil, time taken to reconstitute the plant cover,[44] characteristics of the biological cycle of the species studied, etc.), these findings are a reminder of the sensitive nature of these habitats and the underlying challenge of implementing clean-up and even protection measures for such areas in the event of a spill. From a scientific perspective, these findings also highlight the advantages of long-term monitoring in such habitats in order to further knowledge on the potential effects of spills.

For further information:

Zengel S., Weaver J., Pennings S.C., Silliman B., Deis D.R., Montague C.L., Rutherford, N., Nixon Z., & Zimmerman A.R., 2017. Five years of *Deepwater Horizon* oil spill effects on marsh periwinkles *Littoraria irrorata*. Marine Ecology Progress Series, **576**:135–144.

Deepwater Horizon spill: impact of coastal clean-up vs. impact of the oil?

The 2010 *Deepwater Horizon* (DWH) spill in the Gulf of Mexico off the southern United States was characterised by strandings of crude oil along the coast that were rapidly buried due to local hydrological conditions and sediment dynamics. This situation resulted in episodes of the remobilisation of buried weathered tarballs over several years in certain localities. In addition, the end-point criteria for the clean-up operations established for many sandy beaches due to various sensitive factors (economic or environmental) resulted in the implementation of repeated and sometimes aggressive recovery operations[45] along dozens of kilometres of coastline in Louisiana, Alabama and Florida, in particular in tourist sites.

It is within this context of potentially intensive and renewed recovery operations that experts from the

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[43] According to a process involving the recruitment or survival of the age groups of recruits, and therefore an expression of the impact of the oiling, which remains to be explained.

[44] *Littoraria irrorata* is a grazing species whose diet largely includes microfungi growing on the leaves of seed plants and salt-marsh grass - especially in the marshes studied here.

[45] For example, excavation, tilling, screening (sometimes by large machines requiring complex logistics), etc.

University of North Carolina, the United States Fish and Wildlife Service, and a private consultancy firm (Research Planning, Inc.), published a paper proposing a method for categorising the response injury on the benthic environment of sandy beaches. In addition to the assessment of the DWH spill, this method aims to provide a framework for evaluating the potential impacts on benthic fauna depending on the aggressive nature and frequency of application of clean-up techniques used in this type of environment (from manual spot cleaning to heavy mechanical treatments), and taking into consideration the main types of associated disturbance (trampling, machine traffic, extraction/physical disturbance of the sediment, removal of the strandline, etc.).

This research was based on the available records of the operations conducted in the wake of the DWH spill, as well as on data in the literature on (i) the types of disturbance caused by different clean-up operations on sandy beaches, and (ii) the benthic communities present in the environment under consideration.

This semi-quantitative assessment (application of a response injury score to the clean-up sectors) highlighted the intensity and duration of the levels of disturbance to the sedimentary environment at recreational/tourist sites, exceeding those reported in the literature for comparable substrates. In light of these results, the authors suggest the consolidation, via relevant studies, of knowledge on the potential impacts on and restoration of benthic populations of sandy beaches, with a view to verifying the commonly accepted perception that these populations are relatively insensitive to occasional disturbances (due to their capacity to recover quickly).

For further information:

Michel J., Fegley S.R., Dahlin J.A. & Wood C., 2017. *Oil spill response-related injuries on sand beaches: when shoreline treatment extends the impacts beyond the oil*. *Marine Ecology Progress Series* **576**, 203-218.

• Fines and legal proceedings

Prestige, 15 years on: compensation awarded by the Court of La Coruña

In November 2017, the Court of La Coruña (Spain) announced that it had set at €1.573 billion the compensation to be received by the Spanish State from those responsible for the oil spill caused by the sinking of the *Prestige* fifteen years earlier in 2002. The judgement also included the payment of €61 million to the French State, which had estimated the damage caused by the spill to French victims at €109 million.

In addition, a total of 272 parties were awarded damages (including many Galician local authorities). On the French side, we can note the 17 municipalities of the Landes department that had jointly initiated legal proceedings before the Spanish authorities, awarded €460,000, as well as the Basque municipalities of Saint-Jean-de-Luz and Bidart, awarded €131,000 and €63,000 respectively.