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• Spills

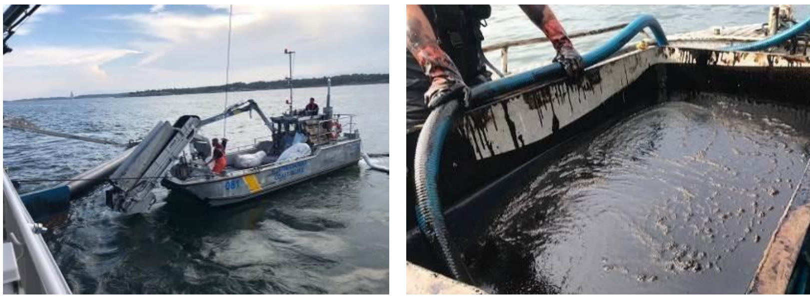
Chemical leak from an offshore platform (BP, Gulf of Mexico, US)

On 11th July 2018, approximately 25 km off the coast of Louisiana (United States), a technical failure occurred in a subsea pipeline on an offshore platform operated by the British company BP. This failure, the cause of which is unspecified in our information sources, resulted in a spill at a depth of 1,900 m of between 60 and 70 m^3 of ethylene glycol (injected to prevent hydrate formation in the natural gas dehydration process). Given the physico-chemical properties of the product, and notably its high solubility in water, the implementation of response operations was not considered appropriate. The U.S. Coast Guard (USCG, notified of the incident by the platform operator) nevertheless issued a request to the National Oceanic and Atmospheric Administration (NOAA) for an estimate of the potential fate and impact of the volume spilt.

Grounding of a ro-ro vessel and resulting spill of fuel oil in inshore waters (*Makassar Highway*, Sweden)

On 23rd July 2018, the Panamanian-flagged ro-ro vessel *Makassar Highway*, en route from Cuxhaven (Germany) to Södertälje (Sweden), ran aground on the rocky coastline near the Swedish town of Loftahammar.[1] Underwater inspections conducted the day following the incident revealed extensive damage to the ship's hull, including several breaches affected at least two fuel tanks. A salvage plan was rapidly submitted to the Swedish authorities by the owner and operator of the *Makassar Highway* (the European subsidiary of the Japanese company K-Line). This plan involved the lightering of the bunkers, which contained an estimated 330 m^3 of intermediate fuel oil (grade not specified in our information sources), 34 m^3 of diesel and 38 m^3 of lubricants at the time of the incident.

Adverse weather conditions nevertheless hindered the salvage operations, with waves and currents unexpectedly refloating the vessel a few days after it ran aground. It was at this point that a quantity of bunker fuel estimated by the Swedish Coast Guard (Kustbevakningen) at approximately 15 m^3 was spilt in the inshore waters.



Recovery of floating fuel oil spilt from the Makassar Highway *in inshore waters: launching an oleophilic skimmer with linear brushes (Lamor Bow Collector) from a recovery barge (**left**); transfer of the viscous fuel oil stored in the barge's tanks (**right**) (source: Kustbevakningen)*

Recovery operations were quickly launched during a lull in the weather, with the mobilisation of Swedish Coast Guard responders and vessels (in particular recovery barges with a low draught suited to shallow depths). It was later indicated that 7 m^3 of floating oil had been recovered over approximately two days of operations.

Meanwhile, the government agency's drift prediction models indicated the short-term risk of oil washing up along a stretch of coastline between the towns of Loftahammar and Valdemarsvik. Indeed, a few strandings of fuel oil were noted shortly afterwards around the fishing village of Flatvarp (Loftahammar). More than 100 responders (notably military and Coast Guard personnel) were involved in the clean-up of the oiled areas. The ro-ro vessel was placed at anchor, surrounded by booms, and made ready (plugging of leaks and stabilising of the vessel) to be towed to the port of Oskarshamn for repairs, escorted by Swedish Coast Guard vessels (KBVs 313, 033, 031 and 003).

With the exception of a minor leak of light fuel (100 litres of diesel according to the Coast Guard), no further spills occurred during this towing operation.

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[1] We have no information concerning the findings of the investigation conducted by the Swedish authorities into the cause of the grounding. However, in the days following the incident, the press reported that the Swedish courts had charged the first officer with negligence.

Diesel spill in port waters from the barge *Savage Pathfinder* (Port Arthur, Texas, US)

On 29th August 2018, the 50,000 DWT ro-ro vessel *Endurance* was hit by the bunker barge *Savage Pathfinder* while it was docked in preparation for a bunkering operation near Port Arthur (Texas, United States). The impact ruptured the *Savage Pathfinder*'s own bunker tanks, causing a spill of some 50 m^3 of diesel into the waters of this coastal port.

Rapidly notified of the incident, whose cause is not specified in our information sources, the U.S. Coast Guard's Port Arthur Marine Safety Unit and the Texas General Land Office (TGLO) coordinated the response operations on site with the support of the National Oceanic and Atmospheric Administration (NOAA) for the modelling of the fate of the oil spill.

The recovery operations on the water consisted in laying booms around the leaking vessel with a view to the mechanical recovery of the contained oil (the technical implementation and results of these operations are not detailed in our information sources).

Coastal pollution by crude oil from a transfer line (CPC, Sri Lanka)

On 8th September 2018, off the eastern coast of Sri Lanka, a rupture occurred on a pipeline connecting an offshore mooring buoy (some 10 km from the coast) and the Muthurajawela Oil Refinery Complex, operated by the state-owned Ceylon Petroleum Corporation (CEYPETCO or CPC). The technical failure occurred during the transfer of a cargo of crude oil from an oil tanker and led to a spill of an initially estimated 25 tonnes of oil into the Laccadive Sea. This figure was later confirmed to be 10 tonnes by Sri Lanka's Marine Environment Protection Authority (MEPA).

Initial surveys at sea were conducted by patrol boats from the Sri Lanka Navy (SLN) and aircraft from the Sri Lanka Air Force. Spill response operations were organised with vessels from both CPC and the Sri Lanka Coast Guard (SLCG) (namely the *Samaraksha* and the *Samudra Raksha*, which had been donated by the Japanese Government on 29th August).

The operations involved the spraying of chemical dispersants, the conditions being deemed favourable by the authorities for the subsequent dilution of the dispersed oil (water depths greater than 10 metres and choppy seas).

Based on information from MEPA, CPC announced the end of the main operations at sea four days after the spill, with the SLN and SLCG indicating that they would nevertheless continue to monitor the area.

Spraying dispersants from a tug using spray arms (source: Ceylon Petroleum Corporation)

The day after the spill, strandings were observed along a stretch of approximately 2 km of coastline between the coastal villages of Dikowita and Uswetakeiyyawa[2] with their sandy beaches and infrastructures including riprap, wharfs, etc.

Slicks of crude oil washing up on beaches (source: Sri Lanka Navy)

Clean-up operations were initiated the same day, mobilising hundreds of responders from CPC, the SLCG and the SLN (also responsible for coordinating the operations), with the assistance of experts from MEPA.

[2] A few kilometres north of the capital, Colombo.

In inshore waters, the free oil was recovered either by pumping up floating accumulations using vacuum tank trucks, with or without skimmer heads, or manually using sorbents (pads, mats, etc.).

The liquid waste was processed at the refinery.

*Pumping up the free oil: directly (**left**) or using skimmer heads (here, oleophilic discs) (**right**) (source: Sri Lanka Navy)*

On the foreshores, the oil deposited in slicks was collected manually and unavoidably involved sand extraction due to the infiltration of the crude oil, relatively unweathered, and/or its burying.[3]

*Manually recovering crude oil deposits, mixed with sediment (background: vacuum tank trucks for pumping floating oil (**left**); temporary storage of solid waste in bags, placed at the top of the beach (**right**) (source: Sri Lanka Navy)*

The cleaning of riprap was also necessary and involved at least initial rinsing (and recovery of the remobilised crude oil at the water surface).

According to our information sources, eight days after the spill at sea, MEPA announced that "70% of the oil" had been recovered and that the residual oil would be left to be degraded naturally (rinsing by rain, photo-oxidation, etc.).

The National Aquatic Resources Research and Development Agency (NARA), responsible for environmental assessment under the terms of the National Oil Spill Contingency Operational Plan (NOSCOP), was tasked with drawing up a preliminary report on the immediate visual impact and the results of sample analyses. Due at the end of September, this report (undisclosed to us) was to contain proposals, where appropriate, concerning the sites and habitats to be monitored and studied in detail ("initially over three to four months, or even longer if necessary", according to the authorities).

Spill of petrol in an urbanised estuary (road tanker, Rhode Island, US)

On 3rd October 2018, in Providence (State of Rhode Island, United States), a tanker truck overturned at a motorway slip road, spilling over 40 m^3 of petrol (gasoline). A significant (although unspecified) quantity of this petrol spilt into a small stream below the slip road, running 200 m downstream into the Providence River, which in turn flows into a large bay opening onto the Atlantic Ocean. Emergency response operations were carried out by state police and local fire department personnel and resources, before rapid notification of the U.S. Coast Guard. Given the nature of the product, it was decided to apply a foaming agent (aqueous film-forming foam or AFFF) in order to limit the fire hazard and potential health risks, a priority operation in this urban context, particularly at the point where the petrol flowed into the watercourse. Moreover, as petrol spreads rapidly, making it difficult to recover, and given its expected low persistence, it was deemed preferable not to attempt to contain the spill in order to avoid slowing down the natural dilution and dissipation processes in the Providence River.

[3] According to the photographs available for a time on the SLN website (from which the photographs in this article are taken), it is possible that the burying of the oil and its mixing with sediments may have been aggravated by trampling by the many responders.

Marine and coastal pollution: collision between the *CSL Virginia* and the *Ulysse* (Ligurian Sea)

On 7th October 2018, some 15 nautical miles north of Cap Corse and in international waters, the ro-ro vessel *Ulysse* rammed into the starboard bow of the Cyprus-flagged container ship *CSL Virginia*, at anchor and unladen at the time. This incident caused a spill of RMG 380 bunker fuel from the damaged bunkers of the *CSL Virginia*.

Rapidly detected, the volume of the leak was later estimated at approximately 550 m^3. The response operations at sea were implemented under the direction of the Maritime Prefect for the Mediterranean in his capacity as Director of Emergency Operations[4]. On 8th October, the highest level of the French maritime emergency management (ORSEC) plan was activated, with the creation of a crisis management team and a crisis treatment centre.

The ro-ro vessel Ulysse *lodged in the starboard bow of the container ship* CSL Virginia*, and leak of bunker fuel from the latter (source: French Navy)*

Slick drift forecasts (towards the north-west according to Météo-France's MOTHY oil slick drift forecast model) suggested that there was no immediate risk of it reaching the Corsican coastline.

The maritime authorities rapidly ordered an inspection of the vessels involved to analyse the options for extricating and salvaging them. Within this context, a French Navy assessment and response team was airlifted onto the *CSL Virginia* by a *Caïman Marine* NH90 helicopter from Flotilla 31F. A study to assess how best to separate the two vessels was launched in the early morning of 8th October, and an order (no. 259/2018) and navigational warning were issued by the Maritime Prefect, who also requested the activation of the RAMOGEPOL Plan.[5] The rapidly mobilised French response effort, composed of the tugs *Abeille Flandre* and *Altagna* and the OSRVs[6] *Jason* and *Ailette*, with support from CEPPOL, was supplemented by Italian vessels (the *Nos Taurus* sent from Livorno, the *Bonassola* sent from Genoa, and the *Koral* sent from Sardinia). Via the European civil protection system CECIS Marine Pollution, the *Brezzamare*[7] from the EMSA's spill response fleet was also mobilised. At the request of the maritime authorities, an expert from Cedre joined the crisis management team on 9th October as a liaison officer.

The chosen response option at sea was containment and mechanical recovery. While initially not very rough, the sea state deteriorated over the days following the incident, causing the fuel oil to disseminate, drifting in more or less fragmented strings and patches over an area several tens of nautical miles long.

*Various appearances of the oil at sea, according to the spread and fragmentation of the fuel oil that leaked out during the first few days (**left, centre**: 07/10/2018; source: French Navy) (**right**: 12/10/2018; source: French Customs)*

The areas with the greatest concentrations of oil (patches and aggregates of different sizes) were monitored via aerial surveys, and several buoys were deployed to help track their movements.

4 *Directeur des Opérations de Secours, DOS*.

5 Joint intervention plan between France, Italy and Monaco for marine oil spill response operations in the Mediterranean, established in 1993 within the framework of the RAMOGE Agreement (the RAMOGE zone, for Saint-RAphaël-MOnaco-GEnova, comprising the maritime zones of the Provence-Alpes-Côte d'Azur, the Principality of Monaco and Liguria).

6 Oil Spill Response Vessel.

7 Oil tanker converted into an oil spill response vessel with a recovered oil storage capacity of almost 3,290 m^3 in addition to its containment and recovery equipment.

Various recovery methods employed (examples, from left to right): containing a floating slick using the sweeping arms of the Brezzamare *(source: EMSA); recovery of fragmented slicks of fuel oil by the OSRV* Ailette *using a mechanical weir skimmer head (SeaSkater) (source: French Customs); trawling for scattered fuel oil using surface nets (THOMSEA) from the OSRV* Jason *(source: French Customs)*

From an operational perspective, the difficult weather and sea conditions hindered the effectiveness and even deployment of the available containment equipment (floating booms, or the sweeping arms of the *Ailette* and *Brezzamare*) and, therefore, the quantity of oil recovered using skimmers. In addition, by causing increased movements of the lodged vessels, the heavy swell also contributed to the occurrence of new leaks of oil from the hull of the container ship. These leaks could only be partially contained as the sea state made it very difficult to ensure the effectiveness of the boom system laid around the vessels. On the evening of 11th October, these conditions led to the "spontaneous" separation of the *Ulysse* from the *CSL Virginia*, after attempts had been made to extricate it by towing. The work of pumping out the residual contents of the *CSL Virginia*'s leaking bunker tank began the next day.[8] As regards recovery operations on the water, the emulsification and fragmentation of the fuel oil prompted the use of surface net systems (notably Thomsea trawl systems deployed from the *Jason*). These operations faced technical difficulties (deployment, configuration, mechanical resistance) due to prevailing conditions.

Periods of relative calm nevertheless enabled the recovery of specific patches of floating fuel oil using weir skimmers (some of which were fitted with paddle drums[9]), without necessarily involving the prior laying of containment booms. This strategy was chosen to ensure the rapid movement of vessels and equipment from patch to patch. In this respect, we can note the assessment, about a week after the incident, of the contribution of drones – here operated from the *Jason* with encouraging results – to facilitate the guiding of the OSRVs in response areas (which also largely drew on aerial surveys by French and Italian planes, including from the French Navy and Customs).

Some seven to eight days after the incident, the fragmentation (into patches, patties, etc.) and dissemination of the heavy fuel oil as well as its physico-chemical evolution (notably emulsification and evaporation) complicated detection and recovery at sea. Meanwhile, aerial observations showed that the unrecovered oil was approaching the French coastline and oil slick drift models were predicting that the oil would rapidly reach the shores of the Provence-Alpes-Côte d'Azur region and more particularly the Var coastline. At this stage, operations at sea by the French and Italian vessels had resulted in the recovery of approximately 1,000 m^3 of a water/oil mixture.

While part of the response fleet was redeployed to the inshore waters (first mostly in the east/north-east of the Gulf of Saint-Tropez, and later towards the west and the Bouches-du-Rhône department), the first strandings of fuel oil were noted on 16th October (nine days after the spill) on the beach of Pampelonne in Ramatuelle (Var department). Close to the coast, the *Jason* was still assigned to search for and recover residual patches of fuel oil, supported by various French Navy vessels (e.g. the *Loire*, the *Taape* and the *Achéron*) and smaller vessels for surveys and/or the possible recovery of scattered patches (*Merry Fisher* type motorboats, and a recovery barge belonging to the company Efinor contracted by the owner of the *CSL Virginia*). The last vessels left the coastal and inshore waters during the first half of November, thereby concluding response operations at sea. According to the Maritime Prefecture for the Mediterranean, around 90% of the spill had been recovered, with the maritime part of the response operations having mobilised more than 500 people (comprising a cumulated total of over 96,000 hours of work), 34 French and Italian

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[8] The day following its extrication, the *Ulysse*, considered fit for navigation, was authorised to sail – escorted by an Italian tugboat – to Tunisia, arriving on 14th October in the port of Radès (before going on to Bizerte). The *CSL Virginia*, after the necessary clean-up operations and securing of the hull, was authorised to leave its mooring on 23rd October. Escorted by the *Abeille Flandre* out of French waters, it left the RAMOGE zone on 25th October bound for Turkey (initially Romania). After being renamed *Virgin Star*, it was sold on 21st December 2018 for ship breaking in Bangladesh.

[9] HiWax skimmer head, in this case suited to viscous products, mounted on TransRec weir skimmers (Framo).

vessels, and 11 French and Italian aircraft (helicopters, planes and drones).

Despite operations at sea, the first tarballs and patches of oil started to wash up along the Var coastline from 16th October onwards, initially in an area comprising the Gulf of Saint-Tropez. More than ten towns in the Var department were affected, and sporadic strandings were reported in early November at a few sites in the Bouches-du-Rhône department.

Under the authority of the Prefect of Var, who activated the POLMAR onshore contingency plan under the departmental ORSEC plan, the first surveys were conducted and clean-up sites were set up along the coastline[10] by local authority, fire brigade, civil protection and military police personnel. A Departmental Operational Centre[11] was set up at Toulon Prefecture while an incident command post was established in Ramatuelle, bringing together various departments and services (DREAL, DDTM, SDIS, etc.) as well as local crisis management stakeholders.

*18/10/2018: manual recovery on the beaches of the affected towns (e.g., **left**, Ramatuelle; **right**, Sainte-Maxime) by local and state services (source: Cedre)*

At the request of the Var Prefecture, experts from Cedre arrived on site on 17th October to conduct surveys of the affected sites and to provide technical recommendations on the clean-up operations to be implemented.

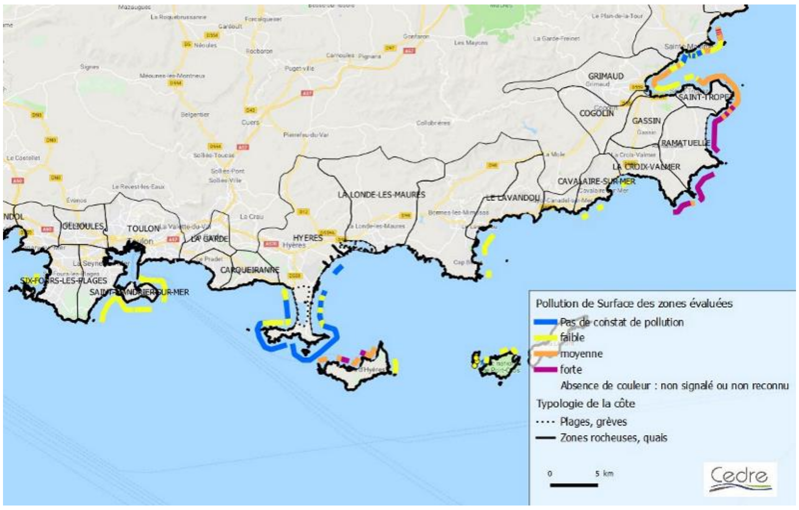
Two weeks after the first strandings, the clean-up operations were contracted out to the private sector, namely the specialised contractor Le Floch Dépollution (LFD) commissioned by the P&I Clubs of the vessels involved, which also requested the presence on site of experts from ITOPF.[12] Within this context, LFD was required to submit an action plan to the Maritime Prefect for validation, describing the strategic and methodological options selected to accomplish the task, and including a provisional schedule. While at this stage the state's resources had been withdrawn and the incident command post demobilised, the progress and management of the clean-up sites remained under the supervision of the Departmental Operational Centre. In this respect, it was agreed that LFD (which set up its own incident command post, first at Pampelonne and then at the former command post) would report on its actions to the maritime authority on a daily basis. Cedre also drafted weekly reports, while continuing to conduct visits to the clean-up sites at the request of the Prefect of Var until completion of the operations, initially scheduled for the end of March 2019.

Generally speaking, the level of coastal pollution was relatively moderate: surveys, launched during the first few days and regularly reiterated to monitor the evolution of the situation, showed that there were no oil slicks as such.

However, the spread of the oil was significant due to its prior fragmentation at sea into emulsified and viscous patches and tarballs.

[10] Public access to which was prohibited.
[11] *Centre Opérationnel Départemental, COD*.
[12] International Tanker Owners Pollution Federation Limited.

Spread by the currents, these patches and tarballs washed up along a large stretch of coastline, mainly in the Var department between the towns of Sainte-Maxime to the west and Hyères to the east (with the sector of the Massif des Calanques in the Bouches-du-Rhône also being affected by tarballs, but the low intensity of these strandings meant that no action was required beyond collection operations under the responsibility of the local authorities).



Extent of oilings 10 days after the first strandings on the coastline (source: Cedre)

For the oiled sites, numerous issues, notably socio-economic and environmental, were involved. For example, the beaches along the Gulf of Saint-Tropez (towns of Sainte-Maxime, Grimaud, Cogolin, Gassin, Saint-Tropez, etc.) are popular for recreational and tourism activities (campsites, hotels, water sports, etc.). Towards the south, and in addition to these economic issues (e.g. Pampelonne beach in Ramatuelle), the spill gave rise to significant environmental concerns. Indeed, certain sites along this coastline have a protection status, notably the "Corniche Varoise" Marine Protected Area[13] (also a Natura 2000 site), the Port-Cros National Park,[14] and numerous sites managed by the Conservatoire du Littoral (French coastal protection agency) in several towns (Saint-Tropez, Ramatuelle, La Croix-Valmer, etc.).[15]

The oiled sites essentially corresponded to east/south-east-facing segments of shoreline with facies that are mostly exposed to waves (strong hydrodynamics). These facies are of two main types:

- Sedimentary, characterised by coarse-grain sand beaches of varying lengths, from the 4 km-long Pampelonne beach to the few dozen metres (or even less) that characterise the numerous small coves affected. The discontinuous oiling here generally took the form of tarballs (measuring between 1 and several centimetres) and oil patties (several tens of centimetres), with more occasionally patches of over 1 metre in length. Their distribution was sporadic (coverage < 10%) to locally fragmented (10-50%).
    - Sedimentary movements in the intertidal zone could cause arrivals to be buried under a few centimetres of sand.
    - These deposits frequently occurred where there were accumulations of seagrass, in successive layers (at varying depths, on the surface for the most recent), with which they were mixed or agglomerated to varying extents.

Pampelonne beach: patches of agglomerated fuel oil and seagrass (source: Cedre)

[13] Extending from the outskirts of Rayol-Canadel-sur-Mer in the west to the Pointe de Ribou in Saint-Tropez in the east.

[14] The oldest French marine national park, including since 2012 an adjacent maritime area corresponding to the coastal waters between the right of La Garde and Ramatuelle and up to 3 nautical miles south of the islands of Hyères (Porquerolles, Port-Cros, Le Levant).

[15] Examples of oiled sites managed by the Conservatoire du Littoral: Batterie de Capon, Pampelonne, Cap Camarat, Cap Lardier, the islands of Porquerolles and Port-Cros, etc.

*Types and sizes of strandings on sandy beaches: **left**, micro-tarballs and tarballs (approx. 1-10 cm); **centre**, tarballs and oil patties (several cm to tens of cm); **right**, semi-buried oil patty under a few cm of clean sand (source: Cedre)*

- Rocky, characterised by (i) low coastlines with many small, steep-sided coves, surrounded by promontories and rocky outcrops, as well as (ii) sectors of high, steep cliffs in the headlands (e.g., Cap Camarat, Cap Taillat, Cap Lardier). Emulsified, viscous, sticky fuel oil was found there in discontinuous deposits, taking the form of persistent spatter, traces, and even patches locally (measuring around 1 metre). These arrivals resulted from (i) deposits of oil washed up on rocky platforms/outcrops, accumulating in greater thicknesses (> mm) in the natural depressions and rugged topography of the terrain (cracks, boulders, etc.), or (ii) spattering from breakers in the supralittoral zone. Generally speaking, these oil stains were sporadic (coverage < 10%) to fragmented (coverage between 10 and 50%), concentrated at points where the topography facilitated the trapping of the oil (e.g., at the upper end of coves or in faults, in natural depressions/channels, or on complex structures such as boulder fields, etc.). It is worth noting that seagrass debris was frequently incorporated in the oil layers, accentuating their thickness.

*Traces of oil generally observed on rocky platforms (**left**). Scattered deposits: on boulders at the upper end of coves (**centre**); in the faults and crevices of rocky platforms (**right**) (source: Cedre)*

*Examples of spattering in the rocky supralittoral zone: splashes (**left**), traces on rocky outcrops (**centre**) or on cliff bases (**right**) (source: Cedre)*

The intensity of the pollution (density and size of oilings) varied within the large stretch of coastline concerned. In natural areas, as expected, the oilings naturally accumulated in the indentations/discontinuities of the coastline (e.g. deep faults, small coves, etc.), were deposited along the strandline, or spattered above the water level.

- In certain coves and faults, the washed-up fuel oil coincided with significant concentrations in the supralittoral zone of plant debris of very different sizes (mainly seagrass, wood, reeds, trunks, etc.) and various types of litter (pieces of fishing nets, various plastics, polystyrene, etc.), which contributed to increasing the volume of the oiled solids recovered.

Examples of strandlines oiled to varying degrees, with plant debris (reeds, wood, trunks, etc.) and litter. On the right: mats/clusters of oil and seagrass debris topped by various debris (near Cap Lardier) (source: Cedre)

- A further observation: in several places, these areas that were naturally conducive to the stranding of floating materials also contained residues of old spills. These corresponded, at least in part and in all likelihood,[16] to the spill of heavy crude oil following the [*Haven* oil tanker incident] (Gulf of Genoa) in 1991. Taking the form of persistent clusters on rocks, they were particularly visible on several strands and headlands, notably between Bonne Terrasse and Cap Taillat (Ramatuelle). A visual examination of these clusters was sufficient to distinguish them from the oil spilt from the *CSL Virginia* (hardened, asphalt-like appearance/texture, rough with incorporation/incrustation of coarse sediments, etc.), but this nevertheless required relatively close observation (i.e. in conditions allowing the surveying of faults, cliff bases, etc., exposed to the waves).

Appearance/close-up view of traces of old oil pollution. Examples in the following areas (from left to right): Bonne Terrasse, Pointe du Canadel, La Douane beach (source: Cedre)

The surveys revealed no indications of any significant impact of the oil strandings on the coastal flora or fauna (no coating/smothering and/or mortalities among benthic species, no carcasses washing up on beaches, no live oiled animals, etc.).

Finally, it should be noted that the weather and oceanic conditions during the acute oiling phase (several episodes of strong easterly winds, with swells and breakers) caused the remobilisation and redistribution of part of the oil. These notably concerned semi-floating accumulations (at the upper end of coves, in the middle to lower mesolittoral zone), requiring new surveys to be conducted in order to locate them and to facilitate their recovery as soon as possible, to restrict their spread.

*Examples of remobilisable oil: 19/10/2018, free/floating patches at the upper end of rocky coves (**left**); 28/10/2018, oil retained (with plant debris) behind boulders in the lower mesolittoral zone (**centre**); 30/10/2018, rocky coastline in the Canadel area: episode of oil remobilisation due to strong winds and waves (note the strings of tarballs/oil patties picked up by the waves) (**right**) (source: Cedre)*

Given the urgency during the first few days, oil clean-up operations - conducted by the state

[16] Based on statements by local stakeholders (notably town halls and site managers) with good knowledge of the Var coastline, and the sites mentioned here in particular.

services, local authorities, etc. - had to be launched without delay and, therefore, without any specific procedure for setting up clean-up sites. Subsequently, with the transfer of responsibility for conducting the operations to the private sector, the local authorities concerned requested that the actions be duly programmed and continued in their areas. This is how the “official” set-up of these clean-up sites, now operated solely by Le Floch Dépollution, was initiated. More precisely, it was a question of opening up zones: relatively large sections of coastline corresponding to geographical areas within which the actual clean-up and recovery sites were organised according to an operational segmentation of the coastline (e.g. rocky coves, sandy beaches, rocky headlands, etc.). This approach by zones responded to the demand (i) by the municipalities concerned for the rapid commencing of operations, as well as (ii) the need – at least during the first few weeks – to deploy teams of responders within the zones in question in a somewhat “opportunistic” manner in order to first recover the semi-free patches of fuel oil, picked up by the waves and moved due to the weather conditions (strong winds and breakers in the eastern sector; see above).

Five zones[17] were thus determined, progressing from the most sensitive areas in various respects (public access/numbers of visitors, environment, etc.) to the most remote or difficult access areas (e.g. rocky areas at the foot of cliffs near headlands). Initial inspections were conducted on each site with representatives of the local authorities, departments and site managers concerned, with experts from ITOPF, LFD and Cedre also being systematically present. During these initial on-site inspections, the different phases, technical options and objectives of the clean-up operations were explained to the participants for their approval. Given the characteristics of the pollution in the shoreline sections included in these zones, the appropriateness and necessity of these operations were also subject to consensus between the experts on site.

As is always the case in such situations, and for each of the various operational sectors, the choice of response techniques and their methods of application took into account both the level of the pollution and the characteristics of the shoreline segments (uses/numbers of visitors, visual impact, environmental sensitivity, self-cleaning potential, etc.). The possible options were relatively limited for many sites due to the small number of and/or difficulty in accessing the areas immediately behind the clean-up sites (see below), which thus restricted the use of machinery and other mechanical equipment, for example.

The following principles were adopted:

- Manual recovery on sandy beaches, a laborious process given the extent of the areas concerned (Pampelonne beach) and requiring the mobilisation of numerous responders by LFD, but these operations made it possible to limit the excessive removal of sediment and unoiled plant debris. Underwater agitation (using impact/low pressure hoses) was necessary locally to dislodge tarballs and patches that had been mixed with the sand due to wave action (e.g. Camarat and Douane beaches, the Cap Taillat tombolo), and performed several times where necessary.
- The following operations were performed on rocky substrates:
    - Manual collection, including the use of handheld tools (forks, rakes, scoops, etc.) where necessary, of oil deposits naturally trapped on wave-cut platforms (or between boulders).
    - Scraping and scrubbing of the layers of oil plastered/spattered on surfaces (boulders, headlands, cliff sides, etc.).
    - In the final cleaning phase, depending on the case:
        - high pressure cleaning (HPC) with seawater of surfaces with no macroflora or macrofauna, and adaptation of the pressure and temperature to the nature of the substrate (friable shales on certain sites);
        - certain clean-up sites (e.g. the Bonne Terrasse rocky platforms) required the responders to be especially attentive to the difference between traces of old pollution (believed to be from the *Haven*) when present concomitantly

[17] From north-west to south-east (the zone numbers from 1 to 5 do not reflect an order of priority): **Zone 1**: Gulf of Saint-Tropez (towns of Sainte-Maxime, Grimaud, Cogolin, Gassin, Saint-Tropez); **Zone 2**: from Salins-d’Hyères to the beaches of Pampelonne (Saint-Tropez / Ramatuelle); **Zone 3**: from Le Migon to Cap Taillat (Ramatuelle / La Croix-Valmer); **Zone 4**: from Cap Taillat to La-Londe-des-Maures (La Croix-Valmer / Cavalaire-sur-Mer / Rayol-Canadel-sur-Mer / Le Lavandou / Bormes-les-Mimosas / La Londe-les-Maures); **Zone 5**: the Giens Peninsula, the islands of Porquerolles, Le Levant, Port-Cros and Bagaud (Hyères).

with fuel oil from the *CSL Virginia*.

- Concerning the numerous deposits of seagrass, sometimes taking the form of thick, more or less consolidated "mats",[18] recovery operations were as selective as possible:
  - manually, for oil deposits on the surface of seagrass mats;
  - using tools (rakes, forks) in the event of a "multi-layered" distribution of the oil within the seagrass mats themselves in order to remove the polluted layers (seagrass/oil clusters) while leaving the unoiled plant debris in place;
  - on some sites, the formation of agglomerated patches of oil and seagrass debris in mats that were sometimes thick (around 1 metre) and very wide (several metres) required complete manual removal.

Oilings in many areas where plant debris (wood, trunks, etc.) had accumulated required extensive manual sorting in order to optimise the selectivity of the recovery operations (unoiled elements left on site).

Manual recovery/shovelling of remobilisable semi-floating patches (source: Cedre)

Scraping of oil layers on rocky surfaces (source: Cedre)

Beaches: manual recovery of deposits (surface/sub-surface) (source: Cedre)

Residual traces after scraping of the oil layers, pending treatment by HPC (source: Cedre)

Sorting of oiled/unoiled plant debris (source: Cedre)

Sorting of oiled pebbles for in-situ *cleaning in a concrete mixer (source: Cedre)*

Agitation (low-pressure water jets) of sand in the surf zone to recover buried tarballs (source: LFD)

Preparation of high-pressure cleaning operations (involving effluent collection systems, protection against spattering, etc.) (source: Cedre)

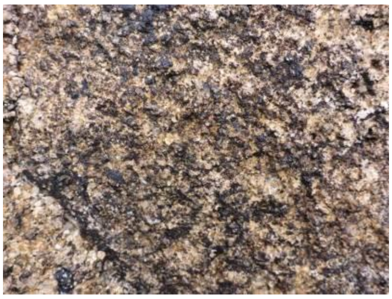
[18] The displacement or removal of which is regulated given their functional role in mitigating beach erosion.

The nature and configuration of the coastline led to local operational difficulties at several levels:

- Accessibility to the clean-up sites, with a high number of private roads requiring the consent of the owners (apartment complexes, campsites, hotels, etc.) for their use. In some areas, there were very few tracks suitable for vehicles providing access to the clean-up sites, making it difficult to install and remove equipment and to evacuate the oiled waste. At certain sites (south of Ramatuelle, for example), the transfer of equipment from one clean-up site to another (power packs, pressure washers, seawater tanks, etc.) and the evacuation of the collected waste in big bags had to be partly performed by helicopter.

Helicopter evacuation of oiled solids in big bags (source: Cedre)

- Available surface area for the *ad hoc* organisation of clean-up sites (e.g. installation of primary storage facilities, HPC systems, etc., in compliance with personnel safety and environmental instructions, protection of soils, etc.), which in some places had to adapt to the very narrow and uneven terrain of the coastal strip.



January 2019: residual traces of fuel oil after the first high-pressure cleaning operations (Casabianca / Roche Escudelier, Ramatuelle) (source: Cedre)

- The tenacity of certain traces of oil pollution on specific types of rock during final high-pressure cleaning operations. In the coves in the Casabianca area (Ramatuelle) in particular, the grainy texture and weathering of granite resulted in the adhesion and impregnation of the fuel oil on their surface. This phenomenon required repeated high-pressure cleaning operations until a satisfactory level of cleaning was obtained (absence of fuel oil “seepage” after treatment).

Finally, it is worth noting that at certain sites, in particular rocky promontories/cliff sides very exposed to wave action and that were difficult to access (sometimes requiring the deployment of responders and equipment by sea), the final cleaning operations (phase II) could not be comprehensively conducted due to the high risk to responder safety. However, these same constraints contributed to the relatively low level of oiling and a high self-cleaning potential over the long term under the action of natural, physical and biochemical processes (waves and currents, photo-oxidation, bacterial and micro-organism activity, etc.).

It was initially thought that the operations would be completed by the end of the first quarter of 2019 for the resumption of socio-economic activities in the spring. While almost all of the clean-up sites were practically completed by this deadline, certain sections required operations to be continued for the following reasons:

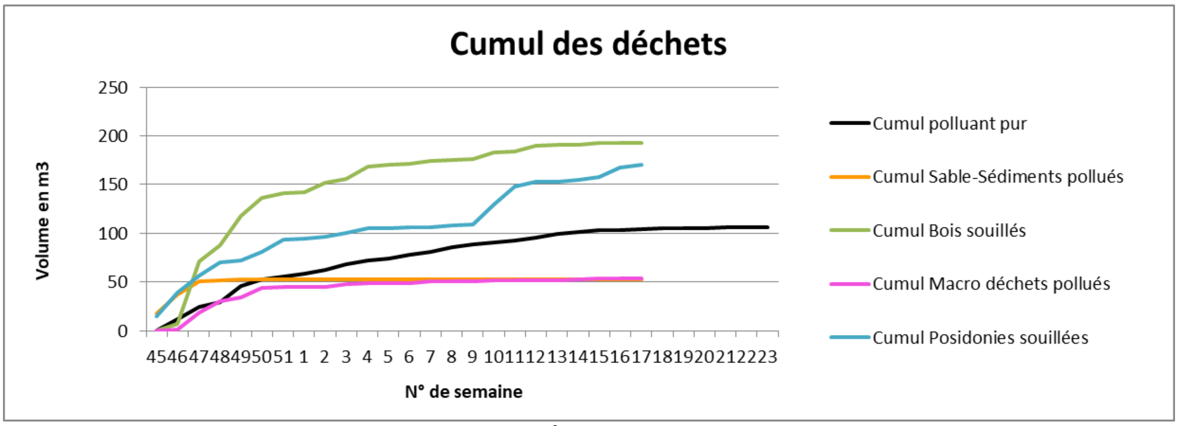
- The re-emergence of residual buried oil (tarballs and micro-tarballs) during weather conditions and sedimentary movements, particularly in the Cap Taillat sector, where occasional arrivals continued to be brought in with the tide, despite many hours of manual recovery and underwater agitation. This motivated the setting up of a shoreline watch and recovery actions where necessary in the run-up to the summer of 2019.

24/04/2019, La Douane beach (Ramatuelle): remobilisation of buried residual micro-tarballs and tarballs, and arrivals along the tide line (source: Cedre)

- The discovery of traces of oil in somewhat inaccessible rocky areas distant from the most frequented sectors, generally at the foot of steep cliffs, inspected during the milder weather conditions in the spring. The very environmentally sensitive nature of these sites (land managed by the Conservatoire du Littoral) led to the implementation of additional scraping and high-pressure cleaning operations in late spring, where responder safety could be ensured.

*April 2019: scraping operations (**left** and **centre**) and HPC (**right**) in remote and difficult access sites (near Cap Lardier, La Croix-Valmer) (source: Cedre)*

By 10th June 2019, a total of 580 m^3 of waste had been recovered,[19] comprising approximately 100 m^3 of emulsified oil, around 170 m^3 of oil combined with oiled seagrass, as well as 200 m^3 of oiled plant debris (trunks, wood, reeds, etc.), around 50 m^3 of oiled litter and a similar quantity of oiled sand.



Summary of the waste recovered: cumulative quantities (in m^3) on 10/06/2019 (data source: daily reports on clean-up operations by LFD)

After more than six months, these combined recovery operations had mobilised a significant number of responders (nearly 18,800 man-days, for 875 site-days) and a large quantity of equipment, as well as considerable efforts in terms of environmental precautions and response to the strong expectations in terms of landscape-related, economic and tourism issues.

Spill of aromatic solvents from a petrochemical terminal (Fujian Donggang Petrochemical Industry, China)

On the night of 4th November 2018, in the Chinese port of Quanzhou (Quangang District, Fujian Province), a leak occurred from an aging loading line at a terminal operated by Fujian Donggang Petrochemical Industry Co., Ltd. during the loading operations of a chemical tanker (*Tiantong 1*). This leak resulted in a spill of approximately 70 tonnes of C9 aromatic hydrocarbon solvents (light naphtha) into the port waters.

[19] Estimates by Cedre, based on a compilation of the data taken from the daily reports on clean-up operations by LFD.

Application of sorbent mats on floating accumulations of aromatic solvent in aquaculture cages (source: www.caixinglobal.com)

Fujian Donggang Petrochemical Industry reported an initial leak of about 7 tonnes, in addition to the contents of the loading line (more than 30 tonnes) and leaks detected at two other storage tanks (accounting for nearly 20 tonnes).
Little technical information on the response – organised and completed the same day – was released, apart from the use of conditioned sorbents (pads, mats, etc.) to recover the floating part of the product, a colourless liquid that is not readily soluble in water and that floats and evaporates (forming potentially explosive vapours). According to press reports, around 100 vessels and some 600 responders were mobilised for these clean-up operations.
The city authorities also announced the immediate implementation of air quality monitoring in the polluted area, indicating a “return to normal levels on 5th November”. The water, considered as “moderately contaminated” on 6th and 7th November, was deemed to have returned to normal levels after these dates (levels I and II, China classifying water quality into levels expressed from I, suitable for drinking after minimal treatment, to VI). The day following the leak, the local Office for Agricultural Affairs banned the marketing and consumption of aquaculture produce.
Local residents and users (fishermen, aquaculturists, etc.) reported a corrosive action of the solvent on fishing gear (plastics, nylons, etc.) in floating accumulations, as well as mortalities among aquaculture populations. Believing that they had been misinformed about the toxicity of the spill, they expressed scepticism concerning announcements that the water and air pollution levels had returned to normal – especially given that more than 50 people suffering from nausea, vomiting, etc., had been admitted to hospital in Quanzhou.
The city authorities blamed the operator of the petrochemical site for the spill, and said it would provide 5 million yuan in aid to aquaculture operators whose equipment had been damaged. Ten days after the spill, the city police arrested seven people for negligence, including three representatives of Fujian Donggang Petrochemical Industry and four crew members of the chemical tanker.

Disconnection of an offshore gathering line and spill of crude oil (Husky Energy, Canada)

On 16th November 2018, a leak of crude oil from a gathering line occurred between the SeaRose FPSO (Floating Production Storage and Offloading) vessel and an offshore well operated by Husky Energy in the White Rose oil and gas field (approximately 350 km off the coast of Newfoundland). This incident, caused by a malfunction, occurred during the return to service of the facility, operations having been suspended the previous day for safety reasons due to strong winds and high seas.

These conditions initially prevented the identification of the leak point and the response at sea. Husky Energy deployed drift buoys and mobilised an aircraft as soon as was possible to conduct initial assessments of any surface pollution.

ROV view of the disconnection on the subsea gathering line (source: Husky Energy)

The specialist company ECRC-SIMEC[20] was also commissioned by Husky Energy to provide support in the event of response operations at sea being necessary.
As the weather and sea conditions eased off (4 m troughs at the most), an ROV was deployed to assess the status of the leak, which was found to be stopped three days following the incident. According to Husky Energy, the leak resulted from a disconnection, for an undisclosed reason (under investigation), while hot crude oil was flowing through the line for reheating prior to the resumption of production.
The spill, calculated at around 250 m^3 based on the estimated rate and duration of the leak, was considered to be one of the largest to date on the White Rose oil and gas field. Aerial surveys did not, however, detect any traces of floating pollution due to the rapid natural dissipation of this

[20] Eastern Canada Response Corporation/Société d'Intervention Maritime, Est du Canada, accredited by Transport Canada – Marine Safety as a response organisation under the Canada Shipping Act (CSA).

volume of crude oil under the prevailing sea conditions.

Concerns for local bird populations prompted the establishment of a treatment centre. Within four days of the incident, 14 oiled birds had been collected, three of which were alive and placed in care.

Husky Energy submitted a plan to replace the failed connector for approval by the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB),[21] a prerequisite for any authorisation to return to service (in addition to a preliminary report provided by the operator, the findings of which were not made public by the authority).

Vandalism and spill in an urbanised coastal bay (Transpetro pipeline, Brazil)

On 8th December 2018, as a result of an act of vandalism aimed at stealing fuel, damage to a pipeline operated by the Brazilian company Transpetro (Petrobras Transporte S.A., a subsidiary of Petrobras specialised in the transportation of oil and by-products) caused a spill of around 60 m^3 of unspecified oil. This spill impacted several kilometres of the Estrela River estuary before reaching Guanabara Bay. The oil company indicated in press releases that it had repaired the breach and mobilised some 400 responders for the oil spill response operations (nature not specified in our information sources), which, according to the company, resulted in the recovery of 75% of the oil. Despite the moderate volume of the spill, concerns about the environmental impact of this incident were reported in the press, particularly with respect to the mangroves near the estuaries at the head of the bay. This concern should, however, be balanced against the chronic pollution characterising Guanabara Bay, which receives wastewater directly from the urban area of Rio de Janeiro.

• Review of spills having occurred worldwide in 2018

This review is based on the spills recorded by Cedre in 2018 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 in the interpretation of the results presented below.

Oil and HNS spills, all origins (Cedre analysis)

• Quantities spilt

In 2018, Cedre recorded 27 spills involving volumes greater than or equal to 10 m^3, for which sufficient information was available for statistical analysis. Just under half of these incidents occurred at sea (44%), and slightly less than a quarter in port waters (22%). Approximately 20% of these spills occurred in estuaries and 15% in coastal waters (Fig. 1).

The number of incidents recorded in 2018 is slightly lower than the median estimated from values calculated in a similar way since 2004 (30 annual incidents for the years 2004-2017) or since the beginning of the 2010s (33 for the years 2010-2017).

The year 2018 thus does not differ significantly from previous years in terms of the occurrence of spills. However, the total quantity of oil and other hazardous substances spilt, around 130,000 tonnes (Fig. 3), is significantly higher than the median estimated using the same method for the previous 14 years (around 30,000 tonnes). It should be noted that this quantity can be explained by a single major event (the *Sanchi* oil tanker incident in the East China Sea in the first half of the year; see LTML n°47) and that, overall, the year 2018 was punctuated by relatively small spills (distributed around a median of some 60 tonnes[22]).

[21] Federal agency responsible for regulating offshore oil activities in the Province.
[22] Calculation based on identified data.

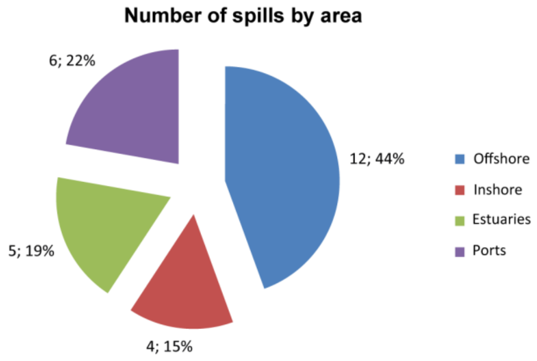


Figure 1

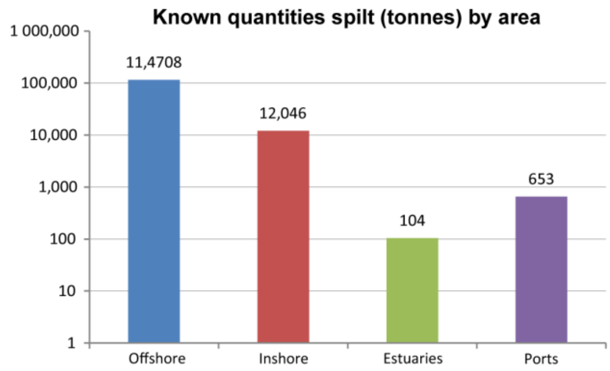


Figure 2

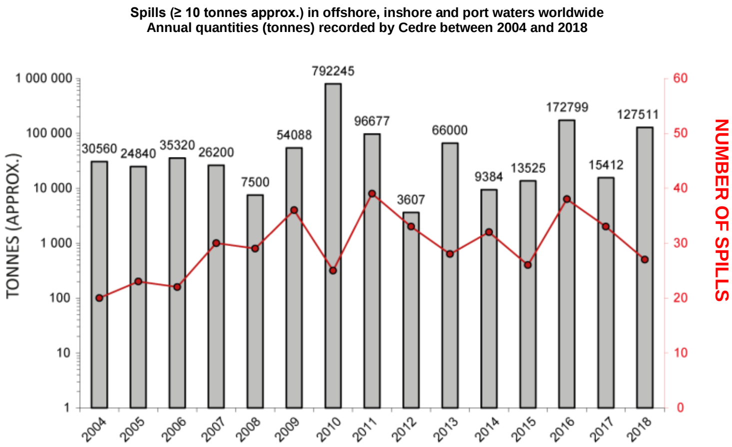


Figure 3

In 2018, the majority share of the total quantity of oil spilt occurred at sea (Fig. 2), again largely related to the sinking of the oil tanker *Sanchi* in January (see LTML n°47), far ahead of other maritime incidents (including that of the *CSL Virginia* and the subsequent spill of more than 500 tonnes of bunker oil, see above).

The cumulative volume of spills in coastal waters was mainly due to a spill of oil-polluted water from a Cuban refinery.[23]

Port and especially estuarine waters were relatively less affected by the volumes spilt in 2018. The spill of heavy fuel oil following the collision of the tanker *Bow Jubail* with an infrastructure in the port of Rotterdam in June accounted for the largest spill in this category (approximately 220 tonnes of fuel; see LTML n°47). It should be noted however that, as in previous years, these quantities are probably underestimated due to sometimes inaccurate information.

[23] On 29th May 2018 in Cuba, heavy rainfall associated with the subtropical depression *Alberto* caused a leak of approximately 12,000 m^3 of oil-polluted water (at undisclosed levels) into the coastal waters of Cienfuegos Bay. This was reportedly due to the partial submersion of facilities within a refinery belonging to the national oil company Cupet (Cubapetroleo).

• Spill locations

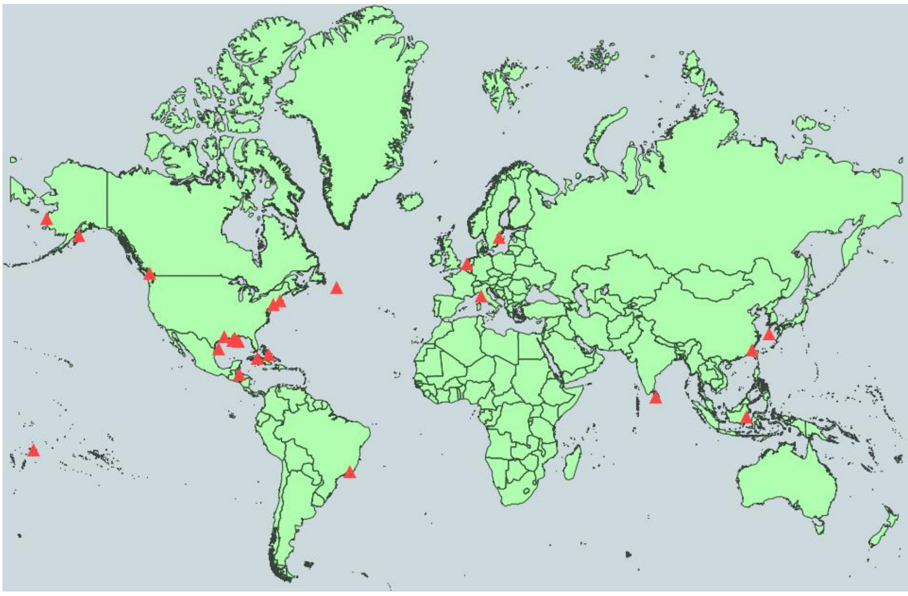


Figure 4 *Locations of the main oil and HNS spills (> 10 T) offshore and inshore in 2018 (recorded by Cedre).*

• Events having caused spills

The majority (around 80%) of the spills identified in 2018 were due to **breaches or ruptures** in various structures (Fig. 5):

- In terms of frequency, just over one third of these incidents resulted from the **loss of integrity** of various structures (most often storage tanks or internal pipelines), particularly in coastal oil installations (wells, storage facilities) or offshore installations (platforms). With generally moderate spills (median value of between 30 and 40 m^3) and totalling less than 500 m^3, these incidents contributed only marginally (less than 1%) to the total volume spilt in 2018 (Fig. 6). The leak from a gathering line on a Husky Energy offshore platform in Canadian waters (see above) was undoubtedly the most significant incident in this category.
- Incidents related to **structure rupture/collapse** represent approximately 22% of the **breaches or failures** category (i.e. 18% of all incidents; Fig. 5), but their share in the volume spilt is negligible (Fig. 6), or more precisely underestimated in this analysis due to a lack of accurate data concerning the volumes spilt during these incidents.
- **Breaches or failures** resulting from **ship collisions** were slightly less frequent (15% of all incidents), but their share in the total volume spilt in 2018 is overwhelming (around 90%; Fig. 6) as this category includes the spill of cargo and fuel from the *Sanchi* in the East China Sea. The collision between the container ship *CSL Virginia* and the ro-ro vessel *Ulysse* is also included here, although the volume of the resulting spill (between 500 and 600 tonnes of bunker fuel) was much smaller.

In 15% of the cases recorded in 2018, the event having caused the spill was unknown (**unspecified or undetermined**; Fig. 5). This category represents approximately 10% of the total volume spilt over the year (Fig. 6). Based on the information available to us, none of the other types of events stood out in the 2018 analysis, either in terms of frequency or of their share in the overall total (Fig. 5 and 6).

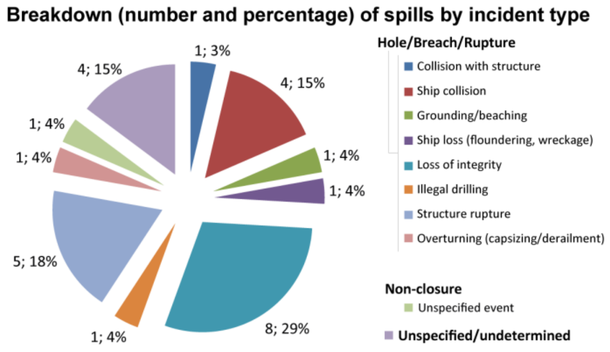


Figure 5

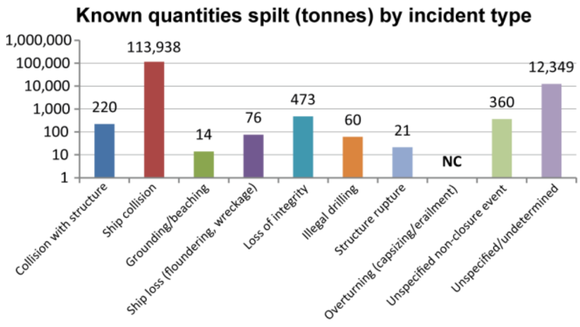


Figure 6

• Spill causes

The analysis of causes shows that they are **undetermined or unspecified** in our information sources for a relatively large share (approximately 33%) of incidents identified (Fig. 7). In terms of volume, these incidents represent 90% of the quantities spilt in 2018 (Fig. 8), an overwhelming share related to the spill resulting from the collision between the oil tanker *Sanchi* (with its cargo of condensates) and the grain carrier *CF Crystal*,[24] the cause of which has not, to date and to the best of our knowledge, been made public.[25]

Another third of the incidents reported are associated with various types of **technical failure**, mostly **unspecified** (Fig. 7), which together represent only a small share in the total spill volume in 2018 (Fig. 8). This is due to relatively small spills (median of around 50 m^3), with that caused by an internal pipeline failure on an offshore platform off the coast of Newfoundland being the largest (and the only one to have exceeded 100 m^3) according to the data identified.

Finally, it should be noted that around 15% of cases are related to **natural causes** (Fig. 7) according to the information collected. These cases represent slightly less than 10% of the overall volume spilt in 2018 (Fig. 8), but this figure is probably underestimated, based on the spill of around 12,000 m^3 of polluted water from a refinery on the Cuban coast (linked to the passage of a subtropical depression in the Caribbean at the end of May). The other incidents in this category were either minor or resulted in spills of unknown volumes, although probably in excess of 10 m^3 according to the information identified.

The other causes reported were noted at low and comparable frequencies. We can note the relatively higher share of **human errors**, in particular **monitoring/checking failures,** in the total volumes spilt (Fig. 8), particularly in connection with the collision between the vessels *Ulysse* and *CSL Virginia* in the Mediterranean in October.

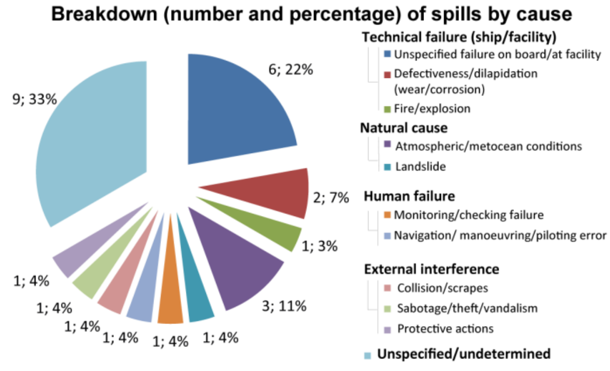


Figure 7

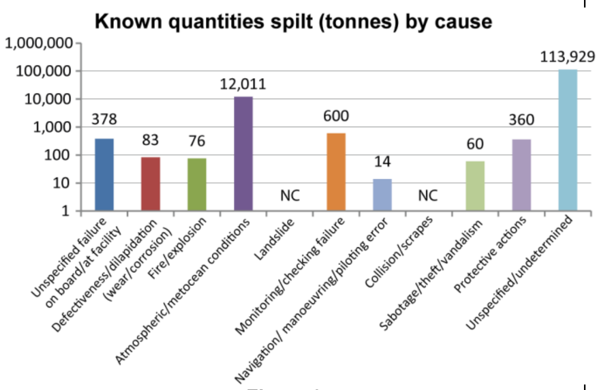


Figure 8

[24] See LTML n°47.

[25] While as early as spring 2018, various sources (notably agencies of the Iranian Ports & Maritime Organization) suggested (in the national media) that "human errors of the CF Crystal officers, putting it on a wrong path 15 minutes before the incident, led to the collision", we have not identified any investigation reports – or other information sources – that would either support or contradict this analysis.

• Substances spilt

The vast majority of significant spills in 2018 involved oil (over 90% of the incidents recorded), half of which were spills of refined products, two to three times more frequent than those involving **crude oil** or **unspecified types of oil** (Fig. 9).

Among the spills of refined products in 2018, it is worth noting the prevalence (around 30%) of incidents involving **light refined products**, twice as frequent as those involving **heavy or intermediate** fuel oils and, even more so, those involving spills of **heavy refined products** (IFO grades above 380) (Fig. 9).

Similarly, oils largely dominate the cumulative volumes recorded in 2018, accounting for nearly the total volume spilt. Although very frequently implicated in the year's recorded incidents, **condensates** clearly represent the majority share (more than 80% of the estimated quantity of oils spilt; Fig. 10) in connection with the major incident involving the oil tanker *Sanchi* (see LTML n°47). **Unspecified types of oil** and **heavy to intermediate** fuel oils (around 10% and 2%, respectively, of the total volume of oil spilt), are the only categories to have exceeded 1,000 or even 10,000 tonnes, according to the figures available to us (Fig. 10).

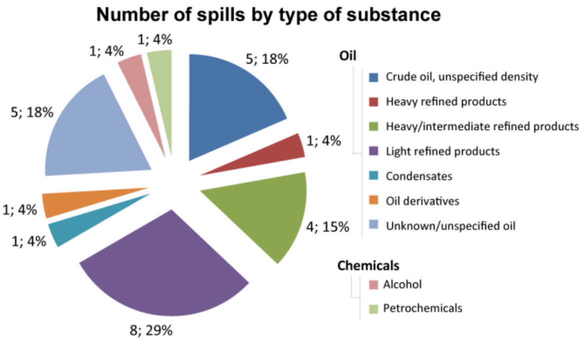


Figure 9

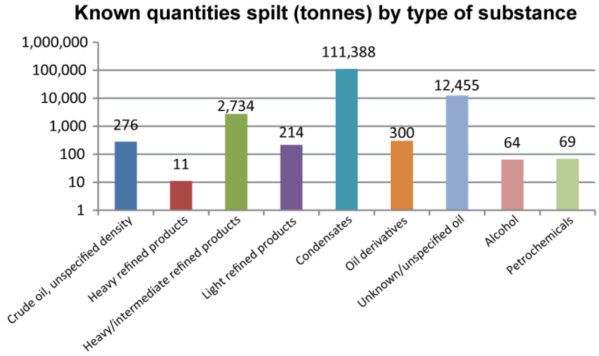


Figure 10

With only two significant incidents identified in our information sources, reports of chemical spills were infrequent in 2018. These incidents involved liquid substances, corresponding respectively to the categories of **Alcohols** (leak of ethylene glycol from an offshore platform) and **Petrochemicals** (pollution of port waters by aromatic solvents spilt from a petrochemical terminal), both of which are described above and whose share in the total spill volume is relatively low given the moderate quantities involved (between 60 and 70 tonnes).

• Statistics

Ship-source oil spills in 2018: ITOPF statistics

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

In 2018, ITOPF reported three large spills (over 700 tonnes according to ITOPF's terminology), and three medium-sized spills (7-700 tonnes category).

- The former included two ship collisions in China, at the beginning (the *Sanchi* incident) and the end of the year, and a third incident (for which we have no precise information) involving a tanker that sank in the Persian Gulf with a cargo of over 1,000 tonnes of oil.
- The three medium-sized spills (over 7 tonnes) reported by ITOPF occurred in the Gulf of Guinea in February (during a ship-to-ship transfer), following a ship collision (with an unspecified structure) in Europe in June, and finally as a result of a collision between two ships in Africa in November.

According to ITOPF, the *Sanchi* incident was the main contributor to the total volume of oil spilt in marine waters in 2018, the largest annual estimate of the last 24 years. However, this does not compromise the significant decrease in the number of medium-sized and large spills observed in recent decades, estimated by ITOPF at 4.7 and 1.9 per year, respectively, since 2010 (despite the simultaneous global increase in the transportation of oil products).

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

• Past spills

***Agia Zoni II*: investigations into the causes of the sinking and compensation for damage**

On 10th September in the anchorage area of the port of Piraeus (Greece), the coastal tanker *Agia Zoni II* was waiting to carry out bunkering operations when it developed a list for an unspecified reason and subsequently sank (see LTML n°46). According to estimates by the IOPC Funds, 700 m^3 of bunker fuel was spilt into the coastal waters, causing arrivals along the coast, mainly on Salamis Island and near Piraeus and its northern borders (over a stretch of some 20 km).

A Claims Submission Office was set up in Piraeus by the IOPC Funds to handle claims arising from the pollution damage. The scale of the spill 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.

On the Greek side, two investigations were initiated to determine the causes and responsibilities related to the incident:

- On the one hand, the Hellenic Bureau for Marine Casualties Investigation (HBMCI), an entity that is separate from the judicial authority, launched its own investigation.
- On the other hand, the Public Prosecutor instructed a judge to carry out a judicial inquiry, with the support of the Piraeus Port Authority and various experts appointed for this purpose, the aim being to assess whether any liabilities could be considered as offences justifying charges and subsequent prosecution under the Greek Criminal Code. This initiative was notably based on the submission to the Public Prosecutor of an inspection and expert report on the wreck of the bunker, which was towed to a shipyard on Salamis Island.

As no clear cause had emerged in the witness statements provided, the 1992 Fund had requested authorisation from the Public Prosecutor to conduct an expert examination of the wreck. This request was denied until completion of the expert assessment in the criminal investigation, initiated in June 2018.

- The National Technical University of Athens submitted its conclusions to the judge in charge of the investigation at the end of 2018. Although these conclusions were not made public, the IOPC Funds indicated on their website that the incident apparently resulted from an explosion (of undetermined cause) which led to an ingress of water and, ultimately, to the sinking of the *Agia Zoni II.* In spring 2019, the 1992 Fund indicated that it was still awaiting a copy of this technical report upon its official publication, as well as information relating to another investigation by the Public Prosecutor into the conditions under which contracts had been awarded to the service companies mandated to clean up the oil spill.
- Similarly, in April 2019, believing that the investigation by the third Marine Accident Investigation Council (ASNA), also conducted for the Public Prosecutor, had been completed, the 1992 Fund was awaiting its official publication, especially as the Greek media had reported various hypotheses (unconfirmed as they had not been made public) concerning the factors leading to the incident and the aggravation of the spill. On this latter point, the IOPC Fund website reported the media's assertion that ASNA had concluded that "none of the above [measures] sought to save the ship", "it was a pre-planned objective and such development should not be disturbed", and that "'the interests served in this case are clearly evident from the economic benefit obtained by companies assigned by the shipowner to manage the anti-pollution and de-pollution operations".

As of April 2019, no further details of the formal inquiry had been made public and the reports of the investigations were pending.

However, while the 1992 Fund chose to refrain from speculating on the hypotheses reported in the Greek press pending the official publication of the conclusions of the investigations, it did indicate the importance of clarification in this respect, in particular in order to assess whether or not the shipowner was entitled to limit their liability and thus to have triggered the process of paying out compensation in excess of the amount concerned by this limitation.

At this stage, the Claims Submission Office had received 361 claims totalling €92.48 million and US$175,000, the 1992 Fund having assessed 219 claims and paid out a total of some €10.8 million in compensation for 70 of these claims.

For further information:

https://www.iopcfunds.org/fr/

• Response preparedness/(inter)national strategies

EMSA: reinforcing stockpiles of equipment and products for response operations at sea

In 2018, and with a view to improving the oil pollution response capacity available to Member States through its Equipment Assistance Service (EAS), the European Maritime Safety Agency (EMSA) purchased two high capacity Lamor LUT 5 80 skimmer systems (140 m^3/hour). Stored on a reel and operated via an umbilical hose and a telescopic crane arm, each of these offshore skimmers is notably equipped with an oleophilic brush module and a Lamor Positive Displacement Archimedes Screw (PDAS) pump for the recovery of viscous/emulsified products. These additional containerised systems are stationed at the Gdansk (Poland) stockpile covering the Baltic Sea area.

EMSA has established and currently maintains three EAS stockpiles, located in Ravenna (Italy) in the Adriatic Sea, Gdansk (Poland) in the Baltic Sea, and, since 2019, Tolkkinen (Finland) in the northern Baltic Sea. The previous stockpile in Aberdeen, Scotland (United Kingdom) no longer appears in the EMSA list of EAS.

Finally, in February 2019, EMSA added a stockpile of chemical dispersants to the Ravenna EAS, including Radiagreen OSD (from OLEON N.V.) and SLICKGONE NS (from DASIC International Ltd.), representing a total of some 600 tonnes according to the Agency.

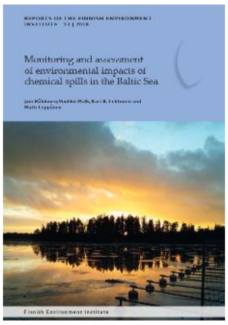
For further information:

http://www.emsa.europa.eu/oil-spill-response/eas-inventory.html

• Hazardous and noxious substances

HNS spills: supporting environmental impact assessments in the Baltic Sea

At the end of 2018, the Finnish Environment Institute (SYKE) and the Finnish Ministry of the Environment concluded a two-year project aimed at laying the foundations for future recommendations in terms of assessing and monitoring the environmental impacts of spills of hazardous and noxious substances (HNS) in the Baltic Sea.



This project, dubbed EKOMON, resulted in the publication of a document intended primarily for the authorities responsible for implementing such programmes in the event of chemical spills.

At this stage, it is less an operational document than an overview explaining the complexity of the numerous and very varied potential impacts of HNS transported by ships.

Although the quantities of HNS transported by ships are globally lower than those of oil products, a real possibility of incidents and spills at sea nevertheless remains, and the associated environmental risk is difficult to identify as it depends on a combination of factors:

- contextual and "conventional" factors, for example specific to the geographical region under consideration (maritime traffic, type and tonnage of the products transported, prevailing weather and sea conditions, biological components, etc.), and the spill scenario (quantities, one-off/continuous incident, marine/coastal waters, etc.);
- factors related to the knowledge or understanding of the intrinsic properties of HNS (behaviour, toxicity, persistence, etc., by product family) that determine their potential impact.

By providing a reminder of the parameters to be taken into account, the knowledge (and gaps therein) in terms of the behaviour of HNS and their potential effects, as well as the existing resources to support response preparedness ("product" databases, behaviour modelling, etc.), the document resulting from the EKOMON project is intended to be a first step towards the development of practical recommendations for the organisation of measures to identify and monitor the ecological consequences of chemical spills.

For further information:

https://helda.helsinki.fi/bitstream/handle/10138/243068/SYKEre_23_2018.pdf?sequence=1&isAllowed=y

• Detection

Direct offshore oil detection and real-time transmission: autonomous buoy prototype and the EU GRACE project (Horizon 2020)

Between November and December 2018, a "SmartBuoy" was deployed offshore in the Gulf of Finland and successfully tested for the detection and monitoring of oil concentrations in the water mass. This prototype comprises a polyethylene buoy equipped with: (i) sensors for the *in-situ* detection of the presence of oil (measured in relative fluorescence), as well as the measurement of dissolved organic matter concentrations, temperature and salinity, wave height and current strength/direction; and (ii) a real-time data transmission system (via satellite).

Manufactured by the Finnish specialised maritime engineering firm Meritaito Ltd., this monitoring buoy was anchored south of Helsinki for these tests. The results are available online (www.luodedata.fi).[26]

It was developed within the framework of the GRACE project ("Integrated oil spill response actions and environmental effects"), funded by the European Union under the Horizon 2020 research and innovation programme and coordinated by the Finnish Environment Institute (SYKE). Initiated in 2016 and scheduled for completion in August 2019, the objective of the GRACE project is twofold: firstly, to identify, assess and compare the benefits of different methods of responding to oil spills in cold seas; and secondly, to develop a real-time observation system for underwater oil pollution as well as a strategic decision-making tool for selecting the most appropriate response strategies.

The GRACE project (the final conference of which was held on 23rd and 24th May 2019 in Tallinn, Estonia) included various research actions (*in-situ* and laboratory experiments) and state-of-the-art studies on several topics. In addition to the detection and monitoring of oil spills at sea, these topics included the processes of oil biodegradation and bioremediation at sea, the weathering of strandings along Arctic coastlines, and the assessment of in-situ burning (ISB) as a potential response technique in coastal waters in cold environments via tests in the natural environment.

For further information:
Oil sensing SmartBuoy:
https://www.grace-oil-project.eu/download/noname/%7BC82DD571-656A-4243-B856-B801D2178C6D%7D/130841
GRACE project progress and deliverables
https://www.grace-oil-project.eu/en-US/About/Deliverables

• Recovery at sea

Pumping: optimising the flow-to-power ratio (SEDOSR Pump One)

For the requirements of a project to develop a system for the recovery/separation of petroleum hydrocarbons or floating microplastics at sea (see below), the Spanish company SEDOSR Engineering S.L. has designed an Archimedes screw pump that ensures a high ratio between pumping capacity/flow rate and power consumption.

Broadly speaking, this concept is based on the search for a mechanical configuration and a selection of materials/part coatings conducive to the reduction of friction between the moving parts comprising the pump.

Two versions of the SEDOSR Pump One (the 300 and the 750 models) were developed, with a one-piece modular sealing disc made of stainless steel and lined with synthetic rubber,[27] connected to the Archimedes screw, which reduces the number of internal moving components inside the prototype to two.

View of the screw and the geared sealing disc of the final version of the SEDOSR Pump One (source: SEDOSR)

[26] Username: grace / password: oil

[27] Made of Viton (registered trademark of the Chemours Company), i.e. a fluorocarbon-based fluoroelastomer material commonly known as fluorine rubber or FKM, used to make O-rings and other components requiring resistance to chemicals, heat, etc.

The performance of these pumps was assessed in 2018 at Ohmsett's test facilities in the United States. The trials involved oils of varying viscosity and different applications: in discharge (integrated in skimmer systems, submersed, etc.), or in suction/discharge as a transfer pump, with a wide range of discharge pressures and under controlled/measured conditions in terms of the power supplied by the associated hydraulic power unit.

At the end of 2018, SEDOSR announced its intention to develop and market a model of this concept with a flow rate higher than 60 m^3/h in 2019.

Although we have no detailed data concerning the performance and operation of this equipment, SEDOSR recently patented a device called OWSKIMMER for the skimming and separation (upstream of the pump) of floating oils or micro-plastics.

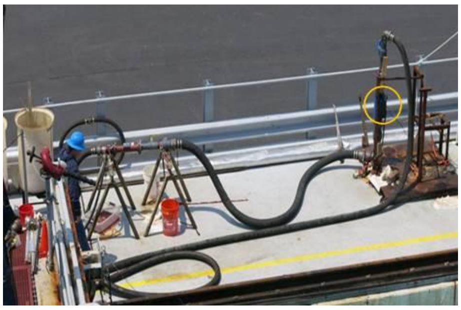
For further information:
https://sedosr.com/pumps/
https://sedosr.com/owskimmer-project/

Real-time assessment of recovery efficiency: prototype developed for BSEE (US)

The United States Bureau of Safety and Environmental Enforcement (BSEE) recently funded a project (which came to an end in autumn 2018), the objective of which was to develop and test a prototype sensor (RE Sensor) enabling the real-time measurement of the efficiency (oil-to-water ratio) of the recovery of floating oil. The ultimate aim of this type of equipment is to enable responders to optimise the implementation of available resources during operations at sea (booms to thicken slicks, positioning of skimmers, use of storage tanks, etc.).

This project stemmed from the observation, during other R&D activities conducted by BSEE, of the low accuracy of commercially available equipment suitable for this type of application, particularly for oil contents of 30% or less; this accuracy also being affected by the salinity of the water and the type of oil concerned. The idea here was to develop a reliably accurate sensor that would not be affected by these parameters and would not require calibration depending on the oil.

A prototype was designed[28] by the American organisation Battelle and tested under controlled conditions at Ohmsett with variable parameters of salinity, oil types/viscosity levels, water-to-oil ratios, pumping rates, etc.



Prototype of the RE Sensor (circled in orange, on the right of the photograph) being tested at Ohmsett (source: Battelle Memorial Institute)

The sensor combines two measurement principles:

- dielectric measurement, used for inverse mixtures/emulsions (i.e. water-in-oil) with relatively low electrical conductivity;
- eddy-current measurement, used for direct emulsions (oil-in-water) with high electrical conductivity.

The performance of the sensor, line-mounted between the skimming/pumping equipment and the storage tank, was reportedly satisfactory, with an estimated average error of 6% (based on a total of 60 trials) and low sensitivity to the factors mentioned above.[29]

More generally, it is suggested that this sensor could be used for any application where oil-water mixtures need to be assessed and where high salinity levels hinder the effective use and accuracy of traditional sensors (e.g. in industrial plants).

For further information:
https://www.bsee.gov/sites/bsee.gov/files/research-reports//1083aa.pdf

• Response operations in inshore waters

[28] And is the subject of a provisional patent application.
[29] As well as the diameter of the transfer line (10 cm when tested at Ohmsett). The developers indicate a relatively uniform sensitivity of the sensor over the entire section of the pipeline, ensuring its correct operation across a wide range of diameters.

Containment and recovery in coastal and port areas: Koseq Compact sweeping arms

For several years now, the Dutch firm Koseq has been offering a compact, containerised version of its sweeping arms: Koseq Compact 502 (see LTML n°41).

Since 2018, Koseq has been marketing the Compact 5 and Compact 8 models (measuring 5.3 and 8.2 m in length, respectively), thus extending its range of sweeping arms designed to equip small vessels of opportunity (note that the Compact 5 is nothing other than a non-containerised version of the 502). Designed for use in harbours, inland and near-shore waters, these models are equipped with a weir skimmer at the base of each sweeping arm that can accommodate an oleophilic brush, disc or drum skimmer, coupled (unless otherwise specifically requested by the client) with a submersible centrifugal pump comprising a worm screw driven by a hydraulic motor, with a rated capacity of 150 m^3/hour (Marflex MSP 100).

In the autumn of 2018, Koseq also announced that it had developed an even smaller model, measuring 2.5 m in length (the Compact 2.5) and weighing 200 kg, which is more specifically geared towards responding to small-scale spills – in port areas or in confined spaces (water bodies, rivers, etc.), for example.

According to various press releases[30] issued by the manufacturer, this model also has a pumping capacity of 150 m^3/hour, and is equipped with a modular skimming system (brush, disc or drum).

View of the Koseq Compact 2.5 sweeping arm (source: Koseq)

For further information:
https://koseq.com/models/compact-5/
https://www.linkedin.com/pulse/koseq-compact-25-new-sweeping-arm-model-annette-bosch?trk=related_artice_KOSEQ%20-%20COMPACT%202.5%20-%20A%20NEW%20SWEEPING%20ARM%20MODEL_article-card_title

• Products

Application of solidifying agents in oil spill response operations: assessment... and outlook?

Researchers from the CanmetENERGY laboratory, which operates under Natural Resources Canada (NRCan), and the University of Alberta recently published a paper presenting the state of the art in terms of knowledge and feedback on the application of solidifying agents in response to oil spills, as well as on the possible avenues of research that may be required to improve the performance of these products.

This work is clearly motivated by the Canadian context, namely the significant production of non-conventional oils (Athabasca oil sands, in particular) and the risks of spills related to their increasing transportation to oil ports along the Pacific coast (British Columbia) or the Atlantic coast (Gulf of Mexico).

The desired effect of applying solidifying agents on floating oil slicks is (i) to limit/slow the spread of the latter, both horizontally (by spreading, fragmentation, etc., on the water surface) and vertically (diffusion of light compounds in the water mass and even in the atmosphere, natural dispersion in the form of droplets, etc.) and, thus, (ii) to facilitate its recovery, which is generally recognised as becoming increasingly difficult in the hours, days, etc., following a spill.

The paper proposes a classification of products understood as “solidifying agents”, for which there is no commonly accepted definition as oil slick response agents, according to their modes of action: physical (various absorbent and/or adsorbent materials, based on the hydrophobic/oleophilic property of the materials) and chemical (essentially gelling agents, which cause an increase in the oil’s viscoelasticity).

Also, pinpointing the current lack of standard effectiveness test procedures for solidifying agents, the authors suggest a certain number of “key” data to be measured. These include effectiveness, speed of action, selectivity with respect to water, incorporation of water into the solidified product, buoyancy, toxicity, biodegradation, mechanical resistance, potential for retention/release of

[30] To the best of our knowledge and at the time of writing, the Compact 2.5 model is not featured on the company’s website.

petroleum compounds, etc.

By discussing the operational aspects identified as problematic (e.g. application methods and procedures, management of waste volumes, etc.), this publication has the merit of re-examining the contribution of solidifying agents, first considered several decades ago and to a certain extent rejected (at least from the perspective of their use in responding to large-scale spills).

In France, for example, Cedre conducted assessments in the 1980s on the effectiveness of various gelling agents (e.g. Rigidoil, Elastol, etc.), which proved to be such that their implementation required application ratios that were perceived as too high (a perception shared at the time by other organisations – the US EPA, for example) and, moreover, as a source of numerous constraints, both operational (means for effective application) and logistical (quantity necessary, costs incurred), etc.

For further information:

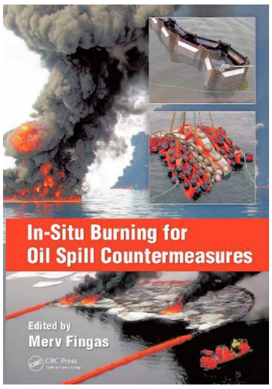
Motta F.L., Stoyanov S.R., & Soares J.B.P., 2018. Application of solidifiers for oil spill containment: A review. *Chemosphere*, **194**, 837-846.

https://doi.org/10.1016/j.chemosphere.2017.11.103

• In-situ burning

In-situ burning: a summary work

The year 2018 saw the publication of a summary work entitled *In-Situ Burning for Oil Spill Countermeasures* on the controlled burning of oil slicks in the event of a spill. In-situ burning (ISB) is an accepted alternative response strategy in particular in North America, where it has been particularly supported by the experience of the *Deepwater Horizon* spill (United States, 2010), although it is not limited to the open sea (coastal areas, tidal marshes, etc., are also potential environments for its implementation in the US).



Despite increasing interest in this technique over recent years, the technical lessons and developments concerning the feasibility and implementation of ISB date back much further, including research, trials and feedback accumulated over more than 30 years. As a result, the methodological and technical guides, procedural manuals, etc., currently available on ISB operations are too numerous to mention. For more information on this subject, certain public institutional websites – mostly American (NOAA, USCG, BSEE, etc.) – offer an abundant selection (e.g. http://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/resources/in-situ-burning.html). The industry has also published a number of works on the subject, such as those by the American Petroleum Institute (some of which pre-date the *Deepwater Horizon* spill, and have since been significantly updated).

This new publication is intended to be an updated reference providing a global state of the art of knowledge and practices in the field of ISB, and covering its various scientific, operational and technical aspects, as well as related topics such as the prevention of risks to human health, burn residues, etc.

For further information:

https://www.crcpress.com/In-Situ-Burning-for-Oil-Spill-countermeasures/Fingas/p/book/9781138735255