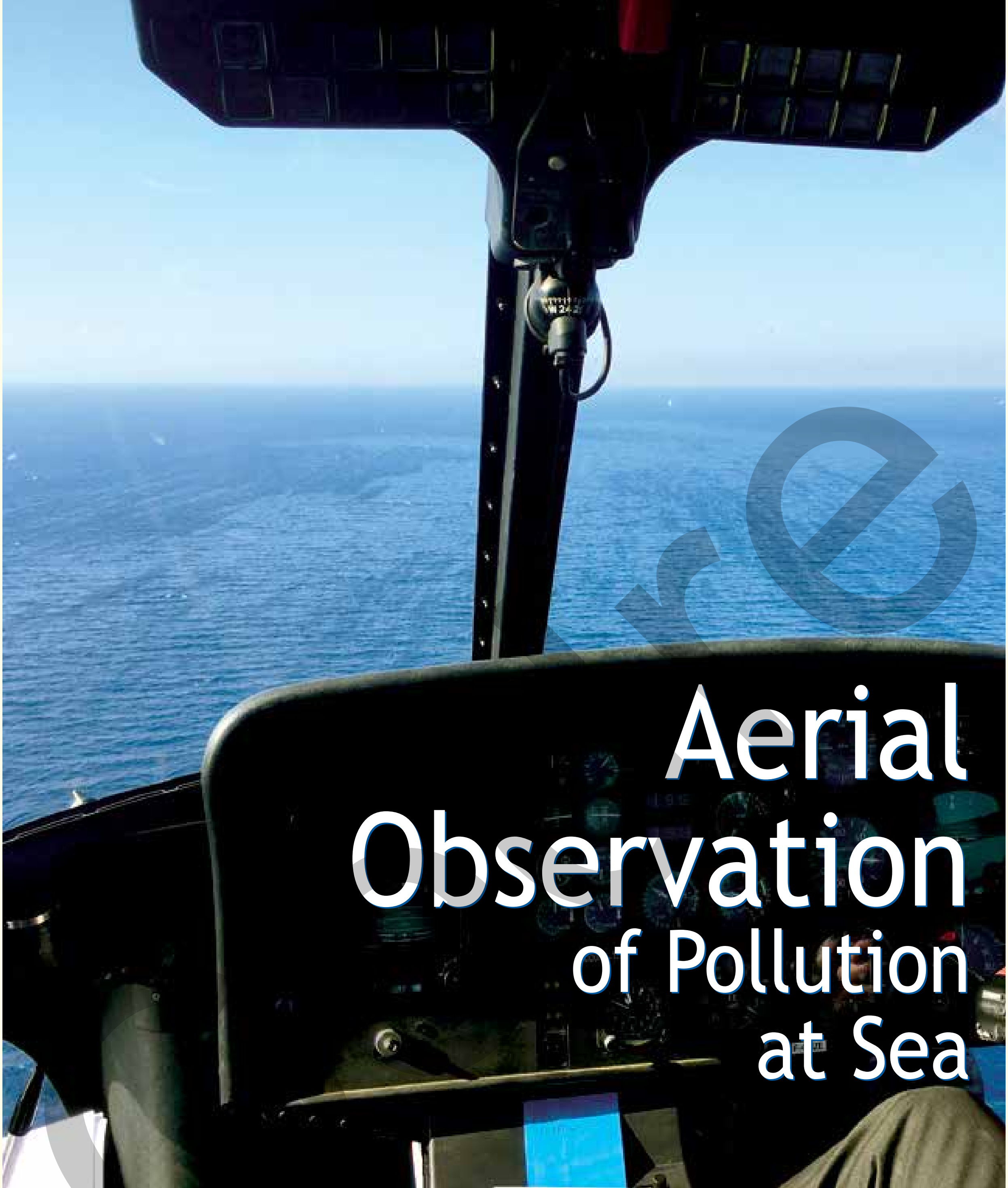

Aerial Observation of Pollution at Sea

Operational Guide

Cedre

Aerial Observation of Pollution at Sea

OPERATIONAL GUIDE

Information
Decision-making
Response

This guide is an update of the guide published by Cedre on this topic in 2009.

This guide was produced with financial support from the French Navy and TotalEnergies.

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Purpose and structure of this guide

The distribution of the results of studies, experiments and feedback from incidents in the form of operational guides is an important part of Cedre's activities, emphasised by its Strategy Committee.

The first version of this operational guide on aerial observation of pollution at sea was published in 1993, before being updated in 2004 and again in 2009.

It appeared necessary to both our specialists and our operational partners (French Navy, French Customs, TotalEnergies) to update it once again, both in terms of its format, by reorganising it to give a more operational approach, and its content, taking into account feedback from the most recent incidents, the use of new vectors (such as drones) and new sensors, as well as the detection of new products, such as gases and very low sulphur fuel oils.

French Naval Aviation and French Customs (Maritime Air Surveillance Brigade) share their knowledge through training courses organised at Cedre. Much of the information presented in this guide has been gleaned from their seasoned observers. They will recognise their contributions for which we are very grateful. We would also like to thank our colleagues from various European Union Member States, and in particular those in the OTSOPA group (Bonn Agreement Working Group on Operational, Technical and Scientific Questions Concerning Counter-Pollution Activities) for their input in the form of texts and illustrations.

The primary vocation of this operational guide is to be present on board all aircraft likely to be involved in aerial observation of oil and chemical pollution at sea. It is also a useful tool to have in MRCCs, incident management centres and communications units.

The words and expressions followed by a • in the text are defined in the glossary on page 73.

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General aspects

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A1

Objectives of pollution detection and reconnaissance

Pollution detection and reconnaissance missions aim to fulfil two distinct purposes:

First, they can be carried out **routinely**, to detect and collect evidence for the repression of operational discharge by ships.

In this case the aims are to:

- detect the pollution;
- accurately locate and describe it;
- identify the polluter

in order to:

- assess the pollution (quantity and quality);
- anticipate the evolution of the situation;
- initiate prosecution proceedings by drawing up an official report.

Secondly, aerial observation is used **in the event of a spill**, to support response operations at sea.

The aims of aerial surveys are to:

- locate all the slicks;
- accurately describe them;
- map the spill;

in order to:

- track the pollution;
- adjust drift models;
- guide the day's response operations;
- prepare response operations for the following days.

In the event of a pollution incident, aerial observation is the only means of obtaining a clear, realistic picture. It is the first link in a chain of key decisions.

Aerial observation and other techniques

Observation can be carried out from a plane with a crew to meet these objectives. Some planes are also equipped with remote sensing• equipment to detect slicks beyond the area that is directly visible to the crew and/or to detect pollution at night or in adverse weather conditions.

Nevertheless, additional complementary techniques can also be useful:

- satellite imagery (mainly radar), which can cover a more extensive geographical area (▶ B13); ideally, overflights can be coordinated with satellite passes to increase the chances of linking a deliberate discharge to a vessel.
- satellite-tracked drifting buoys, designed to produce a similar trajectory to that of the spill (▶ B5);
- UAVs• or drones•, which are particularly useful for guiding response resources (▶ B12).

Aerial observation

A3

Oil and oil products

Oils are complex mixtures of thousands of distinct chemical compounds. Their appearance, physical characteristics and behaviour depend on their composition.

Spills of petroleum products at sea mainly involve three types of products with very different behaviours.

- **light refined products** are colourless or only slightly coloured, highly fluid products made up of the lightest oil fractions (e.g. petrol/gasoline, white spirit, kerosene, diesel oil, domestic fuel oil...);
- **heavy refined products** are black and often viscous, with no or few light fractions (e.g. HFO•, IFO•, bunker fuel, bitumen, bilge discharge...);
- **crude oils** vary in colour from brown to black. They have widely varying characteristics, depending on their composition, in particular according to the proportion of light or heavy fractions, resulting in their resemblance to either light or heavy refined products. After a certain length of time at sea, crude oils lose their light fractions through weathering (► A5), resulting in similar characteristics and behaviour to heavy refined products, in particular their persistence.

The emulsions formed by these products vary in colour from dark brown to orange.

Low sulphur fuel oils

Low sulphur fuel oils (LSFO•, VLSFO• and ULSFO•) have been developed following the introduction of regulations aimed towards reducing the emission of fumes containing sulphur compounds in various maritime areas. Studies carried out (notably by Cedre) on these products have shown that they are very diverse, both in terms of their physico-chemical characteristics and their behaviour when spilt at sea. In principle, they all float when fresh, tend to form stable emulsions and have a flash point above 60°C. Some are potentially dispersible, particularly if their pour point• is not too high (this parameter varies considerably from one product to another and can reach very high values of 25°C to 30°C).

	Behaviour
Highly volatile oil products (kerosene, petrol, distillates, condensates)	
	- low viscosity - complete evaporation in 1 or 2 days or even less - very rapid spreading - tendency to naturally disperse
Light oil products (diesel, home heating oil, marine diesel, biodiesel, light crude oil, condensates)	
	- low to moderate viscosity - relatively rapid evaporation of up to 2/3 of the initial volume after a few days - rapid spreading - moderate solubility
Moderate oil products (most crudes, light lubricating oil, refined residues)	
	- moderate to high viscosity - moderate evaporation (1/3 in 24 hrs) - moderate spreading - low solubility - high tendency to form stable emulsions ("chocolate mousse") - tendency to flow after weathering or adherence to fine particles
Heavy oil products (heavy crudes, heavy fuel oils, heavy residues, weathered emulsions, bitumen)	
	- viscous to highly viscous - little to no evaporation - little to very little spreading - very low solubility - potential emulsification - very slow alteration - possible refluidisation in the sun
VLSFO/ULSFO (Very/Ultra Low Sulphur Fuel Oil)	
	- moderate to high viscosity - little to no evaporation - little to very little spreading - low to very low solubility - potential emulsification - very slow alteration - possible refluidisation in the sun

Table 1: Classification of oils according to their behaviour

Basic physical characteristics

A petroleum product spilt at sea can be characterised by a certain number of physical parameters which provide information on its behaviour. The main physical characteristics are:

Relative density•

The relative density• of oil is usually below 1, which means that it floats on water. However, when spilt, due to weathering processes (evaporation• and particularly emulsification•), the density increases gradually to reach values similar to those of seawater, which makes buoyancy less probable in coastal and estuarine waters.

Viscosity•

The initial viscosity• of oil varies widely. A product's viscosity• will depend on its composition and the temperature. When spilt at sea, the oil's viscosity• will gradually increase, potentially up to very high values (e.g. 10^5 cSt•), due to weathering processes (evaporation• and especially emulsification• (▶ A4), altering the pollutant's behaviour at the sea surface.

Pour point•

The pour point• of a petroleum product is the temperature below which it stops flowing in controlled laboratory conditions. This does not mean that below this temperature the product acts as a solid. The pour point• is measured in the laboratory, in a narrow test tube. When spilled at sea, in an open area, oil will remain more or less fluid at temperatures below its pour point•.

Two other characteristics are important, in particular in the case of refined products, for which a thorough assessment of fire and explosion risks is necessary.

These characteristics are the flash point• and the auto-ignition temperature•.

The following parameters should also be considered:

The toxicity of Volatile Organic Compounds (VOC•)

At a concentration of 900 ppm (0.09%), VOCs cause irritation to the respiratory tract and eyes after about an hour.

Explosive range

The explosive range corresponds to minimum values of gaseous hydrocarbons in the atmosphere, ranging from 2 to 11.5%.

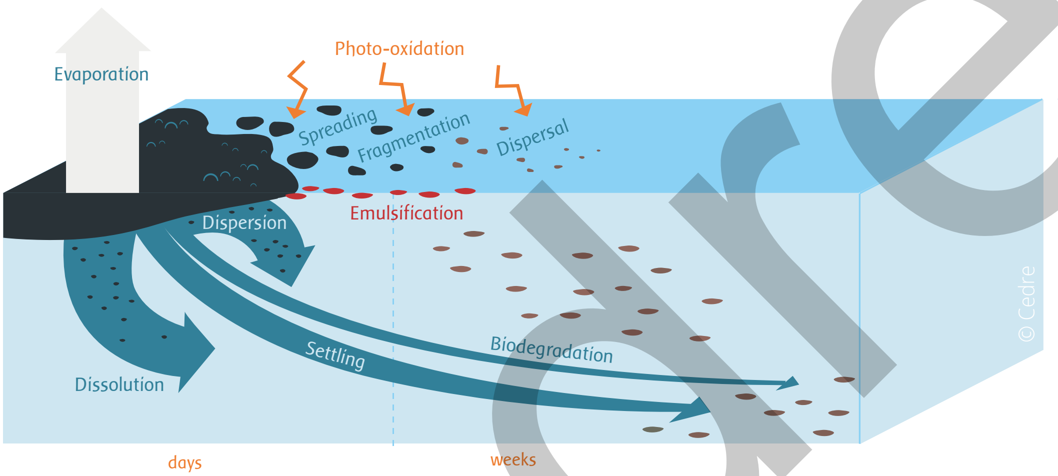
If H_2S (hydrogen sulphide) concentration values are available for the product, this risk should be specifically taken into account.

Lastly, it may be useful to obtain the product's distillation curve, in order to assess the maximum percentage of evaporation• at sea.

A5

Oil weathering

When oil is spilt at sea it gradually undergoes changes.
Its appearance and behaviour are altered over time.



Fate of an oil spill over time

Weathering processes

During the first few hours, oil spilt at sea undergoes the following processes:

1. spreading into a possibly very thin film (a few microns). A small quantity can therefore cover a very large surface area (1 km² for 1,000 litres). However spreading is irregular;
2. evaporation• of the lighter fractions.

Crude oils, condensates and refined products begin to evaporate immediately after a spill, and can continue to do so for a long time if the weather conditions are favourable.

The evaporation• rate depends first on the volatility of the various oil fractions but also on factors such as the quantity spilt, the water and air temperature, water turbulence, wind speed and the rate of spreading of the slick.

When petrol (gasoline) is spilled at 20°C, approximately 50% evaporates in a matter of minutes. Petrols, kerosene and light fuel fractions (volatile compounds with a boiling point• below 200°C) disappear almost completely after 24 hours at 20°C.

For home heating oil at 20°C, 30 to 50% can evaporate in a day. For heavy fuel oils, again at 20°C, loss through evaporation• is estimated at a maximum of 10% of their weight.

3. natural dispersion•, the proportion of which is mainly dictated by the nature of the product and the sea state. Waves and turbulence at the sea surface affect the slick and induce the formation of droplets of varying sizes. The smallest droplets remain in suspension in the water column, while others either coalesce with other droplets or spread into a thin layer. Recoalescence• of droplets in suspension is most prevalent when the sea is calm. However, in these conditions aerial observation is easier;
4. emulsification• occurs mainly with crude oils or black refined products, after a few days, or even a few hours if the sea is rough. The emulsion formed varies in colour from dark brown to orange. This phenomenon increases the apparent volume of pollutant, reduces spreading (by forming thick patches) and eventually increases the apparent relative density• of the pollutant until it is almost equal to that of seawater. It may therefore remain below the surface, or even sink, especially in coastal or estuarine waters, due to the presence of matter in suspension and reduced salinity.

Warning

Chemicals with a high vapour pressure•, such as petrol/gasoline, are dangerous if inhaled and can explode or ignite, even at a low concentration in the air (▶ B2).

Behaviour of other products

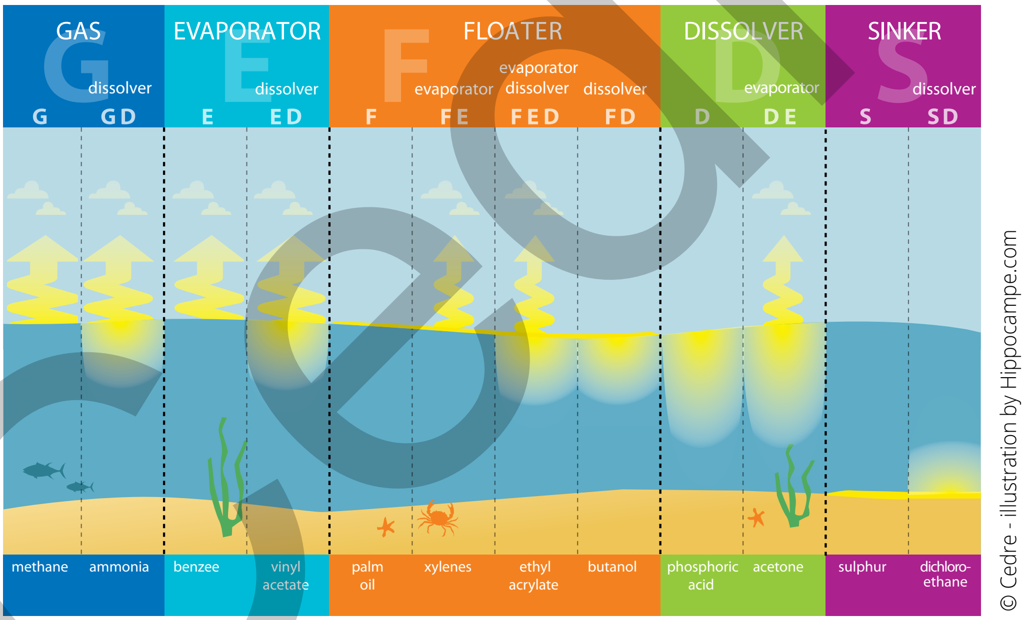
A6

Chemicals

Every chemical product has its own specific behaviour. The expected behaviour of a substance can be quickly and simply assessed based on some of its physico-chemical properties: state, solubility, density•, etc.

The overall behaviour of a substance can be determined using the Standard European Behaviour Classification or SEBC•.

The different types of behaviour are presented below, however it is important to note that the environmental conditions (in particular the weather conditions) can affect this behaviour.



Different types of behaviour of substances spilt

Floaters, and to a certain extent evaporators, can be detected by aerial observation. In the case of evaporators, like for volatile oil products, specific safety measures must be implemented (▶ B2).

Specific case of solidifiers

Certain substances (such as some vegetable oils and paraffins) turn from liquid to solid when they come into contact with seawater at a temperature below their shipping temperature. They form balls, or aggregates, which float at the water surface.

Appearance of slicks at sea

Case of crude oils and heavy refined products

Spreading is irregular. Black to brownish-black (possibly greenish) slicks form very quickly. They are surrounded by a dark, continuous, thinner film, of varying abundance according to the nature of the product and the weather and atmospheric conditions.

Over the first few hours (after the loss of the light fractions due to evaporation•), the patches thicken and retract (becoming several millimetres to several centimetres thick), turning brown or orangey brown if an emulsion is formed. The thinner films take on a “sheen”, “rainbow” or “metallic” appearance (▶ B7). The appearance of the thicker parts of the slicks contrasts increasingly with these films. The thickest parts of the slick are often downwind (▶ A7).

After a few days, the thinnest layers disappear. They may, however, reappear at the edges of the slicks in calm, sunny conditions.

Slicks and patches of emulsion can display behaviour known as "porpoising", i.e. dropping down a few centimetres during the night and rising to the surface as the temperature increases during the day. Near the coast, when slicks encounter less saline and/or more sediment-laden waters (typically in river plumes), they may drop below the surface or even settle to the bottom.

Patches of emulsion fragment and form small tarballs which are only visible close up.

Some light crudes do not form emulsions. They form very thin layers that can break up and gradually disappear.

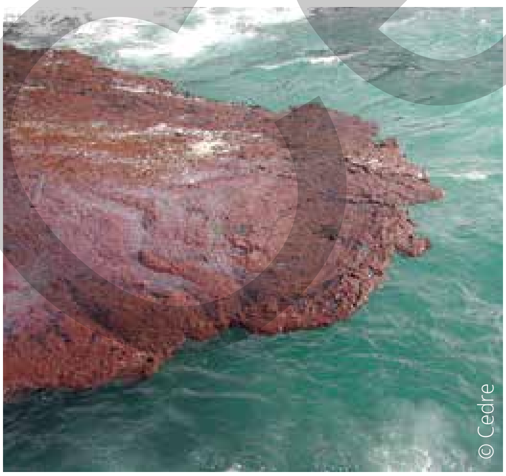
Slick of crude oil
(Nassia *spill, Bosphorus, Turkey, 1994)*

Heavy fuel oil spill, Ulysse/CSL Virginia *collision, France, 2018*

Recent spill (a few hours old): the fresh oil spreads out like a film, scattered with thicker patches.

Over time, the slick fragments and the thicker areas become increasingly distinct from the thinner parts (sheen, rainbow or metallic) within a few hours to 1 day of the spill.

As weathering processes occur, brick-red patches of invert emulsion may form between thinner layers (rainbow, sheen or metallic) and thicker patches of oil (2 to 8 days after the spill).



Subsequently, the films (sheen, rainbow or metallic) gradually disappear and, eventually, only patches or streaks of emulsion may remain (several days after the spill), especially in rough seas. Sheen can however reappear at a later stage, even several weeks or months after the spill, if the sea is very calm and the sun is shining.

Case of light refined products

Light refined products spread quickly over very large surface areas forming thin films, which mainly have a metallic appearance initially. Very soon, "sheen" and "rainbow" can also be distinguished.

Unless the product is contained (either naturally or in a boom), true oil colour is not visible.

Depending on the quantity spilt and the metocean conditions, the whole spill can disappear from the sea surface within 2 or 3 days, or even a few hours.

The different thicknesses can be distinguished and characterised by observation from directly above the slick.

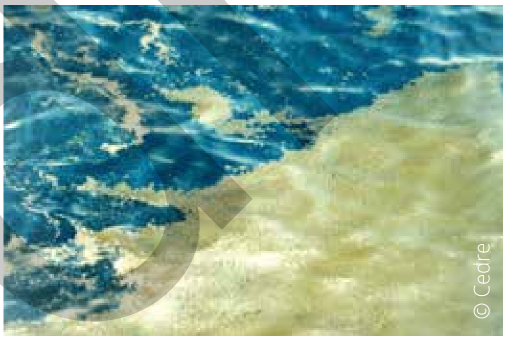
Heating oil spill observed from a hill, Saint Pierre and Miquelon

Slick of light refined product rapidly spreading into a thin film

Case of products with a high paraffin content and bitumen

Certain products containing heavy paraffins solidify at seawater temperature. They can form thick or lumpy patches, which then fragment into patties and tarballs. During the first few hours, thinner layers may be present around the edges of the slick (sheen, rainbow, metallic).

Except in very specific circumstances, when bitumen is spilt in water it will sink either immediately or very quickly.



Congealed paraffinic oil: close up, the patches can be seen to be made up of lumps

Bitumen spill

Special cases

- Oil treated with dispersant•: dispersed oil appears as an orange to light brown (or sometimes dark brown) plume, just below the water surface;
- oil and ice: in ice-infested waters, if the current is strong enough, it can entrain the oil under the ice. The oil will then accumulate in natural crevices in the ice, making it very difficult to detect. If the ice is forming while the oil is at the water surface, the oil may become encapsulated in the ice. The oil may then reappear when the surface layer melts.

  Finally, oil trapped in ice may well up through cracks and spread over the surface of the ice. The presence of ice also interferes with the operation of remote sensing equipment.
- Product forming little or no emulsion, for instance a light crude oil or refined product: only thin films remain, which gradually break up and disappear.

Oil treated with dispersant•

Experimentation in the Arctic environment

Oil in ice

A8

Slick structure

For fairly fresh oil slicks (several hours to a few days old), the shape and thickness distribution (thick, medium, thin) depend mainly on the wind.

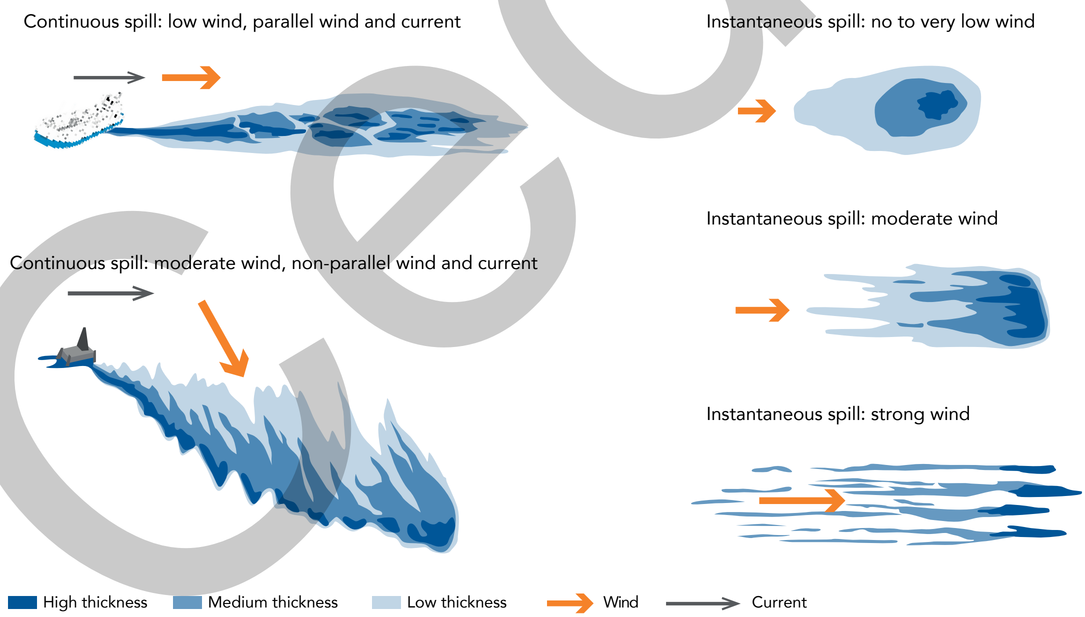
The wind spreads and elongates slicks, eventually slicing them up into windrows and then fragmenting them.

The thickest patches lie furthest downwind.

When the wind is very strong, the iridescent zones (sheen - rainbow - metallic) tend to disappear.

In the case of weathered slicks (several days old or more), sheen, rainbow or metallic films gradually disappear. Only very thick, highly emulsified patches remain, barely floating on the surface.

Older slicks often become mixed with floating litter and debris.

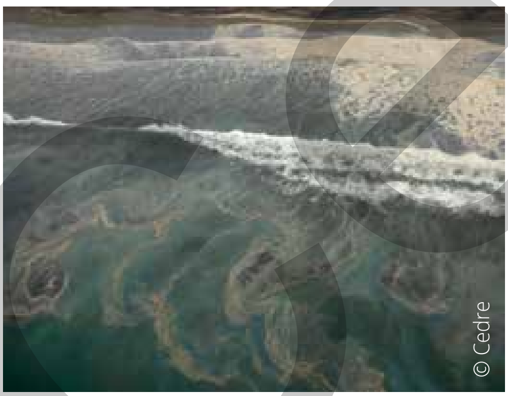


Appearance of slicks on the coast

A9

1. Slicks or floating patches can accumulate in wind-exposed coastal areas (coves, bays, inlets...).
2. With the ebb and flow of the tides, the pollutant can be deposited in accumulation zones (i.e. sites where litter is regularly deposited), in the form of a more or less continuous band, along the high tide line (strandline).
3. The pollutant is often mixed with varying quantities of litter and debris, in particular seaweed.
4. The pollutant may be carried back out to sea if the wind or currents change direction.

Small quantities of oil or fragmented slicks which arrive on the coast are very difficult to identify from aircraft, especially in rocky areas.



Remobilisation of oil washed up on the shore (Peru, 2022)

Liquid oil on the shoreline (Spain, 2006)

A10

Drift of floating substances

An oil slick drifts at 3- 4% of the wind speed and 100% of the current speed.

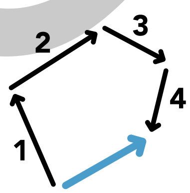
The actual trajectory of a slick (or "course made good") can be determined graphically by vectorial addition of the speed of the current and 3 - 4% that of the wind, established on an hourly basis.

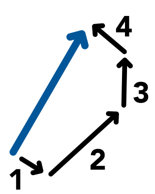
The drift of other floating products (such as vegetable oils) shows similar characteristics. It is important to note, however, that they generally spread across the water surface in a different way to oil. An oily wake behind a ship will splay out as it spreads, gradually forming a “triangle” or “fan” shape, whereas a vegetable oil will appear more like a "ribbon".

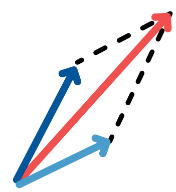
Slick movement and drift models: computer software exists for calculating the movement or drift of oil slicks.

It can be useful in preparing a mission. However, modelling results must be regularly compared with actual observations.

	Current (flowing towards x°)	Wind (blowing from x°)	Drift
1st hour	1.5 knots at 340°	12 knots x 3/100 = 0.36 knots at 300°	
2nd hour	1.5 knots at 60°	30 knots x 3/100 = 0.9 knots at 230°	
3rd hour	1 knot at 110°	25 knots x 3/100 = 0.75 knots at 185°	
4th hour	1 knot at 190°	20 knots x 3/100 = 0.6 knots at 130°	







Calculation of the drift of an oil slick over 4 hours
The black arrows show the successive effects of the current (100%) and the wind (3%) on the slick each hour. The blue arrows show the outcome after 4 hours for each vector. The red arrow shows the overall outcome.

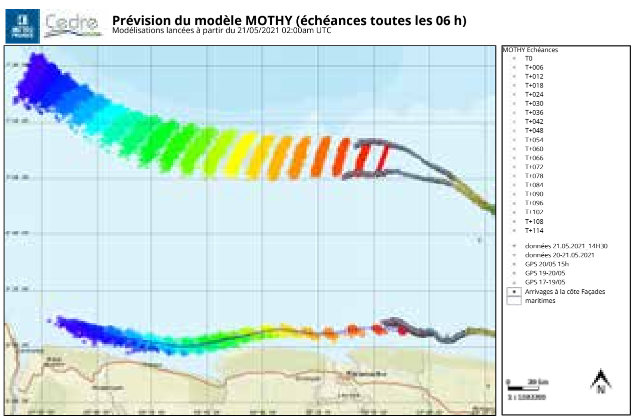
Drift modelling

A11

The expected drift of an oil slick can be modelled using mathematical models integrating metocean data. Model input data is obtained from pollution observation (usually aerial observation) and will include the spill's appearance (degree of fragmentation, buoyancy), dimensions, position and the time of observation.

The model must be regularly adjusted using observation data. Buoys can be dropped onto the slicks to help to locate them in relation to predictions (▶ B5). The reliability of meteorological data enables routine forecasting for 3 to 4 days ahead and drift backtracking for up to 3 days, depending on the model.

In the event of a major pollution incident affecting a vast area at sea, drift model outputs, such as the example presented below, are used to draw up maps which compile all the observation data for that day and the drift predictions for the coming days. The observations are accompanied by indications of the overflight zones of the different aircraft, showing which areas have been explored and those which have not.



Example of slick drift forecast for experts (data obtained from modelling and results formatted by Cedre)

Observation platforms: aircraft

Aerial surveys can be carried out from planes or helicopters. Planes are of course less limited in terms of range and are the most appropriate choice if the pollutant is far from the coast.

For safety reasons, twin-engine planes (at the least) should be used, with crews authorised to work above the sea.

The aircraft must be capable of flying at sufficiently low speeds and altitudes to allow observation, detection by sensors and to enable photographs and videos to be taken. High wing aircraft provide better visibility.

Helicopters should be prioritised for coastal overflights, for their ability to fly at low altitude and to hover. On the coastline, aerial observation is particularly important in areas that are difficult to access by land or by sea, or along particularly intricate areas of coastline terrain. Surveys conducted from helicopters can also help to dispel any doubt as to the nature of the pollution (▶ B17 and ▶ B18).

Many States own aircraft for missions which include conducting pollution surveillance overflights. These aircraft may also be used for other purposes such as sea rescue, fire surveillance, fisheries surveillance, drug trafficking surveillance or border protection.

In offshore oil production areas, it is often possible to make use of the helicopters that transport personnel to and from these facilities.

These aircraft should either have a crew trained in pollution observation and description or be able to take an observer on board, ensuring they have a sufficiently extensive view.

Some specialised aircraft are fitted with remote sensing• equipment (▶ B11).

Aircraft belonging to Canada's National Aerial Surveillance Program (Dash 8)

Dauphin SA365N helicopter belonging to the French Navy

Other observation platforms

Several other platforms exist that can be used for pollution detection, observation and monitoring. These complementary methods are implemented in addition to observation from aircraft, without superseding this method.

Unmanned Aerial Vehicles (UAVs)

UAVs•, commonly known as drones•, fitted with specialised sensors can be used to detect and monitor spills of oil, or even other products. Either fixed-wing or rotary-wing UAVs can be deployed from an onshore platform or from a response vessel. (▶ B12)

Tethered aerostats

To enhance visibility from a ship, various models of aerostats, typically in the form of a balloon tethered to the vessel, have been developed and tested. Depending on the altitude at which they are deployed, they have a range of several kilometres (3.5 km at 150 m altitude for one such model) and can be fitted with specialised sensors. (▶ B12)

Satellites

Various sensors installed on satellites can detect pollution, particularly petroleum oil or vegetable oils, using radar imagery.

Optical sensors can also be useful, but more in the case of floating objects. (▶ B13)

Drifting buoys

Drifting buoys, or drifters, are a type of buoy specially designed to drift in the same way as oil at the sea surface. They can be deployed from a ship or an aircraft onto slicks and can be tracked by satellite. They can be used to monitor slicks when metocean conditions prevent overflights or observation, or in the case of very scattered pollution. (▶ B5)

Sensor mounted on an aerostat

Drone deployed from a French Navy spill response vessel

Remote sensing

A14

Remote sensing• is a complementary method of observation, in addition to observation by the human eye. A number of different sensing systems are able to detect and map the presence of oil (or other products) on the sea surface in certain conditions.

This observation method has the following advantages over visual observation:

- detection is carried out from a distance [SLAR• (Side-Looking Airborne Radar): 15 to 20 nautical miles on each side];
- slicks can be accurately plotted on maps
- imagery from sensors can be recorded
- visualisation is possible outside of the visible spectrum.

In the case of aerial surveillance missions to track illegal releases, remote sensing• means that oil detection can be carried out at night.

Various types of equipment can provide the identification of the ship involved: AIS• (Automatic Identification System), new generation electro-optic or infrared systems, LLLTV (Low Light Level Television) camera.

Active sensors transmit a signal and receive another signal in return. Passive sensors do not transmit a signal but simply use the radiation emitted by the sea surface.

Further information is available in Tech Sheet ▶ B11

Tactical operator on board a Canadian spotter plane

Screen showing SLAR imagery on board a French Customs spotter plane

Objectives and findings of aerial surveys

An aerial survey may aim to achieve various objectives:

- confirm the presence of pollutant and determine its nature or, if it turns out to be a false positive, specify the phenomenon (▶ B17 and ▶ B18);
- record the position of the pollutant;
- describe the appearance of the slicks (▶ B6 and BAOAC•);
- describe their geographical distribution;
- estimate the volume of pollutant (▶ B16);
- take photos and videos (▶ B10);
- map the pollution (▶ B15);
- guide response resources and assess the effectiveness of their actions (▶ B14);
- collect evidence.

Tactical operator station on board a French Customs Cessna 406 plane

Information processing

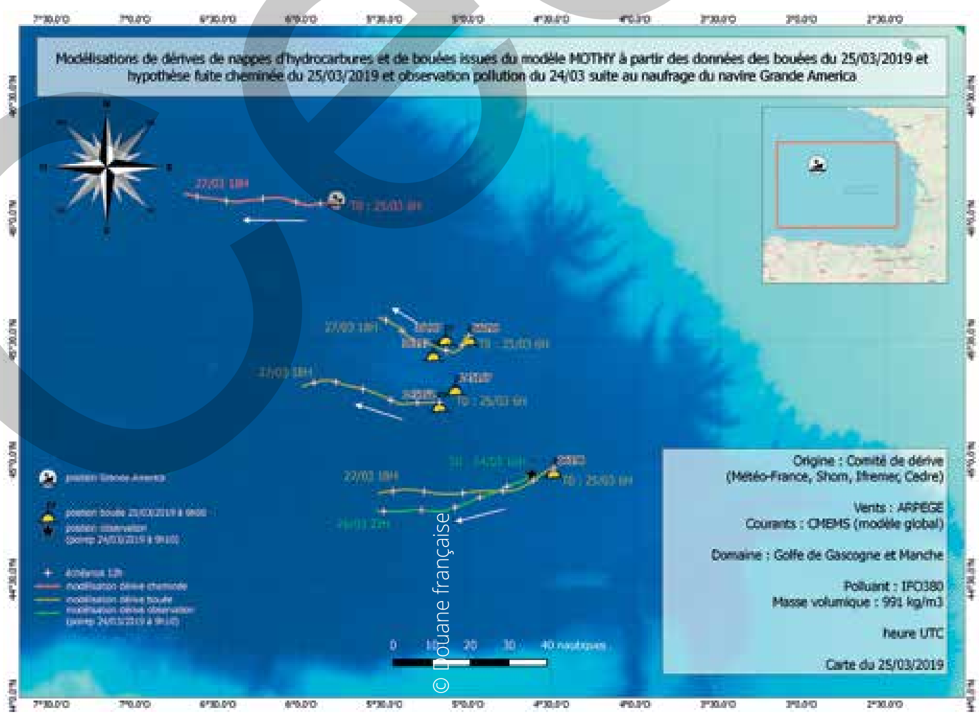
A16

To manage a pollution incident, many factors must be taken into consideration, including aerial observation data (position of the pollution, remarks about observations, initial and actual flight plans, photos, remote sensing imagery...), drift forecasts and signals sent by drifting buoys deployed at sea (▶ B5).

Experience from the most recent major oil spills shows the benefits of establishing a national slick drift• prediction committee gathering experts from competent national organisations in a bid to:

- analyse observations (aerial, shipboard, satellite);
- transmit the selected data to forecasting/modelling specialists;
- define recommendations for future observation flights;
- develop a daily summary map and disseminate it;
- propose study and experimentation programs which could reinforce predictions.

Setting up such a committee helps to improve the quality of predictions and facilitates decision-making by the authorities while proving to be a valuable innovation in terms of information and communication.



Map produced by the drift committee during the Grande America *spill in 2019*

Example of the *Grande America* spill, France, 2019

On 10th March 2019, the roll-on/roll-off container ship *Grande America*, bound for Casablanca (Morocco) from Hamburg (Germany), suffered major damage. The vessel was travelling through the Bay of Biscay, some 140 nautical miles from the French coast, off the south-west of the tip of Penmarc'h (Brittany), when a raging fire broke out in the containers on deck. The fire was not controllable.

The crew abandoned the *Grande America* which was drifting slowly eastwards and sank on 12th March in waters 4,600 m deep in the Bay of Biscay, off La Rochelle, despite the best efforts of the French Navy and the salvage tug *Abeille Bourbon,* called in for support to attempt to extinguish the fire and tow the ship.

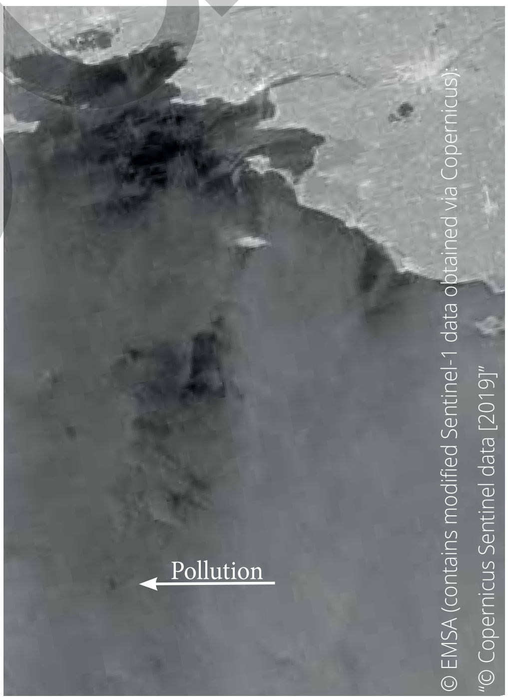
On 13th March, a French Navy surveillance plane spotted a large oil slick, some 10 km long by 1 km wide, in the area of the wreck, as well as around ten containers fallen overboard. The Maritime Prefect for the Atlantic ordered the pollution response vessel *Argonaute* to be sent onsite and to begin spill response operations.

In total, the response involved around ten vessels, including:

- vessels belonging to or chartered by the French Navy;
- Spanish vessels, sent onsite under the Biscaye Plan•, a French-Spanish agreement, activated on 15th March;
- EMSA (European Maritime Safety Agency) vessels;
- vessels chartered by the shipowner.

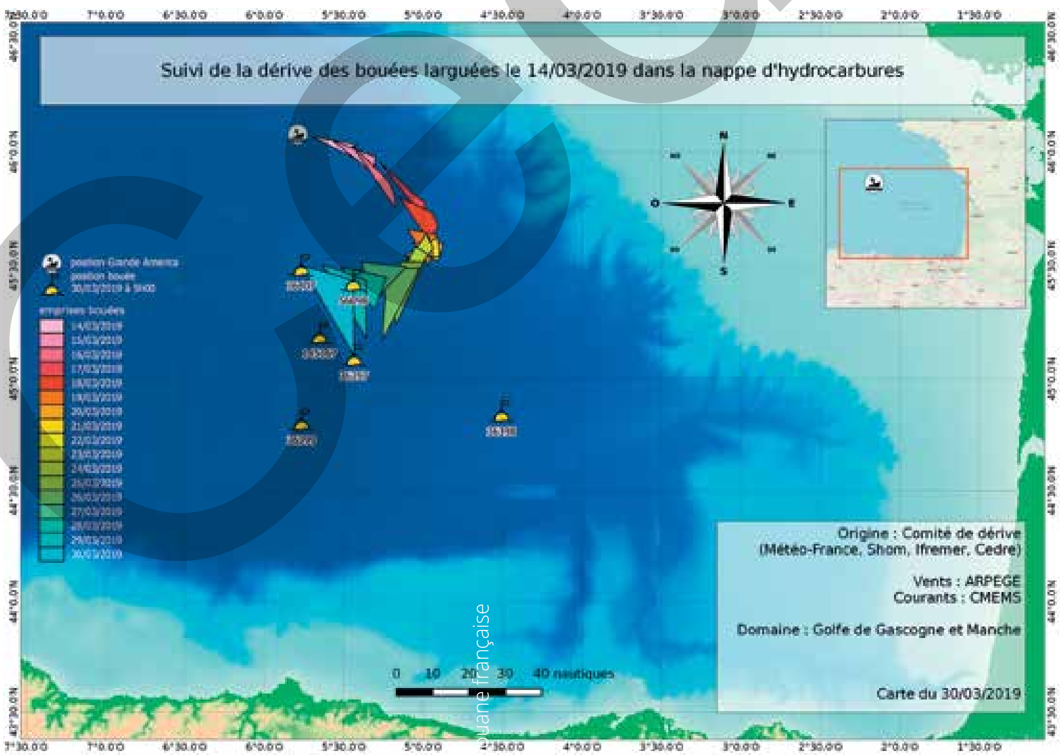
On 14th March, the Maritime Prefect for the Atlantic activated the drift committee led by and coordinated by Cedre with Ifremer, Météo-France and SHOM•.

The committee remained activated until 2nd April. It held virtual meetings on a daily basis and took into account observations made from French Navy and French Customs aircraft, SASEMAR• aircraft (Spain), as well as satellite imagery (CleanSeaNet) and the trajectories of drifting buoys. Every day it provided the authorities (Maritime Prefect for the Atlantic) with a summary comprising the locations of oil observations at sea, the associated drift forecasts, and a short list of recommendations.



Satellite image (radar) showing the pollution as well false positives

Wider view of the spill area



Long-term monitoring of drifting buoys

Gas detection/measurement

A17

Gas emissions from ships have been a concern for several years. Annex VI of MARPOL• 73/78, adopted in 1997, establishes limits on emissions of nitrogen oxides, sulphur oxides, volatile organic compounds and particulate matter.

Since the adoption of this annex, technical solutions for controlling these emissions have been sought.

In terms of aerial surveillance, efforts have been focused primarily on SOx• detection in ship exhaust. The measured concentration can be used to calculate the sulphur content of the ship's bunker fuel.

Since 2020, the maximum authorised sulphur content of bunker fuel for sea-going ships is 0.5% (mass by mass) worldwide, outside of certain areas:

- so-called Sulphur Emission Control Areas (SECA•), currently the Baltic Sea and the North Sea, and Emission Control Areas, i.e. the North American area (East and West coast of the United States and of Canada) and the US Caribbean area, where the sulphur content limit is 0.1% (mass by mass); IMO has decided to designated the whole of the Mediterranean Sea as an Emission Control Area from 2025.
- European Union ports, where the sulphur content limit is also 0.1% for ships at berth for more than 2 hours.

Experiments carried out as part of European projects and routine monitoring by a number of countries have demonstrated one point: there is no correlation between the colour of the plume and the sulphur content of the bunker fuel.

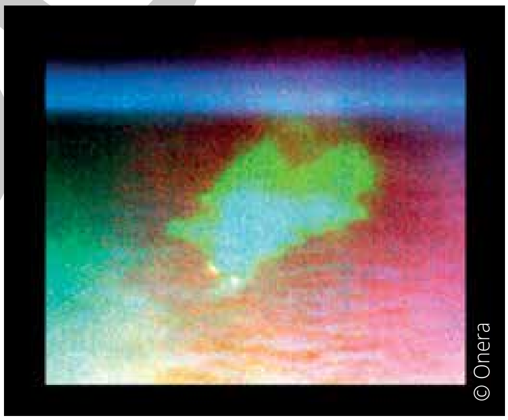
Currently, the SOx• concentration in ship emissions is measured:

- from fixed installations (sensor mounted on a bridge or other high point);
- from manned aircraft (one example is Belgium, which carries out regular controls from its Britten Norman Islander aircraft. Sensors that can be installed on a helicopter also exist);
- from UAVs• fitted with specialised sensors. One example is the remotely piloted aircraft systems made available to Member States by the European Maritime Safety Agency.

Aircraft used by the Royal Belgian Institute of Natural Sciences to measure gas emissions

In the case of both spill surveillance and the repression of illegal discharges, it is of major benefit to characterise the nature of the chemical released at sea, in particular to identify the risks for responders and the general public. The information obtained by the incident management unit or the data provided by modelling software must systematically be supplemented or backed up with field measurements. Through research projects, various sensors have been developed based on remote sensing• technologies, in particular using hyperspectral• or multispectral• infrared detection.

However, these developments need to be improved or adapted according to the environmental conditions surrounding the incident. Experimental trials, initiated by Cedre and supported by the French Navy, are conducted to test these technological developments and, for some chemicals, to observe, identify and visualise a gas cloud formed following a spill at sea. Once they have been validated, such sensors can be installed on aircraft for use during routine surveillance missions.



Images of chemicals detected during trials at sea organised by CEPPOL and Cedre (ONERA's SIMAGAS camera)

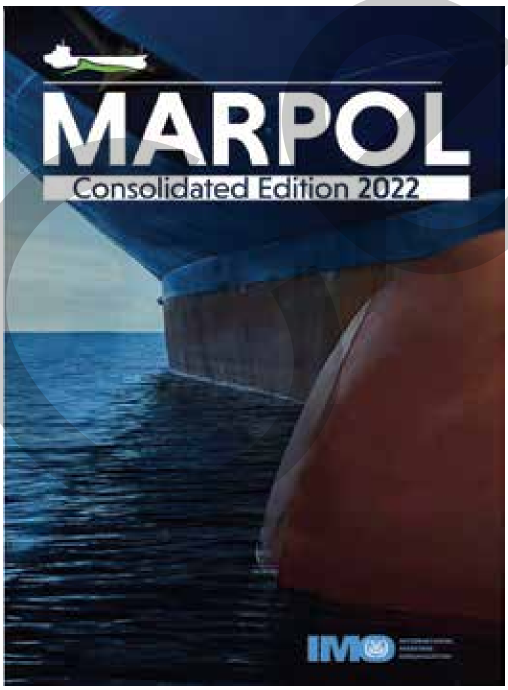
MARPOL 73/78 Convention

The International Convention for the Prevention of Pollution from Ships (MARPOL• 73/78) is the main international convention dealing with pollution of the marine environment, either caused by incidents or by normal operation.

The Convention includes regulations aimed at preventing and minimising pollution from ships – both accidental pollution and that from routine operations – and currently includes six technical Annexes. Special Areas with strict controls on operational discharges are included in most Annexes.

Annex I – Regulations for the Prevention of Pollution by Oil (entered into force 2 October 1983)

This annex covers prevention of pollution by oil from operational measures as well as from accidental discharges.



Front cover of the MARPOL Consolidated Edition (IMO)

Annex II – Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk (entered into force 2 October 1983)

This annex details the discharge criteria and measures for the control of pollution by noxious liquid substances carried in bulk; some 250 substances were evaluated and included in the list appended to the Convention; the discharge of their residues is allowed only to reception facilities until certain concentrations and conditions (which vary with the category of substances) are complied with.

In any case, no discharge of residues containing noxious substances is permitted within 12 miles of the nearest land.

Annex III – Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form (entered into force 1 July 1992)

This annex contains general requirements for the issuing of detailed standards on packing, marking, labelling, documentation, stowage, quantity limitations, exceptions and notifications.

For the purpose of this Annex, “harmful substances” are those substances which are identified as marine pollutants in the International Maritime Dangerous Goods Code (IMDG Code•) or which meet the criteria in the Appendix of Annex III.

Annex IV – Prevention of Pollution by Sewage from Ships (entered into force 27 September 2003)

This annex contains requirements to control pollution of the sea by sewage; the discharge of sewage into the sea is prohibited, except when the ship has in operation an approved sewage treatment plant or when the ship is discharging comminuted and disinfected sewage using an approved system at a distance of more than three nautical miles from the nearest land; sewage which is not comminuted or disinfected has to be discharged at a distance of more than 12 nautical miles from the nearest land.

Annex V Prevention of Pollution by Garbage from Ships (entered into force 31 December 1988)

This annex deals with different types of garbage and specifies the distances from land and the manner in which they may be disposed of; the most important feature of the Annex is the complete ban imposed on the disposal into the sea of all forms of plastics.

Annex VI – Prevention of Air Pollution from Ships (entered into force 19 May 2005)

This annex sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances; designated emission control areas set more stringent standards for SOx•, NOx• and particulate matter.

Tech Sheets

Preparing an aerial survey

Surveys must always be prepared in advance. During this phase, we will try to predict what is likely to be encountered, including the appearance, extent and location of the slicks.

For the observer:

- prepare base maps of the area, on which the pollution can be mapped and observations noted during the flight.
- Clearly indicate on these maps the orientation, coastline, geographical coordinates, scale, the nature of the coast (beach, rocky shoreline, marsh, urban, industrial and harbour areas) and its uses.

For the crew:

- gather as much information on the spill as possible:
    - nature of the pollutant: crude, refined, light or heavy oil (its density•, viscosity•, pour point•, etc.). In the case of crude or light refined oil, beware of the risk of explosion (▶ B2) and use an explosimeter• if possible;
    - type of accident (sinking, grounding, explosion during operations ...);
    - type of spillage (isolated event, continuous flow, on surface, below surface);
    - last slick observation (date, appearance, location);
- gather all the necessary data on the local conditions (weather since last observation, sea currents, sea state, etc.).

Contact the incident management centre to obtain the latest drift forecasts, recommendations from the drift committee, etc.

In the absence of specific instructions from a coordination centre, estimate the most likely location of the slick, by calculating its probable drift (▶ A10), either from the spill location or the last observed position.

- investigate the possibility that other areas, so far unobserved, may be polluted. This should be carried out taking into consideration the prevailing local circumstances, for example the shipping route before the accident, a new leak in the wreck, additional quantities of pollutant due to slicks, previously having reached the shore, breaking away and drifting...;
- identify from this information the zone to be covered by the survey and establish a flight profile for maximum coverage (▶ B4);
- predict the expected slick appearance according to the characteristics of the pollutant (determine viscosity at ambient temperatures, assess tendency to form an invert emulsion), or according to available observation data, and anticipate any potential detection difficulties (e.g. low buoyancy of the pollutant, fragmented slicks...);
- take on board drifting buoys to be dropped on the slicks, then tracked by satellite.

The example of the *Erika*

Before breaking in two, the *Erika* had already been leaking for many hours and the spilt fuel oil reached the coastline without being observed at sea. This occurred because no specific searches aimed at locating this spilt oil were conducted, as it had not been reported by the ship's master.

Flight safety

In-flight safety

Aircraft working offshore must have at least two engines and a certificate of airworthiness. The aircraft and crew must be qualified to carry out overflights at sea.

The aircraft crew must explain the safety rules to all personnel taken on board specifically for the observation mission:

- Use of personal protective equipment (PPE•): lifejacket, locator beacon...;
- Conduct on board (wearing seatbelts, communications, etc.);
- What to do in the event of a crash at sea or on land.

Product-related hazards

Hazards are primarily related to gases or evaporators (oil or chemicals) whose flammable, explosive and/or toxic vapours could reach the aircraft and the personnel on board.

Prior to takeoff, the crew must be informed of the product's characteristics by the incident management centre: expected appearance (colour, etc.), expected behaviour, relative density• of any vapours in relation to air, hazards related to the product(s).

The incident management centre must also inform the crew of the restrictions associated with the overflight, in particular the minimum altitude and distance to ensure that the aircraft does not enter a hazardous zone.

The centre will also recommend appropriate PPE•, such as cartridge masks, and possibly certain detection equipment to be taken on board (explosimeter•, toximeter•).

The Bonn Agreement Aerial Operations Handbook recommends that, unless and until clear information is available on the nature of the chemical released and if the crew does not have specialised PPE•, the aircraft should remain upwind of the release, unless the wind is more than 15 knots, in which case over flying may be acceptable at an altitude of not less than 1,000 feet•. These recommendations may change as more information about the product becomes available and if the crew is protected.

In practice, depending on the product spilled, this altitude may be considerably reduced. Vapours emitted by unleaded petrol, for example, have a relative density• of around 3 to 4, which means they will not rise. A minimum altitude of around 100 feet• could therefore be envisaged.

B3

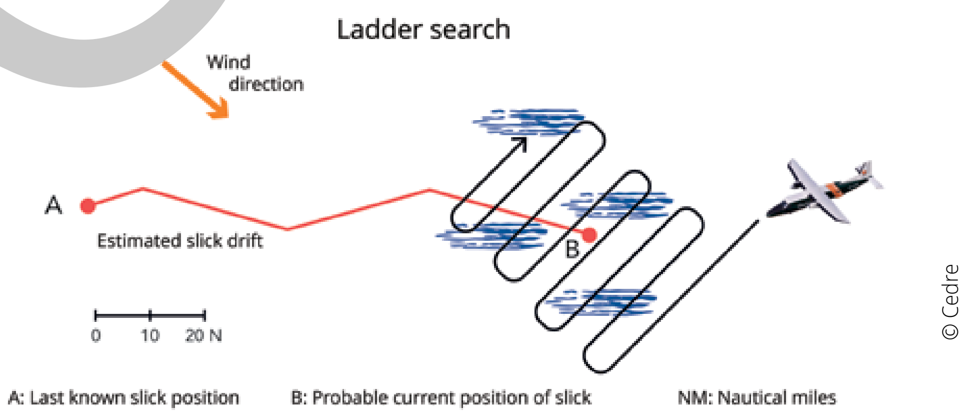
Pollution search methods

In the event of a significant spill, slick drift forecasts should be produced daily, or even twice a day, following overflights (▶ A11). These forecast maps, together with all comments, must be sent to the authority responsible for organising overflights. The forecast maps will be used to draw up appropriate flight plans. It is also important to take into account the comments provided, which may, for example, recommend extending the overflight zone to a particular area.

As oil tends to spread in windrows to the wind (▶ A7), the zone to be investigated should be covered flying cross wind, to increase the chances of detecting any slicks (ladder search).

- mist and dazzle caused by the sea surface often hamper visibility. Sometimes the best way to fly will be governed by the position of the sun.
- the flying altitude is determined by the size of the slicks to be located, the visibility and the sea state. It is important to obtain maximum sweep while ensuring that all the details remain clearly visible. In general, a search altitude of around 1,500 feet• is a good compromise;
- first of all, look for the most polluted zones (thick patches or slicks, accumulation zones). Offshore, follow thin patches or stripes (sheen, rainbow or metallic appearance) downwind, in order to detect any possible thick patches located downwind of the contaminated area (▶ A7);
- if a fresh windrow or oily wake is sighted, follow it in order to determine the source of pollution. This source will usually be located upwind, particularly if the spillage point is fixed, but also upcurrent (▶ A10).

SLAR• can be used to speed up the search phase, as these sensors can scan an area of 15 to 20 nautical miles on either side of the aircraft, depending on its altitude.



Flight profile

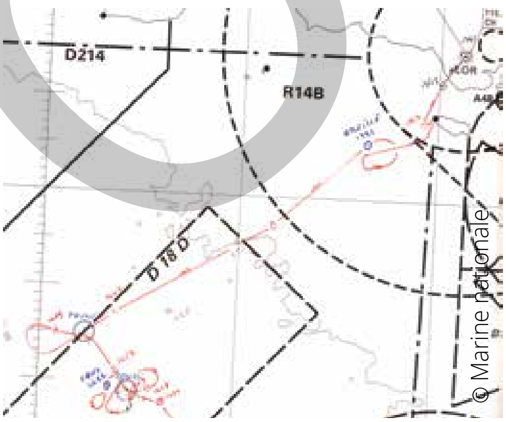
The flight profile outlined below is designed for the detection, identification and description of a coloured product floating on the sea surface (oil product). In the case of another type of product, it will need to be adapted.

Case of a routine surveillance flight

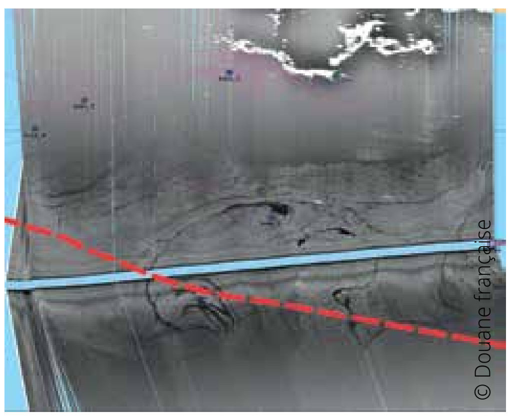
- if the aircraft is fitted with remote sensing• equipment, operate at the optimal altitude for searching using SLAR• (between 1,500 and 5,000 feet•). If pollution is detected, record the imagery;
- if the aircraft is not fitted with remote sensing• equipment, operate at the optimal altitude defined for the patrol mission;
- if the aircraft is fitted with other remote sensing• equipment, reduce altitude to between 800 and 1,500 feet• in order to record images from these sensors (infrared/ultraviolet line scanner, FLIR/hyperspectral camera, etc.);
- reduce altitude to between 100 and 500 feet•, to take photographs that may be used as evidence (▶ B9). Several passes at different altitudes and on different bearings are likely to be useful in obtaining the clearest images. In all cases, a photograph must be taken from directly above the pollution in order to show the different Bonn Agreement Oil Appearance Codes•.

Case of a spill

- if the aircraft is fitted with remote sensing• equipment, operate at the optimal altitude for searching using SLAR• (between 1,500 and 5,000 feet•). If pollution is detected, record the imagery;
- in the detection zone, reduce altitude to enable visual validation (Bonn Agreement Oil Appearance Codes• or other information obtained prior to the overflight [▶ B1]).



Searching for pollution after the sinking of the Erika *in 1999*



Searching for pollution after the Ulysse/CSL Virginia *collision in 2018*

Use of drifting buoys

B5

In the event of a spill, it is important to be aware of the pollutant's drift patterns and to be able to anticipate its movements, in order to direct spill response vessels at sea and to inform the onshore response authorities as soon as the pollutant threatens to reach the shore. In addition to aerial observation and satellite images, satellite-tracked drifting buoys (or "drifters") can be deployed. Experience of past pollution incidents (e.g. major spills, illicit discharge, wrecks) has shown that drifting buoys dropped from aircraft or from boats have a number of advantages:

- the drift can be followed remotely (useful when poor conditions prevent overflights and observation operations);
- if slicks disappear from view they are not lost;
- the location where small-scale pollution from illicit discharges reaches the shoreline can be identified;
- information can be provided about how potential pollution from wrecks would evolve.

Several models of buoy, of varying sizes, are available on the market.

It is also possible to build drifting buoys: following the sinking of the *Grande America* (► A16), Spanish Basque organisation AZTI• used custom-made buoys, composed of a shop-bought GPS and a plastic box partially filled with sand and expanded foam. These buoys gave very encouraging results. This performance was confirmed by Cedre during sea trials.

Sampling buoys

Sampling buoys which can be dropped directly from an aircraft onto a slick have recently been developed. They contain a piece of Teflon®• material, which can absorb oil for subsequent analysis. The buoys can be identified by a light and a radio signal.

Marker buoys

Slick appearance

Slicks can have varying appearances:

- thin films (sheen, rainbow or metallic) which are silvery and/or coloured (in the case of light refined products or small widely spread spills), with a thickness of a few microns (< 50,000 l/km^2);
- slicks of varying thickness with dark discontinuous colour (black or brown depending on the product), often surrounded by thin films (sheen, rainbow or metallic), depending on the degree of weathering – thickness of 50 to 200 µm (50,000 to 200,000 l/km^2):
- black slick and thin film: recent spill, little weathering;
- brown to red slick with gradual disappearance of thin films: emulsion weathered by several days at sea;
- thick patches with clear edges, usually dark brown to orange in colour and sometimes surrounded by thin films (patches of very weathered emulsion having been at sea for a week or more), substantial in thickness, 0.2 to 3 cm and more, i.e. 200,000 to 30,000,000 l/km^2, or more in the case of extremely viscous oil or emulsions;
- tarballs of emulsion resulting from the fragmentation of thick patches into increasingly small elements, which are increasingly difficult to detect;
- a brown to orange (or sometimes black) plume can sometimes be seen below the water surface, indicating the presence of oil dispersed by treatment with a chemical dispersant•.

Warning

Discontinuous true oil colour (► B7) is caused by the appearance of thicker slicks edge to edge with thinner (metallic) slicks. It is an effect created more by the combination of two appearances than of one specific appearance.

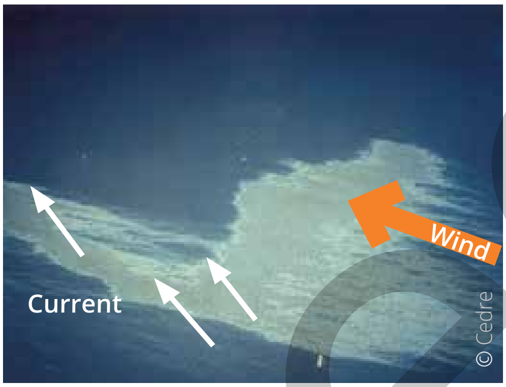
The colour of the slicks, patches and streamers will vary according to the light level, the colour of the sky and the observer's position in relation to the sun.

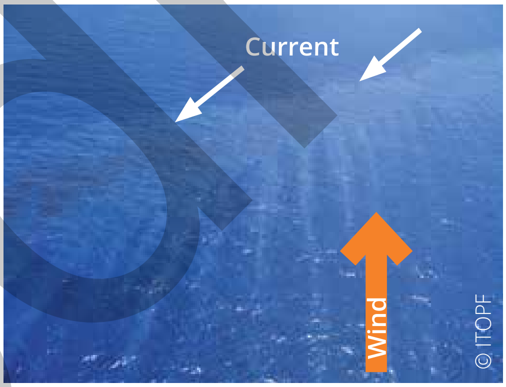
Oil slicks may adopt various random behaviour patterns or lie in windrows, parallel to the wind direction.

Slick appearance

Sheen, rainbow, metallic

Fresh slick spread widely





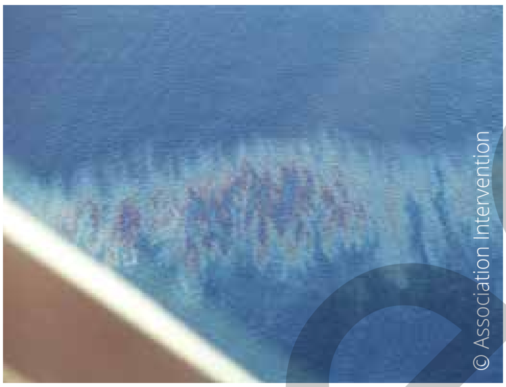
As the slick weathers, thicker zones appear downwind

First thick patches of emulsion begin to appear

After a few days, the thin layers have been dispersed and only patches of emulsion remain

Slick appearance

The patches of emulsion fragment and form small tarballs which are only visible close up



The wind slices the slicks into windrows. If the wind is strong, sheen may even disappear

Weathered emulsion blown into windrows

Oil slick partly dispersed by chemical dispersant

B7

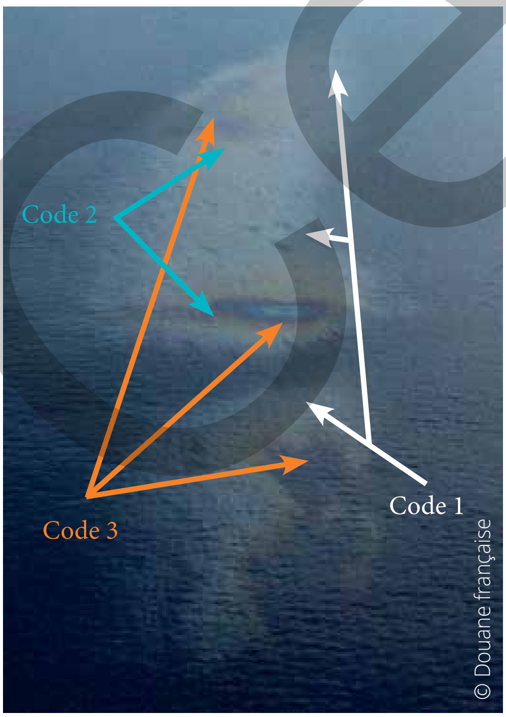
Bonn Agreement Oil Appearance Code

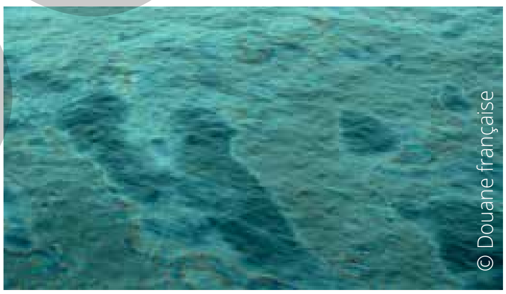
The Oil Appearance Code is the result of a scientific program, aiming to determine the quantities of oil spilt using visual aerial observation. Studies carried out under the auspices of the Bonn Agreement• led to the adoption of a new Appearance Code, applicable since January 2004, which replaces the former Colour Code. This code should be used for preference over other existing codes such as that of the Paris Memorandum of Understanding.

Appearance code	Layer Thickness Interval (µm)	Quantity (Litres/km^2)
1. Sheen (silvery grey)	0.04 - 0.30	40 - 300
2. Rainbow	0.30 - 5	300 - 5,000
3. Metallic	5 - 50	5,000 - 50,000
4. Discontinuous True Oil Colour	50 - 200	50,000 - 200,000
5. Continuous True Oil Colour	> 200	> 200,000

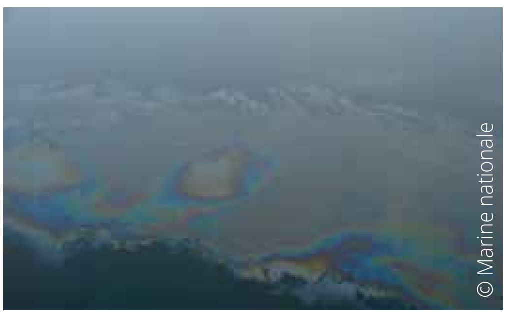
Code applicable since January 2004

This code is used to characterise thin layers and to estimate the quantities.





Metallic appearance, mainly code 3



Appearance: codes 1, 2, 3 and 4

Code 1 - Sheen (< 0.3 µm)

- The very thin films of oil reflect the incoming white light slightly more effectively than the surrounding water and will therefore be observed as a silvery or grey sheen. The oil film is too thin for any actual colour to be observed. All oils will appear the same if they are present in these extremely thin layers.
- Oil films below approximately 0.04-µm thickness are invisible. In poor viewing conditions even thicker films may not be observed. Above a certain height or angle of view the observed film may disappear.

Code 2 - Rainbow (0.3 µm - 5 µm)

- Rainbow oil appearance represents a range of colours: yellow, pink, purple, green, blue, red, copper and orange. This is caused by an optical effect which is independent of the type of hydrocarbon involved. The colours will range from pale to highly luminous according to the angle of view and the thickness of the layer.

  Oil films with thicknesses near the wavelength of different coloured light, 0.2 µm – 1.5 µm, (blue 0.4 µm, red 0.7 µm) exhibit the most distinct rainbow effect. This effect will occur up to a layer thickness of 5 µm. Poor light conditions can lead to reduced appearance of colours. A level layer of oil in the rainbow region will show different colours through the slick because of the change in angle of view.

Code 3 - Metallic (5 µm - 50 µm)

- The appearance of the oil in this region cannot be described as a general colour, as it will depend on the type of hydrocarbon as well as oil film thickness. Where a range of colours can be observed within a rainbow area, metallic will appear as a quite homogeneous colour that can be blue, brown, purple or another colour. The 'metallic' appearance is the common factor and has been identified as a mirror effect, dependent on light and sky conditions. For example blue can be observed in blue sky.

Code 4 - Discontinuous true colours (50 µm - 200 µm)

- For oil films thicker than 50 µm the true colour of the oil will gradually dominate the colour that is observed. Brown oils will appear brown, black oils will appear black. The broken nature of the colour, due to thinner areas within the slick, is described as discontinuous.

  This is caused by the spreading behaviour under the effects of wind and current.

  'Discontinuous' should not be mistaken for 'coverage'. Discontinuous implies colour variations and not non-polluted areas.

Code 5 - Continuous true colours (> 200 µm)

- The true colour of the specific oil is the dominant effect in this category.
  A more homogenous colour can be observed with no discontinuity as described in code 4.
  This category is strongly oil type dependent and colours may be more diffuse in overcast conditions.

Shipboard observation

The direct observation of pollution from the bridge of a ship is very limited: even if you can see far into the distance, it is difficult to spot a thin slick on the surface, and impossible to identify areas of significant thickness or to estimate the polluted surface area.

This observation capacity can be enhanced using the following:

Specialised radars

Various companies produce radar systems for detection from ships. They work on the same principle as SLAR• installed on an aircraft by detecting ‘flatter' areas on the surface of the water, which may indicate the presence of an oil slick causing a damping effect on the waves. To a certain extent, they can provide an indication of the relative thickness of slicks, and therefore of the priority areas for response operations.

These systems can operate in the dark but are penalised if there is no wind (minimum wind speed: 4 knots). Detection is also difficult if the sea is too rough.

The theoretical range depends on the models, but does not exceed 4 nautical miles.

Tethered aerostats

Various models of aerostats exist, typically in the form of a balloon tethered to the ship, on which different cameras and sensors can be mounted.

For example, a few years ago Cedre carried out tests on a helium-filled balloon with a volume of 8.5 m^3 and a payload of 3 kg. In addition to a high-definition video camera with a zoom, it can be fitted with an infrared camera. It can be deployed in less than an hour and requires an area of 2 to 4 m^2 on the deck of the vessel. Its detection range is around 2 nautical miles at an altitude of 150 m, with an autonomy of 8 hours. It cannot be deployed in winds exceeding 15 knots.

Unmanned Aerial Vehicles (UAVs•)

Small rotary-wing UAVs•, commonly known as drones•, can be launched and retrieved from response vessels. It is possible to use commercially available drones•, some of which may be fitted with infrared sensors. However, their flight time is restricted to a few dozen minutes and their range to a few nautical miles. Such drones are particularly useful for optimising the position of the response vessel(s) in the spill area.

All these devices help to accurately position the vessel after it has been directed towards the polluted area based on an aerial survey. They cannot however, under any circumstances, be used to search for pollution at sea.

Photographic and video imagery

Case of illegal discharge

In certain countries, photographic and video imagery can be provided as evidence for the repression of illicit discharge. Ideally, all the necessary information can be provided in three complementary shots:

- a detailed shot of the slick, taken almost vertically, from an altitude of less than 900 feet•, with the sun at the photographer's back;
- a long range shot of the ship and the slick, showing that the oil came from the ship in question;
- a detailed shot of the ship for identification purposes (colour of the hull and of funnels, name...).

In practice, a series of photographs should be taken, showing the ship and its polluted wake, the extent of the wake (without discontinuity), the name of the ship, and finally the surroundings (in particular, if possible, other ships with "clean" wakes for comparison) to clearly show that it is the ship in question which is releasing pollutant or else a photo of the "clean" sea in front of and around the ship.

A shot showing where the discharge seems to have originated can also be added, although this could potentially lead to confusion. Whatever the case may be, do not claim definitively that it is the discharged pollutant that is visible in the photograph.

It is important to remember that ships can also discharge non-pollutant liquids (cooling water).

If the aircraft is equipped with remote sensing equipment, include SLAR• and infrared imagery in the file of collected data.

If no photos are available, the case file transferred to the legal authorities should include at least the following elements: SLAR• imagery, infrared thermography of the wake and the identification of the ship. In order to respond to spills and voluntary discharges as efficiently as possible, all those involved must be informed about the capabilities of remote sensing• equipment.

Case of a spill

In the case of a major spill, it is impossible to photograph all of the pollutant. However, it is important to take photos of the different types of slicks, patches and patties, always from directly above: these views will be useful for confirming or refuting hypotheses about the weathering of the product and for estimating the volume remaining in the sea. If possible, take photographs to assess the extent of the pollution and the position of the pollutant on the surface.

Photo showing a vessel next to a slick

B9

Aerial photography

Photos and videos can be taken using cameras, video cameras or smartphones, with recent models often offering excellent resolution.

Tips

- before the assignment, set the date and time on the digital camera. If necessary, synchronise the date and time on the camera with the GPS device.
- during the flight, do not lean against the inner wall of the aircraft, or lean the camera against the cabin window (to avoid vibrations);
- place the camera very close to the window (about 1 cm away) and parallel to its surface to avoid any coloured reflections.
- pay attention to the position in relation to the light, as well as the colours of the sea and sky which may be difficult to distinguish. Do not hesitate to take several photos from different angles;
- if possible, take photographs around midday (solar time), avoid dawn and dusk (when the light may affect the colours);
- take the tides into account for photographs of the coast;
- fly at low altitude to capture as much detail as possible;
- after the flight, carefully archive the photos taken.

Onboard operator taking photos

Remote sensing

The table on the following page summarises the operating modes, capabilities and limitations of different sensors that are currently available.

Most maritime patrol aircraft are equipped with photo and video recording equipment for the visible spectrum, infrared and ultraviolet sensors and side-looking airborne radar (SLAR•).

Microwave radiometers•, which can provide useful information on the actual thickness of the pollutant, and laser fluorosensors, which can identify certain products listed in a database, were installed on some of these aircraft but were finally abandoned, as their operational input could not justify the additional weight in the aircraft.

Multispectral• and hyperspectral• cameras, which give good results in terms of the qualification and quantification of products (particularly chemicals), are not yet routinely installed.

The analysis of the images obtained from most of these sensors requires input from an experienced operator.

Imagery obtained from synthetic aperture radars, side-looking airborne radars and infrared and ultraviolet sensors features black/grey marks of varying intensity on a grey background. In the case of an oil spill, the shades of grey provide an indication of the relative thicknesses.

In all cases, visual validation is required.

When gathering evidence for legal purposes, in the absence of photos, the case file transferred to the legal authorities should include at least the following: the SLAR• imagery, the infrared thermography of the wake and the identification of the ship. In order to respond to both accidental spills and voluntary discharge as efficiently as possible, all those involved must be trained in remote sensing• equipment capabilities.

Screen showing infrared and visible imagery on board a French Customs spotter plane

MAIN TYPES OF EXISTING DETECTORS AND KEY CHARACTERISTICS				
Detector name	**Synthetic Aperture Radar (SAR)**	**Side-Looking Airborne Radar (SLAR)**	**Microwave Radiometer (MWR)**	**Laser Fluorosensor (LFS)**
USAGE CHARACTERISTICS				
Detection method	Backscattering	Backscattering	Microwave emission	UV-induced fluorescence
Sensor type	Active	Active	Passive	Active
Satellite/ Aircraft/RPAS	Satellite/Aircraft	Aircraft	Aircraft/RPAS	Aircraft/RPAS
ENVIRONMENTAL CONDITIONS				
Time of day	Night and day	Night and day	Night and day	Night and day
Atmospheric limitations	Less effective in heavy rain	Less effective in heavy rain	Clear skies only	Clear skies only
Sea surface (in Beaufort (Bft))	1 < Bft < 6	1 < Bft < 6	1 < Bft < 6	< 3 Bft
Presence of ice	Limited detection	Limited detection	Limited detection	Limited detection
DETECTABILITY				
SEBC behaviour	Floaters	Floaters	Floaters	Floaters
LIMITATIONS				
Operational	False positives, look-alikes	False positives, look-alikes	Need comparison of spectra recorded in a database. In some cases, only substance transmission databases may be required	A database of spectra associated with the types of substances being investigated. In some cases, only substance transmission databases may be required
Presence of islets	Can interfere with detection	Can interfere with detection	Can interfere with detection	Can interfere with detection
Determining thickness	No certified method for determining thickness. Visible differences in thickness	No certified method for measuring thickness. Visible differences in thickness	No measurement if thickness < 50 µm. Can determine thickness after calibration	Identification possible if 0.1 < thickness < 10 µm

(Visible + infrared)	Multispectral optical and thermal (visible and infrared)	Ultraviolet (UV)	Videos and photographs	Human observer
Reflectance	Reflectance	Reflectance	Reflectance	Reflectance
Passive	Passive	Passive	Passive	Passive
Aircraft/RPAS	Aircraft/RPAS	Aircraft/RPAS	Satellite/Vessel/ RPAS	Aircraft
IR: night and day	IR: night and day	Day	Day	Day
Visible: clear skies only	Clear skies only	Presence of sun	Clear skies only	Clear skies only
< 5 Bft	< 5 Bft	< 5 Bft	< 5 Bft	< 5 Bft
Limited detection	–	Limited detection	–	–
Floaters (visible), evaporators (IR)	Evaporators (IR): 5-12 μm, Floaters (if in the visible spectrum)	Floaters	Floaters if in the visible spectrum	Floaters and evaporators if in the visible spectrum
In some cases, only substance transmission databases may be required	False positives, look-alikes. A database of spectra associated with the types of substances being investigated. In some cases, only databases relating to substance transmission are required	–	False positives, look-alikes	HSE limitations, fatigue, difference in interpretation, false positives
–	–	–	–	–
Can only detect the lowest thickness values	~ 10 μm	~ 0.1 μm	No certified method for measuring thickness. Use of Bonn Agreement Appearance Code•	No certified method for measuring thickness. Use of Bonn Agreement Appearance Code•

Use of UAVs

B12

Unmanned Aerial Vehicles (UAVs•), or drones, are an additional means for observing pollution.

They can be used to:

- confirm or rule out the presence of pollution, with the advantage of being able to be deployed in areas that are potentially hazardous for operators due to the presence of toxic, flammable or explosive vapours (although there is a risk of losing the UAV in the latter case),
- locate the pollution and, more specifically, identify the thickest parts where response operations should be focused first,
- guide and assess response operations,
- record images, both by day and night, given that it is now possible to fit them with infrared sensors,
- in the case of UAVs equipped with AIS• receivers, identify nearby vessels.

Fixed-wing UAVs have long flight times (more than 10 hours) and therefore a range of several hundred kilometres, and can be deployed at altitudes comparable to those of aircraft. However, they may require a runway for take-off and landing.

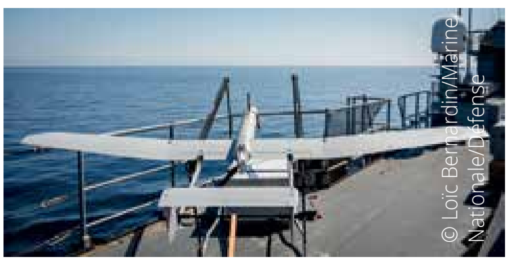
Rotary-wing UAVs have much shorter flight times (from a few dozen minutes to a few hours) and a lower altitude. However, observations can be made from a stationary position as they are able to hover and can theoretically be deployed and retrieved from a vessel with a large enough platform (15 to 20 m^2). This remains a delicate manoeuvre, particularly in rough seas or strong winds.

UAVs must be operated by certified operators.

In most countries, the use of these systems requires authorisation from the civil aviation authority. Overflights may be prohibited in certain areas.

Extremely caution must be taken when deploying such devices, and rigorous air traffic control must be put in place. In particular, it is essential to ensure that there is no risk of interaction between UAVs and other aircraft (for example, by setting aside certain time slots for UAV flights and others for overflights by planes and helicopters).

As concerns the detection of illegal discharges, to date no conviction has yet been made in France based on an observation made by a UAV.



Deploying a UAV from a French Navy vessel

Satellite-based detection

Synthetic aperture radar (SAR•) images provide the same type of information as side-looking airborne radar (SLAR•) images. SAR• has a constant spatial resolution over the whole swath that depends on the radar mode requested when programming the satellite.

As previously indicated (▶ B11), the images show black or grey marks of varying intensity and therefore require interpretation. On-site validation by a human observer is necessary.

In the event of major spill, these images provide an overview of the spill area and help to improve flight scheduling.

During routine surveillance of maritime traffic, voluntary discharges from vessels should be reported as soon as possible. If the discharge is on-going at the time of the satellite pass (i.e. a slick clearly appears in the wake of a ship), an aircraft may be deployed to confirm the pollution and catch the polluter red-handed.

This implies a very short time between the satellite overpass and transmission of the oil spill detection report to the authority in charge.

Within the European Union, this is possible thanks to EMSA's• CleanSeaNet• service through which analysed images are transmitted, together with a report, to the relevant authority within 30 minutes.

For the purposes of pollution response operations at sea, the frequency of satellite passes over the area may be increased.

Outside Europe, there are also companies that offer interpreted images.

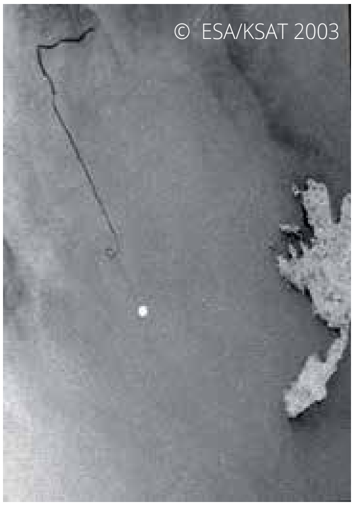
Optical images are also available. It is still currently difficult to use such images to detect oil slicks, as there is a high risk of mistaking natural elements (shadows formed by clouds, seaweed, the seabed, etc.) for pollutant. However, they are very useful for locating containers lost overboard or coloured debris.

Ulysse/CSL Virginia collision (France, 2018)

EMSA• provided 15 images in total, with the first one being transmitted the day after the collision. Eleven SAR• images were produced, including one showing a 50 km-long slick. Four high-resolution optical images of inshore areas were obtained.

Fire and sinking of the *Grande America* (Bay of Biscay, 2019)

EMSA• provided 57 images in total, with the first few being transmitted the day after the incident. SAR• images were used to track the heavy fuel oil slicks; optical images were used to locate floating containers and debris.



Ongoing discharge. The polluting vessel is represented by a white dot. Envisat ASAR wide swath image acquired at 20:30 UTC

Same oil spill observed by Radarsat-1 in ScanSAR Narrow mode the following day at 16:13 UTC

Ulysse/CSL Virginia *incident, 2018*

Guiding and assessing the performance of response operations

Recent spills at sea have re-emphasised the importance of guidance during offshore response operations. Although certain onboard systems can provide an indication of the polluted area around the vessel (▶ B8), aerial guidance significantly improves the efficiency of recovery operations. In the case of dispersant• application, aerial spraying is carried out at such low altitude that operators need guidance to target the thickest parts of the slicks.

Various actions are possible:

- provide a detailed description (map) of the pollution in the area where the vessel or fleet is operating;
- direct the vessel towards what appear to be the thickest parts of the slicks by indicating the azimuth angle/distance;

  E.g. a slick 20 m wide by 200 m long is located 30° right at a distance of 200 m.
- indicate the location and shapes of the slicks, pointing out the thick zones (or patches) where response operations should be focused;
- deploy tracking buoys (and informing the vessel of their location) or flares to indicate the area where response operations should be conducted as well as the wind direction;
- guide operations in real time and assess their effectiveness.

Containment and recovery

The aircraft crew can guide response vessels towards the thickest areas and check the effectiveness of containment (spotting any leaks of pollutant, estimating their volume using the Bonn Agreement Oil Appearance Code•) and even of recovery (if sweeping arms are used, for example).

To be successful, these operations must be carried out at very low speed, which means that the guidance aircraft will have to constantly manoeuvre to return to the response area. Guidance from a helicopter may be smoother.

Recovering using sweeping arms (Ulysse/CSL Virginia *collision, 2018)*

Dispersant application

For dispersant spraying operations, the aim of aerial guidance is to guide vessels and aircraft towards the thickest slicks, indicate when to start spraying and when to stop, and to evaluate the effectiveness of the operation.

Once the decision to apply dispersant has been made, it is useful to start by conducting a trial run on a limited area in order to ensure that this technique is appropriate. From the air, it is relatively easy to perceive changes in the appearance of the slick, which forms a yellow to orange plume visible below the surface. If an emulsion has formed, a second application is often required to achieve this result.

If the trial run is successful, larger-scale operations can begin.

Dispersant is generally sprayed into the wind. It is only applied to areas of Bonn Agreement• codes 4 and 5.

Operating into the wind requires very regular manoeuvres for repositioning. This significantly increases the flight time for the guidance aircraft.

Aerial spraying is carried out at very low altitude: depending on the circumstances, the type of aircraft, the sea state and local safety regulations, dispersant can be sprayed at between 30 and 150 feet•, at a speed of between 100 and 150 knots. The aircraft only flies at this altitude during the spraying operation: it gains altitude again at the end of each pass and carries out its repositioning manoeuvre, for example at 300 feet•, before making its descent again for a new pass.

It is essential for the guidance aircraft to fly at a very significantly different altitude (e.g. 700 feet•) to prevent any risk of collision. The crew of the guidance aircraft must have a clear view of the spraying aircraft at all times and there must be frequent radio contact on a dedicated frequency.

*Aerial spraying of dispersant
(*DeepWater Horizon *spill, USA, 2010)*

Mapping

B15

Observations must be recorded on a map: this presentation offers an immediate understanding of the situation and the possible developments.

There are various possibilities:

- mapping directly using the aircraft's system
- mapping performed on land via a Geographic Information System using the coordinates provided by observers
- mapping carried out in-flight by observers, on a paper map (possibly laminated) or, for instance, on a tablet or smartphone to which a suitable base map has been downloaded prior to the flight.

The method proposed in this chapter is directly derived from the internationally adopted method for observing icebergs in the polar areas.

Map identification

In a corner of the map, the following should be recorded:

- the date and times of the flight
- the flyover zone
- the map number (if several maps are produced during the flight)
- the name of the observer and of the organisation to which they belong
- the type of aircraft and the sensors used
- the meteorological conditions: cloud cover, colour of the sky and the sea, the sea state.

Observation log

On a base map prepared prior to the mission:

- mark the contours of each polluted zone observed with a continuous line
- specify the nature of the slick for each zone according to the criteria explained on the following page (use the given abbreviations) and trace the flight path with a dotted line
- This log will contribute to the survey report. Note-taking during the flight can be adapted to the circumstances and the practices of the observer.

Using the aircraft's navigation system linked to a mapping system, a mission report can be generated showing the flight path and the observations made

Description of the pollution	Abbreviation
Colour/appearance (▶ B7)	
1. Sheen	code 1
2. Rainbow	code 2
3. Metallic	code 3
4. Discontinuous True Oil Colour	code 4
5. Continuous True Oil Colour	code 5
For 4 and 5, indicate colour:	
black	bl
brown	br
orange	or
Size	
• Slick (Ø or L > 30 m)	sl
• Patch (50 cm < Ø or L < 30 m)	ptc
• Patty (10 cm < Ø < 50 cm)	ptt
• Tarball (Ø not detectable)	tb
State of pollutant	
• Fresh oil	fo
• Dispersed oil	disp
• Emulsion	emul
Arrangement	
• Random	•
• Windrows	//
Debris	deb

Degree of coverage

The degree of coverage is indicated as a percentage, with reference to the schematic representations (▶ B16). If both thick patches and thin layers (sheen, rainbow, metallic) are present, if possible, specify their respective coverage (e.g. 5% pat – 30% code 3).

Slick dimensions

The average dimensions for patches of emulsion (or potentially for slicks of fresh oil) are expressed in metres.

The information about the slick is reported as a list in the following order:

- type and arrangement
- coverage
- dimensions

Example of notation: pollution in the form of rainbow stripes, covering 40% of the sea surface, combined with patches covering 3% of the sea surface, average size of the patches: 10 m.

- ptc + code 2 //
- 40% code 2 – 3% ptc
- 10 metres

For clarity, these indications can be recorded on the edge of the map and arrows used to identify the point to which they refer on the map.

If the same description applies to several different zones, the descriptive criteria should be recorded in a corner of the map with an identification by letter, and this letter noted in each of the zones concerned (for an example, see map, next page).

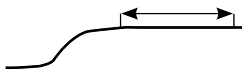
When a slick spreads beyond the horizon, the limit of visibility should be shown using a dotted line.

Other indications

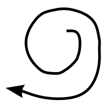
- indicate the flight path using dashes and crosses

  e.g. - + - + - + -

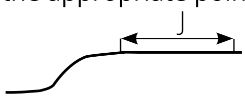
- indicate the parts of coast affected

  e.g. 

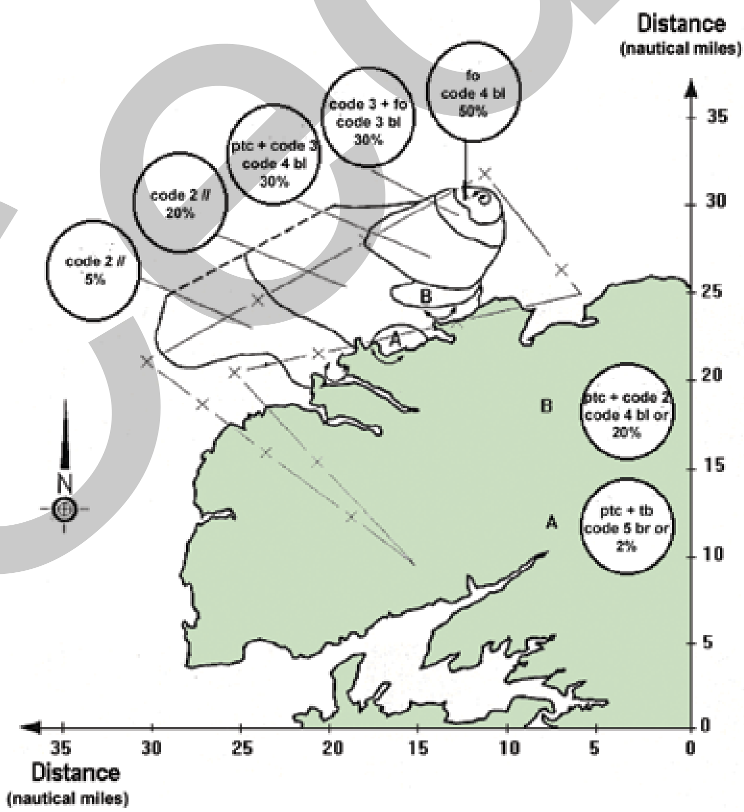
- also identify the points at which the oil surfaces (in the case of a pipeline leak or a sunken wreck)

  e.g. 

- various remarks and observations may be noted on the edge of the map or on an attached sheet, making sure that the place they refer to is clearly identified on the map by a letter at the appropriate point

  e.g. 

  J = polluted pebbles on the upper foreshore



Example of a summary map using the above-mentioned abbreviations

Calculating quantities

B16

Although estimating the quantity of pollutant is no easy task, it is nevertheless a necessary one. Estimations are made using maps, taking into consideration the polluted surface area and the thickness of the slicks.

Estimation at sea

◗ Surface area

Only thick patches and accumulations which represent the bulk of the pollution should be considered; areas of sheen (thin layers) should be excluded.

The surface area is obtained by multiplying the overall surface area of each zone by its degree of coverage (thick patches).

The surface area of a slick or an accumulation of tarballs can be calculated directly using an onboard GPS, SLAR• or an IR/UV scanner•.

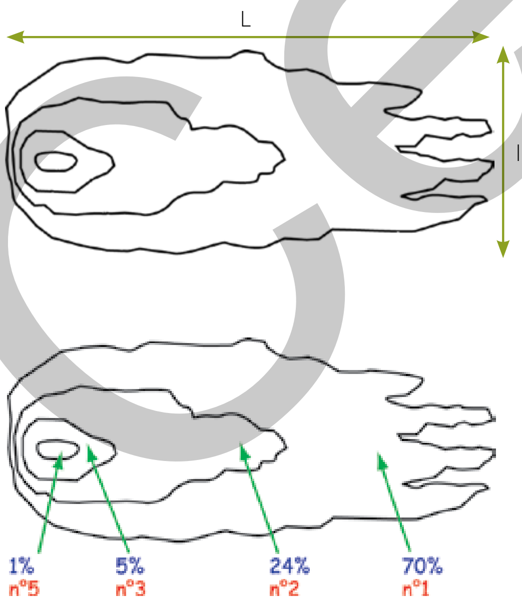
◗ Thickness

1) Visual observation

For a major oil spill, as a first estimation and in the absence of indications to the contrary, take the higher value of the range provided in the appearance code for the pollution observed (▶ B7);

2) Calculation with instruments

Use a microwave radiometer (MWR•) or a laser flurosensor (LFS•).



N° 1 (sheen) 0.04 / 0.3 µm
N° 2 (rainbow) 0.3 / 5.0 µm
N° 3 (metallic) 5.0 / 50 µm
N° 5 (continuous true oil colour) over 200 µm.

L = 12 km / W = 2 km
Total surface area = 24 km^2
Coverage = 80%
Surface area covered: 24 x 80% = 19.20 km^2

Minimum estimation	Maximum estimation
N° 1 19 x 70% x 0.04 = 532 l	x 0.3 = 3,990 l
N° 2 19 x 24% x 0.3 = 1,368 l	x 5.0 = 22,800 l
N° 3 19 x 5% x 5.0 = 4,750 l	x 50 = 47,500 l
N° 5 19 x 1% x 200 = 38,000 l	38,000 l
TOTAL 44,650 litres	TOTAL 112,290 litres

As the thickness may be considerable and cannot be determined from the air, the minimum thickness is taken here by default.

Example of estimation using the Bonn Agreement Oil Appearance Code (design: J-P Castanier, French Customs; calculation: Alun Lewis, consultant)

Use of SLAR•: slick mapping - surface area calculation by the system on board the Spanish surveillance plane

Estimation on the coast

Although the surface area of pollution can be estimated fairly quickly (stretch of the coastline affected multiplied by width of the zone covered), the thickness varies widely (from a few millimetres to several decimetres).

Moreover, on the coast, the risk of error and confusion is increased by the presence of other factors such as litter, seaweed, etc. (▶ B18).

For greater accuracy, the assessment of coastal pollution requires on-land reconnaissance surveys.

Warning

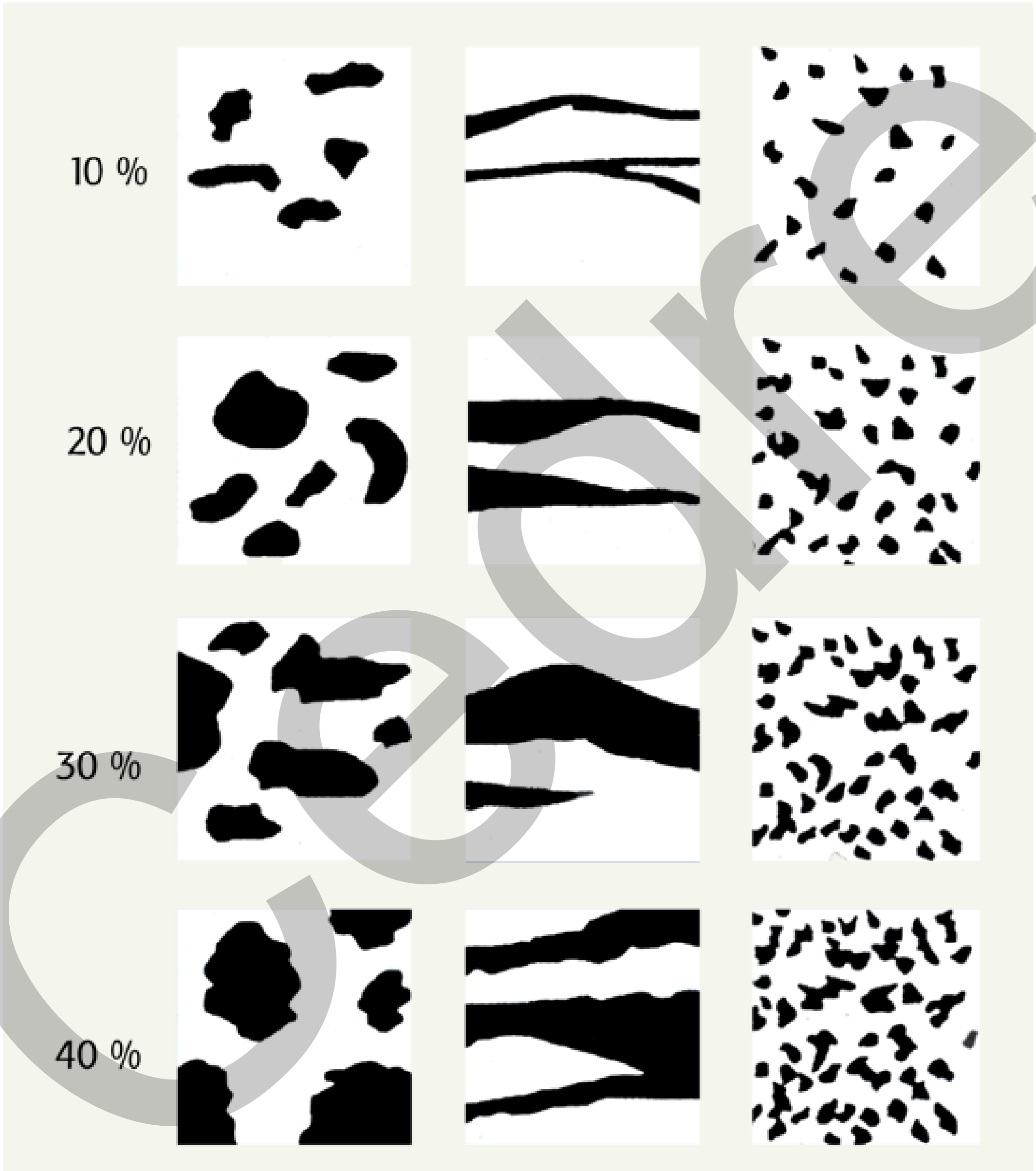
Evaluations based on aerial observations only provide an order of magnitude. Uncertainties about the true thickness of slicks can lead to estimations of volume that vary up to a factor of ten. Nevertheless, minimal estimations should be considered a reliable source of information in determining the minimum quantity that was actually spilt.

Emulsified heavy fuel oil reaching the shore following the Prestige *spill (Galicia, Spain, 2002)*

To find out more

See Cedre's operational guide:
"Surveying Sites Polluted by Oil"

Assessing the degree of coverage *



Visual aid (source: Owens E. H. and G. A. Sergy, 1994)

See Bonn Agreement Oil Appearance Code (▶ B7).

* This is an approximate schematic representation.

Examples of other products

Images of various chemicals and food products spilled at sea can be confused with the appearance of oil slicks. It is therefore useful to have a number of reference images to avoid interpretation errors.

Vegetable oil and certain chemicals also show up on remote sensing• equipment.

Emulsified palm kernel oil in the form of white discs (Allegra spill, Western Channel, October 1997)

Styrene slick observed from a French Customs plane (Ievoli Sun incident, Les Casquets, France, October 2000)

Molasses slick

Palmor I experimentation: from left to right - soyabean oil, fuel oil, palm oil

Vegetable oil release

The drift of vegetable oils is similar to that of petroleum oil, but their surface spread is generally different: an oily wake behind a ship will splay out to form a “fan” shape or “triangle”, whereas vegetable oil will appear more like a "ribbon".

POME (Palm Oil Mill Effluent) off Belgium

Slick of brown algae (Sargassum)

Paraffin slick in the Mediterranean

Palm oil slick

False positives

Various floating objects and other phenomena can be mistaken for oil slicks.

For instance, the following have been known to give rise to confusion:

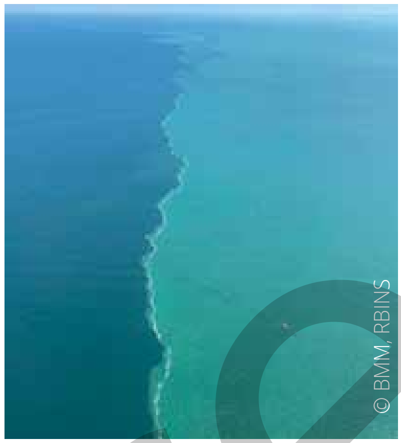
- shadows of clouds making darker zones on the water surface;
- when the sea is relatively calm, surface currents or convergence of cold and warm water can, with a small angle of incidence, give the appearance of a film (sheen, rainbow, metallic);
- muddy waters at river mouths, in bays or simply near to the coast, can catch the eye because of their beige appearance in comparison to the surrounding water (coloured water without any sign of a film – sheen/rainbow/metallic – on the surface cannot be an oil slick).
- floating algae or phytoplankton blooms• can appear as coloured patches;
- shoals which look like dark patches;
- calm areas;
- fish spawn;
- pollen;
- coral larval dispersal.

Tips for avoiding false positives:

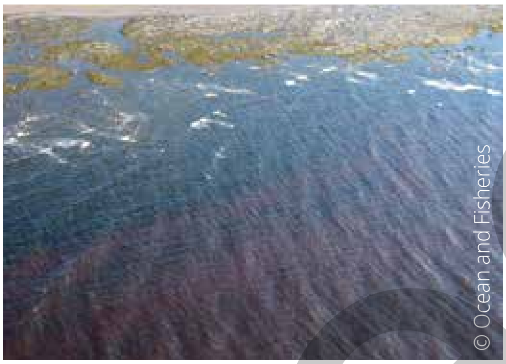
- Remember that the different categories of the Bonn Agreement Oil Appearance Code•, in particular rainbow, are best seen from directly above the slick;
- similarly, do not hesitate to take several photos from different angles;
- when using a helicopter, attempt to get close and hover;
- certain phenomena are seasonal: for instance the presence of pollen in mainland France mainly between March and September, the observation of plankton blooms• and strong algal growth often in summer, etc.
- various publications cited in the bibliography (NOAA Job Aid, Bonn Agreement• Photo Atlas, etc.) include photographs of different phenomena.

If in doubt, it is important to report the observation. Shipboard observation, or even sampling, may then be carried out.

Shadows formed by clouds



Surface effect due to the presence of two different water masses



Algal bloom

Peat at the water surface

Seaweed near the coast. Clumps of seaweed drifting at sea (close-up)

Muddy water near the coast. Silt from the seabed (muddy bottom) becoming suspended in the water due to the movement of the propellers

Examples of oil-like effects due to the presence of shoals, seaweed, coral reefs etc.

Calm patches can be confused with a thin film of oil

Coloured trails due to phytoplankton growth (observation from a hovering helicopter, note the effect of the wind made by the rotor demonstrating that in this case it is not an oil slick)

Plankton bloom•

Document templates

C

Standard pollution reporting format (POLREP)

INITIAL INCIDENT REPORT

To (for action): *relevant MRCC•*

Copy (for information): *relevant maritime authorities*

Title/subject: *POLREP•*.

A – Classification of report:

Doubtful – probable – confirmed.

B – Date and time pollution observed/ reported.

Identity of observer/reporter.

C – Position and extent of pollution.

If possible, state range and bearing of some prominent land mark, and estimated amount of pollution (i.e. size of polluted area, number of tons spilled, or number of containers, drums lost, etc.). Where appropriate, give position of observer relative to the pollution.

D – Tide, wind speed and direction.

E – Weather conditions and sea state.

F – Characteristics of pollution.

Give type of pollution, e.g. oil (crude or otherwise), packaged or bulk chemicals. For all, give also appearance, e.g. liquid, floating solid, liquid oil, semi-liquid sludge, tarry lumps, weathered oil, discolouration of sea, visible vapours, etc. Any markings on drums, containers etc. should also be given.

G – Source and cause of pollution.

e.g. from vessel or other undertaking. If from vessel, say whether as a result of apparently deliberate discharge or a casualty. If the latter, give brief description. Where possible, give name, type, size, nationality and port of registry of polluting vessel. If vessel is proceeding on its way, give course, speed and destination.

H – Details of vessels in the area.

To be given if the polluter cannot be identified, and the spill is considered to be of recent origin.

I - Evidence gathered.

Any photographs or samples.

J – Remedial action taken or intended to deal with the spillage.

K - Forecast of likely effects of pollution

e.g. arrival on shore and estimated timings.

L – Names of other States and organisations informed.

M - Any other relevant information

e.g., names of other witnesses.

C2

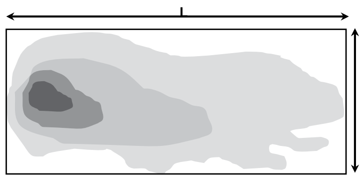
Survey report template included in the contingency plan

AERIAL SURVEILLANCE REPORT

OBSERVATION				CONDITIONS	
Incident		**Date**		**Wind**	Wind direction (*blowing from*): Strength (knots):
Aircraft type		**Take-off time** (local)			
Company		**Landing time** (local)		**Cloud ceiling** (feet)	
Call sign		**Overflight zone diagram**		**Weather**	☐ Sunny ☐ Cloudy ☐ Thundery ☐ Rainy
Observer				**Sea state** (Beaufort)	
Observer assistant				**Visibility**	☐km ☐nm
Average altitude				**Tools**	☐ GPS ☐ Photos ☐ Videos ☐ IR ☐ UV ☐ SLAR ☐ Other

NOTES

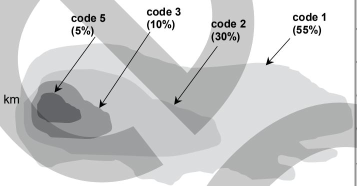
Estimation at sea



Example:

L = 12 km
W = 2 km
Surface area = 24 km²
Coverage = 80 %
Polluted surface area = 24 x 80 % = 19.20 km

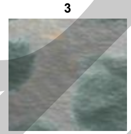
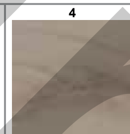
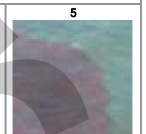
Code 3:
19.20 x 10% x 5 = 9.6 m³ minimum
19.20 x 10 % x 50 = 96 m³ maximum



Appearance code

	Appearance	Slick thickness (µm)	Minimum volume in m³/km²	Maximum volume in m³/km²
1	Sheen (silvery grey)	0.04-0.30	0.04	0.30
2	Rainbow	0.30-5	0.30	5.00
3	Metallic	5-50	5.00	50.00
4	Discontinuous True Oil Colour	50-200	50.00	200
5	Continuous True Oil Colour	>200	200	> 200

REPORT

Slick	Position (latitude S / longitude E)		Slick dimensions		Surface area	Coverage of pollutant (%)	Polluted surface area	Coverage for each appearance code (%)					Minimum volume (m³)	Maximum volume (m³)
No.	Slick start	Slick end	L: Length (km)	W: Width (km)	LxW: Length x width (km²)		Surface area x Coverage	1 	2 	3 	4 	5 		

C3

Bonn Agreement pollution observation/detection log

☐ HELCOM ☐ BONN AGREEMENT **STANDARD POLLUTION OBSERVATION / DETECTION LOG** ☐ NO POLLUTION DETECTED

REPORTING AUTHORITY	AIRCRAFT REG	MISSION No	CAPTAIN	CO PILOT	OPERATOR	OBSERVER	DAY	DATE	MONTH	YEAR

FLIGHT TYPE	ROUTE / AREA				TIME OVER THE SEA DAY		TIME OVER THE SEA NIGHT		TOTAL TIME OVER THE SEA	
					hrs	mins	hrs	mins	hrs	mins

No	AREA CODE	TIME UTC	POSITION		DIMENSIONS		AREA COVER	OILED AREA	OIL APPEARANCE COVERAGE (PERCENTAGE - %)						MINIMUM VOLUME	MAXIMUM VOLUME	COMBAT
			LATITUDE 'NORTH'	LONGITUDE 'EAST/WEST'	LENGTH Km	WIDTH Km	%	Km^2	1	2	3	4	5	Oth	m^3	m^3	Y / N

No	POLL TYPE	DETECTION						PHOTO	VIDEO	FLIR	WEATHER					REMARKS
		SLAR	IR	UV	VIS	MW	LF	Y / N	Y / N	Y / N	WIND	CLOUD	VIS	SEA	Wx	
											°	FT				
											°	FT				
											°	FT				
											°	FT				
											°	FT				

No	REMARKS

OIL APPEARANCE TABLE

No	OIL APPEARANCE DESCRIPTION	MINIMUM VOLUME m^3 / km^2	MAXIMUM VOLUME m^3 / km^2
1	SHEEN	0.04	0.30
2	RAINBOW	0.30	5.00
3	METALLIC	5.00	50.0
4	DISCONTINUOUS TRUE COLOUR	50.0	200
5	TRUE COLOUR	200	>200

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Further information

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Glossary and acronyms

The words and expressions followed by a • in the text are defined below.

AIS: Automatic Identification System

Auto-ignition temperature: minimal temperature at which vapours ignite spontaneously

AZTI: scientific and technological centre based in the Basque Country, Spain, specialising in the marine environment and food, in particular the fisheries sector

BAOAC: Bonn Agreement Oil Appearance Code

Biscaye Plan: a French-Spanish operational agreement that sets out the terms and conditions of joint response by SASEMAR (*Sociedad de Salvamento Marítimo y Seguridad Marítima*) and the French maritime authority for the Atlantic area (Préfecture Maritime de l'Atlantique), for rescue operations, pollution response and assistance to vessels in difficulty in the Bay of Biscay

Boiling point: temperature at which a liquid begins to boil; more specifically, when the temperature at which saturating vapour pressure of a liquid is equal to standard atmospheric pressure (1,013.25 hPa). The boiling point measured depends on atmospheric pressure

Bonn Agreement: the Bonn Agreement (1969) is the mechanism by which ten Governments, together with the European Union, cooperate in dealing with pollution of the North Sea by oil and other harmful substances

CleanSeaNet: a European satellite-based oil spill and vessel detection service

cSt: unit of measurement for viscosity 1 cSt (centistoke) = flow of 1 mm^2/s

Dispersant: product containing a solvent, used to condition active matter and to diffuse it in the water. A mixture of surfactants ensures the dispersal of oil into small droplets in the marine environment

Drift committee: this committee is composed of representatives of Météo-France, Ifremer, SHOM and Cedre

Drone: common term for a UAV.

EMSA: European Maritime Safety Agency

Emulsification: the formation process of an invert emulsion

Evaporation: transformation of a liquid into a vapour via its free surface, at a particular temperature. The rate of evaporation of oil depends mainly on the proportion of volatile products and the combination of hydrocarbons, as well as other factors such as the wind speed, the water and air temperature, the roughness of the sea surface and extent of spreading. The lightest fractions evaporate first, and the least volatile fractions form a residue, with a higher density and viscosity than the original product

Explosimeter: appliance used to measure the concentration of inflammable gas in the atmosphere

Flash point: lowest temperature at which the concentration of vapours emitted is sufficient to cause ignition upon contact with a flame, spark or hot spot, but is insufficient to propagate combustion in the absence of a pilot flame. By definition, a product is extremely flammable when its flash point is below 0°C, highly flammable when it is between 0 and 21°C and flammable when it is between 21 and 55°C

FLIR: Forward Looking Infra Red = Infrared sensor used for remote sensing of oil slicks. In optimal atmospheric conditions, it can detect a slick approximately 20 nautical miles from the aircraft when flying at 3,500 feet. It can detect Bonn Agreement code 2 (rainbow) slicks, and has no upper thickness limit. It can also be used to read the name of a vessel at night

Foot: a unit of length equivalent to 12 inches, or 30.48 centimetres

GIS: Geographic Information System

HFO: Heavy Fuel Oil.

Hyperspectral: hyperspectral imaging is a technology which consists in obtaining an image of a scene in many (generally over 100) narrow and contiguous spectral bands. It can be used to determine the chemical composition of a photographed surface and can provide indications of the concentration and physical properties of the components

IFO: Intermediate Fuel Oil

Ifremer: French Research Institute for Exploitation of the Sea.

IMDG: International Maritime Dangerous Goods Code. An international code for the maritime transport of dangerous goods in packaged form (including containers and vehicles), in order to enhance and harmonize the safe carriage of dangerous goods and to prevent pollution to the environment

Invert emulsion: or water-in-oil emulsion. This emulsion may be made up of a large proportion of water (often 60%, can be up to 80%). It varies in colour from brown to orange and is often referred to as "chocolate mousse", which gives an indication of its consistency

IR: infrared

LFS: Laser Fluoro Sensor

LLLTV: Low Level Light Television

LSFO: Low Sulphur Fuel Oil

MARPOL: International Convention for the Prevention of Pollution from Ships

Méteo-France: a French public institution involved in ensuring maritime safety both on the French coast and under international mandates, and which, in the event of marine pollution, contributes to the drift committee to conduct monitoring using modelling software (MOTHY)

Microwave Radiometer (MWR): Sensor used for remote sensing of oil slicks. The detection method is fairly similar to that of an infrared scanner. It can also determine the thickness of slicks

MOTHY: Météo France's Oceanic Oil Transport Model, a drift prediction model for oil slicks and objects at sea

MRCC: Maritime Rescue Coordination Centre

Multispectral: technique for simultaneously acquiring images of the same scene in several spectral bands, whether contiguous or not

Natural dispersion: formation of oil droplets of varying sizes, due to wave action and turbulence on the sea surface. These droplets either stay in suspension in the water column, or resurface to form another slick. This natural process can be encouraged by the use of dispersants, depending on the viscosity of the product and on whether the geographical and bathymetric situation makes their use possible

NOx: nitrogen oxide, atmospheric emissions produced by the combustion of a ship's fuel for which specific regulations are in force

ONERA: French national aerospace research centre

Plankton bloom: vigorous proliferation of plankton

POLREP: POLlution REPort

Pour point: temperature below which a substance no longer flows. If a substance's pour point is above ambient temperature, it is less fluid. Pour points are measured in laboratory conditions and are not an accurate representation of the behaviour of a particular product in an open environment

PPE: Personal Protective Equipment

Recoalescence: phenomenon whereby two identical but dispersed substances tend to merge

Relative density: the ratio of the density (mass of a unit volume) of a substance to the density of water for a liquid substance. Also called specific gravity.

Remote sensing: range of techniques used to detect and identify phenomena from a certain distance, either through human capacities or special sensors. In the case of aerial observation of oil pollution, remote sensing relies on the use of detection systems, including SLAR, FLIR, infrared and ultraviolet scanners and microwave radiometers

RPAS: Remotely Piloted Aircraft System

SAR: Synthetic Aperture Radar

SASEMAR: *Sociedad de Salvamento y Seguridad Marítima* (Spanish Maritime Rescue and Safety Organisation). Spanish organisation in charge of search and rescue services at sea, as well as pollution response for the Spanish state, within its responsibility zone which covers approximately 1,500,000 km^2. Renamed *Salvamento Marítima* in 2009

SEBC: Standard European Behaviour Classification

SECA: Sulphur Emission Control Area

Settling: process in which particles of matter gradually stop moving and come together to form layers

SHOM: *Service Hydrographique et Océanographique de la Marine* (French Naval Hydrographic and Oceanographic Service). This organisation takes part in the Drift Committee

SLAR: Side-Looking Airborne Radar

SOx: Sulphur oxide, atmospheric emissions produced by the combustion of a ship's fuel for which specific regulations are in force

Sweeping arms: spill response equipment deployed from vessels for containment and recovery operations. This system is positioned perpendicular to the vessel and gathers the pollutant, which is then recovered using a pump installed at the apex

Teflon®: material used to take samples. It prevents the risk of leakage and allows traces of oil to be analysed in good conditions

Toximeter: device designed to continuously detect toxic gases, vapours or oxygen

UAV: Unmanned Aerial Vehicle. It is generally piloted remotely and can be used to detect and observe pollution

ULSFO: Ultra-Low Sulphur Fuel Oil

UV: Ultraviolet

Vapour pressure: partial pressure of gas molecules in a state of equilibrium with the liquid phase for a given temperature

Viscosity: property of resistance to uniform pouring without shaking, inherent in the mass of a substance. It is expressed in centistokes (cSt)

VLSFO: Very Low Sulphur Fuel Oil

VOC: Volatile Organic Compound. This term covers a wide variety of chemicals which are all compounds of carbon and are volatile at ambient temperature

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