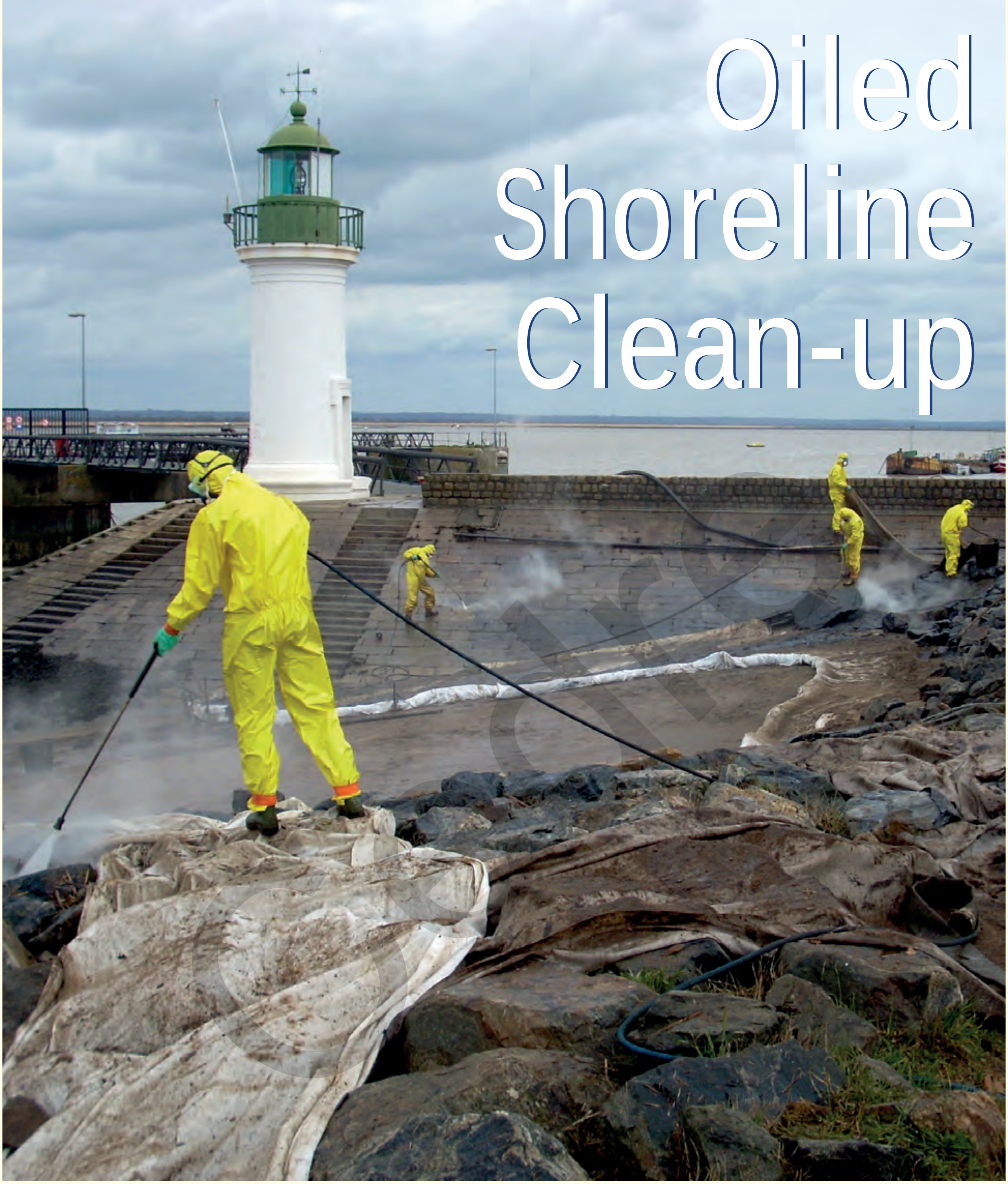
Oiled Shoreline Clean-up



OPERATIONAL GUIDE

Cedre

Oiled Shoreline Clean-up

OPERATIONAL GUIDE

Information
Decision-making
Response

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Purpose and structure of this guide

This operational guide on oiled shoreline clean-up summarises Cedre's knowledge acquired through the different studies and experiments conducted since its creation, as well as during real spills in France and internationally.

The guide is divided into 6 parts:

- generalities (“what you need to know”) about the environment (relevant environmental processes and factors and the resulting classification), the spill (the evolution, behaviour and impact of different oils on the shoreline) and the general framework of the response (its phases, organisation and the decision-making process);
- the response itself ("what to do"), in which the different response techniques are presented (protection and clean-up);
- selection criteria, constraints and procedures for implementation;
- worksite management;
- Tech Sheets on the different techniques to be implemented during the various response phases, including prior protection measures, clean-up techniques and worksite management practices;
- further information.

Clean-up operations

Contents

Generalities: what you need to know

The environment

Shoreline morphology varies according to the shore's geological history, exposure to waves, type of substrate and, in the case of sediment accumulation, their average grain size (ranging from mud to boulders) and the volume of sediment stock available.

Waves and tides – and the currents they respectively induce – are the main forces at work on shorelines, shaping and changing them.

These same factors influence the behaviour and fate of oil that is washed up on the coast and may help or hinder clean-up operations.

Shorelines can be classified according to their configuration, substrate, exposure and sensitivity.

Dynamic coastal processes

Waves

Waves, generated by the sea, wind or swell, dissipate their energy both in the shallows (by refraction on the bottom) and on the shore (by diffraction and refraction). The intensity of this energy depends on the wind's fetch (i.e. the distance of water over which the wind blows unobstructed), its duration and its average speed. This means that certain coastal areas, depending on the direction they face and how open they are to the sea, are more exposed or wave-beaten than others, which are naturally more sheltered from the waves.

Waves are at the origin of coastal and subsea geomorphology. They control sediment movements (transport, sedimentation and remobilisation). They create accumulations of sediment (mud, sand, gravel or pebbles) and deposit additional inputs by redistributing sediment transported by watercourses or released by coastal erosion, which they continually generate. The sediment budget of a coastal area is balanced by the predominant hydrodynamic forces (waves, currents and tides) that characterise it; the local coastal geomorphology results from this equilibrium. This equilibrium is regularly disrupted, either episodically (during a storm, for example) or seasonally (change in wave regime): part or all of the beach's sediment stock is then set back into motion.

In the event of an oil spill, waves have various effects which can sometimes be antagonistic:

- mixing of the oil with the water by dispersion (oil in water) or emulsification (water in oil);
- directing, together with the wind, the drift of the spill at sea and determining where it will reach the shore;
- preventing the oil from reaching the most exposed cliffs, by reflection off the walls;

- burying the stranded oil by sand accretion/replenishment (beach nourishment);
- cleaning the beach by leaching, abrasion and erosion;
- projecting oil into the supratidal zone where it cannot be washed back out to sea and where it will be temporarily directly exposed to atmospheric factors, in particular UV rays from the sun, a major factor in the photochemical degradation of oil;
- jeopardising responder safety and the implementation of response operations, or even breaking equipment.

Agitation: oil being washed back out to sea

Tides

The tides expose the foreshore• to wave action on a more or less regular basis, alternately covering and uncovering it to varying levels.

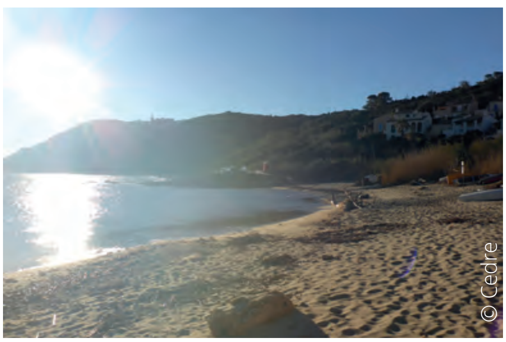
The rhythmic movements of water masses, caused by the constant ebb and flow of the sea, generate currents which, although they have little influence in the open sea, are significant in narrow passes and shallow bays along the coast.

Tides affect the horizontal and vertical spread of a spill. They often determine how clean-up sites are organised (adaptation of working hours, sometimes interruption of clean-up actions on a daily basis).

Nearshore currents

Various types of local currents need to be taken into account:

- **tidal currents**, which vary according to the type of tide (diurnal, semi-diurnal) and whose intensity increases with the tidal range (which varies from one coast to another) and in narrow stretches along the coastline. The flow tide carries the pollutant towards the upper foreshore•, where it is deposited with the ebb tide•;
- **wave-induced currents** of which there are two types:
  - **longshore drift**, which runs more or less parallel to the shoreline, generated by waves approaching the coast at an oblique angle. This drift governs sediment transport and determines



Mediterranean site at low tide

Mediterranean site at high tide

the general direction of sediment migration along long linear stretches of coast, whether dunes (sand) or cliffs (pebbles);

- **rip currents**, which are oblique or perpendicular to the coastline, drive large water masses back out to sea in a powerful, narrow channel, countering the series of very strong waves that are sometimes propelled towards the coast with the flow tide.

- **river-induced currents**, which can extend beyond estuary areas, vary seasonally (flood and low-flow periods) and with local rainfall variations. At the mouths of large rivers, these currents affect the drift of an oil spill beyond the estuary, but also its buoyancy due to the drop in salinity they can cause: the oil, floating below the surface, is no longer visible, especially as the water is generally turbid in these areas.

Driven by the general currents and local coastal currents, then under the influence of turbulence at the coast due to the topography of the coastline, the pollutant will wash up on the shore at certain sites, which represent the average result of the prevailing metocean factors (wind, current, waves) in these areas.

Pollutant floating at the surface

Wind

The wind, which plays a key role in generating waves, affects the spill in various ways:

- it influences the drift and evolution of the pollutant (by contributing to the evaporation of the volatile fractions of the oil);
- it plays a key role in remobilising oil that has washed up on the shore and depositing it at other sites;
- it can also spread the pollution landwards, by projecting oil onto the backshore, particularly in the form of sea spray, but also sometimes in clusters;
- it can conceal oil washed up on the beach by depositing aeolian (wind-blown) sand (a phenomenon that can cause response teams to believe that there is no oil remaining).

Sedimentary cycles

Beaches undergo natural cycles of sediment erosion and accretion. These phases are controlled by wave action, which at times is erosive (e.g. storm waves or long swell waves in winter) and at times constructive (e.g. short swell waves in the early summer). The quantity of sediment on the upper shore is at its maximum in summer. After the summer season, this

Upper foreshore during erosion phase

Upper foreshore during accretion phase

sediment migrates to the lower foreshore where reaches its maximum in winter. In the spring, the sediment gradually begins to shift back up the beach. In addition to this seasonal cycle, short episodes of significant sediment movement occur, triggered by sudden, one-off erosion or accretion events.

The beach profile can therefore be altered in the space of one or two tides, which can cause oil deposits to be temporarily covered over with sand from the lower beach; this oil can remain buried for several weeks or months, then reappear later when the sediment migrates down the beach.

Climate factors

In the event of pollution on the shoreline, in addition to dynamic processes, it is also important to take into account climate factors which can influence the pollutant's behaviour and the conditions for response operations:

Latitude or climate zone

The climate zone broadly defines the climate (wave and storm patterns, rainfall, sunshine, ambient temperatures, daylight hours, etc.), the flora and fauna, and certain sediment-related aspects (production, inputs).

Temperature

The temperature directly affects the physical and chemical characteristics of the oil. It can therefore very suddenly (in a single day) alter its viscosity and, ultimately, the concentrations of various components, thereby reducing or increasing the oil's potential physical and biological impact.

It can facilitate, penalise or prevent the implementation of response operations. Extreme temperatures will have a severe impact on the working conditions for response operations, and therefore on the performance of the clean-up teams.

Sunshine

Exposure to the sun's rays will promote the degradation of the oil, in particular due to ultraviolet (UV) radiation, which completes the clean-up process by eliminating residual films.

Shoreline classification criteria

A diverse patchwork

The general shoreline configuration is linked to the geological history of the submarine and continental areas it intersects. The great diversity of shorelines can be explained by their geological characteristics, alternating between low and high coasts, straight and indented coasts, with a steep or moderately sloping shoreface, sometimes dotted with islets or reefs. These characteristics therefore define the structural features of the shoreline: bays, cliffs, estuaries, peninsulas, islands, dune massifs, etc.

Geology

The general geometry of the shoreline is closely linked to the geological history and characteristics of the submarine and continental areas it borders. The first distinction is made between low sedimentary coasts and high rocky coasts.

Substrates

The shoreline is composed of fixed materials (bedrock or man-made structures•) and/or loose materials (sediments). These substrates form specific types of shores:

- Rocky shores: platforms, cliffs, coves, caves, etc. (in this category we can also include man-made structures, port constructions and erosion defences: jetties, walls, quays, riprap, groynes, etc.);

Cliffs

- Sediment shores: boulder fields; pebble beaches, shingle bars, shingle beaches; mudflats, marshes, estuary banks; sandy beaches, dune ridges, etc.

Sediments are classified into different categories based on grain size: boulders (> 500 mm); cobbles or pebbles (< 500 mm); gravel (< 25 mm); fine to coarse sand (< 2 mm); silt or mud (< 0.063 mm).

Rocky platform

Boulder field

Fine-grain sand beach

The nature of the substrate is critical, as it determines whether and the extent to which the oil will penetrate into the ground, as well as its persistence•. In addition, response methods vary according to the nature of the substrate.

Different sizes of sediments

Exposure

Exposure defines the level of wave energy that is dissipated on the coast.

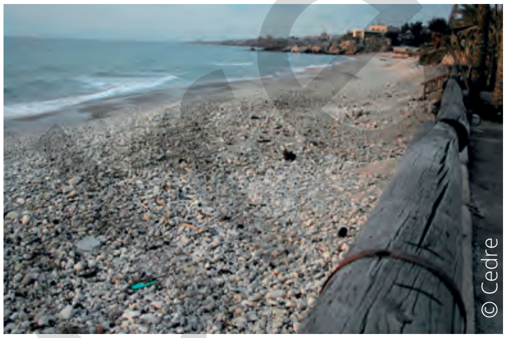
Shores are classified according to their mode of exposure, ranging from exposed (e.g. rocky headland) to sheltered (e.g. marshland). When coastal wave energy is high, for hard surfaces this causes pounding, beating and, in the presence of sediment, abrasion; for sediment shores, it means regular mixing and remobilisation.

Marshland

Contaminated mudflat

Exposure dictates sediment distribution across the beach, as it does on the coastline in general; this distribution depends on the energy available, i.e. the waves' capacity to mobilise and move the sediment it encounters on the foreshore•. In this way, the sea sorts the sediment: the characteristics of the sediment must be consistent with the forces at work.

At the scale of the beach, the average energy dissipated varies along the beach profile; sediment is generally deposited at specific levels that are clearly visible in the beach profile (for example: clusters of pebbles or cobbles on the upper section of a sandy beach). On less exposed sites, where hydraulic sorting is less pronounced, the beach is composed of a heterogeneous mixture of sediments of varying sizes.



Exposed beach with heterogeneous sediment

To give an initial indication, exposure can be assessed using various morpho-granulometric or biological indicators:

- the existence of muddy deposits (synonymous with sheltered mode);
- average grain size, based on the principle that the coarser the elementary grain, the greater the energy and therefore the more exposed the beach is (this parameter can, however, only be significant if the sediment stock on the beach is relatively homogeneous. In fact, the homogeneity of sediment grain size, which characterises the efficiency of sorting by wave action, is a more reliable indicator of high energy);
- grain wear, which is also a reliable indicator of the beach's exposure: angular, chipped shapes indicate very low energy, while blunt, rounded shapes are a sign of

strong mechanical abrasion;

- the slope of the beach, which is the result of the interaction between grain size and wave energy. Generally speaking, the more exposed a beach is to waves, the coarser its average grain size and the steeper its slope;
- the predominance of plant and animal species characteristic of wave-beaten shores (e.g. barnacles, *Perforatus perforatus*) or sheltered shores (e.g. knotted wrack, *Ascophyllum nodosum*).

In the case of oil pollution, this energy drives a natural cleaning process, the effectiveness of which is proportional to the intensity of the energy exerted. The natural cleaning rate determines how long the oil will remain on the shoreline, a notion referred to as persistence•.

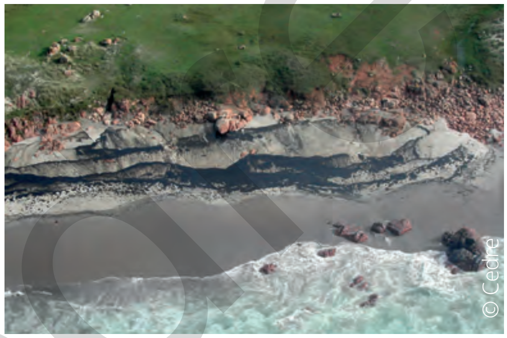
The coastal system

The beach profile is generally divided into three zones:

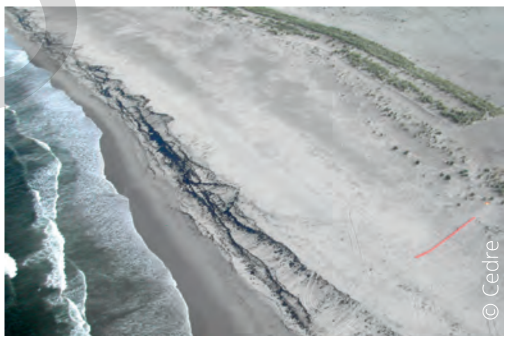
- the shoreface: located below the spring low water level, it is never uncovered and is therefore relatively sheltered against major oil spills (except in the event of natural or chemical dispersion or natural or artificial sinking of the pollutant);
- the foreshore•: or intertidal zone, is the area between the spring low water level and the spring high water level. The length, width and slope of the foreshore• vary according to its nature (sedimentary and/or rocky) and its wave exposure. It is where all types of deposits tend to occur. In the case of pollution, slicks tends to be deposited on the upper foreshore under the combined influence of waves, tide and wind. However, at sheltered sites, slicks can be deposited on any part of the foreshore•;
- the backshore: although located above the spring high water level, the backshore can occasionally, in the event of a severe storm, be affected by pollution (airborne particles, sea spray, patches).

Depending on the nature of the shore and its exposure, the respective lengths of these three zones will vary.

Shoreface



Sloping foreshore•



Flat foreshore•

Pollution on the backshore

The hydrodynamic and morpho-sedimentary relationships within this trio define what is known as the beach system, i.e. the area within which longshore and cross-shore sediment movements, even in the case of large quantities, occur without jeopardising the beach's overall sediment balance. For example, after major natural episodes of erosion, which can sometimes cause the beach to "disappear", the sediment naturally returns to the upper beach because it has remained within the system. This is no longer the case if the sediment has exited the system, by migrating either to great depths or beyond the physical boundaries of the beach — past a headland, for example — into a neighbouring system where it is then deposited. In this case, if there is no new source of sediment input, the sediment budget of the system is imbalanced, a situation that can lead to coastal erosion.

Shoreline classification

Based on the conventional categorisation of temperate shoreline substrates into rock, boulders, cobbles, pebbles, sand, mud and marsh, it is possible to define several types of coastal facies, taking into account the degree of exposure to hydrodynamic forces (wave-beaten vs sheltered mode). Table 1 presents this classification. It summarises the main environmental characteristics (physical and ecological) of the different types of coastline and briefly describes how the pollutant is trapped, its fate and its potential impacts.

In addition to this classification based on physical criteria, it is also important to apply an ecological sensitivity and vulnerability classification. We strongly recommend consulting the following publication: Impact Reference System: Community Information System for the Control and Reduction of Pollution (European Commission, Directorate General Environment, Jacques, T., O'Sullivan, A., 2004).

Exposed sites

	Characteristics	*Oil behaviour and impact*
Cliffs and rocky headlands		
	- vertical or steep cliffs - very narrow intertidal zone, generally free of sediment - plant species absent from the foreshore but dense in the subtidal zone - reduced number and variety of animal species on the foreshore - often shelter large bird colonies	- most often kept away by wave movements - rapid self-cleaning due to wave energy except sometimes for oil deposited during storms above the high tide line - limited ecological impact, except for birds and close subtidal flora and fauna in the case of (naturally or chemically) dispersed pollutant
Wave-cut platform		
	- platform or rock bench formed by marine erosion in the widest sense - intertidal zone of varying width - coastal hinterland, either low-lying or highly elevated - possible accumulation of boulders, cobbles, pebbles and coarse sediment on the upper beach - surface may be very irregular (cracks, rock pools) meaning that fine to coarse sediments may be deposited in the crevices - ecologically rich and diverse	- does not stick, or not for long periods, to exposed rocky surfaces - tends to accumulate on the upper foreshore and in sheltered areas (dips, rock faces...) - likely incorporation of sediment (with variable persistence) - variable impact according to the ecological richness and the levels reached
Port structures and coastal defences		
	- steep or vertical hard walls of the most exposed structures in ports - usually smooth stonework - very limited to no ecological value	- oil is most often kept away by wave movements - can only stick to the upper parts of structures, above the high tide level - low persistence - little to no ecological impact
Riprap		
	- riprap which is constantly in contact with water: large boulders and tetrapods used to shelter jetties, breakwaters, reclaimed land; varies from very ecologically rich (crustaceans) to little ecological importance - riprap positioned on the upper beach and subject to considerable erosion; not ecologically rich	- often traps oil: high level of penetration, high risk of subsequent release of oil

Exposed sites

	Characteristics	*Oil behaviour and impact*
Boulder fields		
	- cover exposed rocky outcrops - often conducive to thin deposits of fine to coarse sediments, in the sheltered area at the base of the boulders - variable ecological density and diversity according to exposure	- generally kept away by the effect of turbulence - can only adhere to the upper parts of boulders and outcrops (above the high tide level) - persistence: low to high (if oil cannot be reached by the sea) - variable ecological impact according to richness and type of oil
Fine-grain sand beaches		
	- generally vast foreshores with a large area uncovered at low tide and often bordered with dunes or protective walls to prevent erosion - hard-packed ground - moderate to limited density of fauna and varies greatly according to the season	- accumulation on the upper foreshore or over practically the whole beach, according to the extent of the pollution - limited infiltration (* 10 cm), especially in the case of ground water emergence, but possibility of burying due to beach growth (20 to 30 cm, or a lot more at the beginning of the beach growth stage) and by wind-borne sand - effective natural cleaning with the first storms - low to moderate ecological impact, with a short duration, except for vegetation on the upper beach (at the foot of the dunes)
Coarse-grain sand and gravel beaches		
	- moderate to steep slope - very mobile sand - limited ecological diversity and density	- high infiltration potential - possible rapid and large-scale burial (fluid oil) due to seasonal beach growth or a storm; potential gradual migration towards the lower beach (leaching by ebb tide•) - low to moderate ecological impact
Pebble beaches		
	- in rocky coves at the foot of cliffs or in exposed bays and coves protecting low-lying hinterland - generally well sorted sediments, at least locally homogeneous distribution - steep (upper beach) to moderate (mid beach) slope, proportional to the average grain size - variable degree of ecological richness (flora, nesting birds at upper levels)	- high degree of infiltration especially in the coarser sediments (50-60 cm, or even 1 m or more) with slow breakdown of the oil - possibility of burial (1 m and more) due to beach growth on the upper foreshore - possible formation, in the long term, of hardened deposits (heavy fuel oil) in sheltered areas - relatively low persistence (intensive washing) but can be high in the case of buried oil or large-scale infiltration - limited ecological impact except at high and very high levels of the foreshore

Sheltered sites

	Characteristics	Oil behaviour and impact
Sheltered cliffs		
	- steep cliffs such as fjords or Mediterranean "calanques" - very small, steep intertidal zone• - ecologically rich (subtidal and intertidal)	- deposits in strips - persistence of the oil mainly on the upper part, not permanently in contact with the water - variable impact according to levels
Platforms and rocky outcrops		
	- generally scattered, or even covered, with boulders and unsorted, very heterogeneous finer sediments (from broken stones to mud) - extension of a low or steep rocky coast, or sometimes a small crumbly and eroded cliff, with clastic fossil deposits - numerous crevices, cracks and rock pools• - great variety of species and ecologically rich (abundance, diversity)	- deposits over the whole foreshore• but the oil deposited on the lower beach, generally saturated with water, is moved up the beach with the following tides - strong tendency to infiltrate through cobbles and boulders, less through smaller sediments; concerns the surface layer made of the coarsest sediments; practically impermeable to oil from below due to the presence of fine to very fine sediments - high persistence• in sediments and crevices - very high ecological impact
Port structures		
	- sheltered parts of all types of structures in ports and harbours (quays, riprap, etc.) - generally steep to moderate slope - smooth, rough or chaotic surfaces - often colonised by seaweed	- particularly conducive to accumulation - oil is deposited with the falling tide at high levels in the form of strips - oil released in the long term - ecological impact varies according to the sensitivity of the species affected (of which some have already adapted to a chronically polluted environment)
Fine- to medium-grain sand beaches		
(a)	Narrow sandy foreshores• with good bearing capacity	- moderate to high persistence• of the oil especially in the case of large initial deposits with the formation of hardened crusts on the beach's surface - very limited possibility of oil being buried (except by wind-borne sand) - possible deposit on the whole foreshore• (fluid pollutant) - in principle limited infiltration due to the presence of very fine sediments, and saturation with water, but risks of penetration via animal burrows - high persistence• (several months or years) - moderate to high ecological impact

Sheltered sites

	Characteristics	Oil behaviour and impact
Fine- to medium-grain sand beaches		
(b)	Generally very wide muddy/sandy foreshores• possibly with tidal channels, and with low to good bearing capacity	- can be deposited in different places on the foreshore• but ends up moving to the upper beach - infiltration impossible on sediments saturated with water (except via animal burrows) - very severe ecological impact
Mixed beaches with fine- to coarse-grain sand and pebbles		
	- deposits of heterogeneous sand, mainly from local sources, due to erosion or reworking of crumbly cliffs - irregular profile and surface - generally narrow foreshores• or upper part of very wide foreshores• with fine-grain sediments	- limited infiltration due to the presence of very fine sediments in the spaces between the gravel and pebbles - formation of hardened crusts in the long run in the case of major deposits especially on upper beach - very high persistence• - potentially high ecological impact
Mudflats		
	- Made up of fine to very fine sediments (silt, clay) and free of vegetation but with colonisation in the long term - ground almost constantly saturated with water - ground with very low bearing capacity - generally has a network of tidal channels - very ecologically rich (diversity, abundance)	- does not adhere to the water-saturated mud - tends to accumulate on the upper beach - mixture with the mud only possible before settling (in the case of high turbidity or a storm during the pollution) - ecological impact can be very severe - very high persistence• if incorporated into the mud
Marshes		
	- located at the apex of bays, sheltered by relief (spit or bar) on the banks of an estuary - vegetated areas with clearly marked belts of species according to their tolerance in terms of frequency of immersion and level of salinity - ground generally has a low bearing capacity and is sensitive to trampling (deconstruction, erosion) - generally bordered with mudflats - very ecologically rich (diversity and abundance) and important - very fragile and sensitive	- extent of spreading varies according to tidal cycle - high adherence to plants - tends to be deposited on the upper stratum then run down towards the base of the plant - if fluid, can penetrate the substrate via animal burrows and tunnels - impact by smothering (heavy oil) or by direct toxicity (light oil) - potentially severe ecological impact, but variable according to the species, season and oil - very high persistence• in the case of infiltration of the substrate

Table 1: Shoreline classification: oil behaviour and impact according to the physical characteristics of the shoreline

The pollutant

The definition of clean-up techniques, the choice of equipment and the organisation of worksites will depend heavily on the characteristics of the pollution.

Over and above the volume spilled, several factors will affect the form of oil deposits on the coastline, such as:

- the characteristics of the pollutant: principally its viscosity and its tendency to adhere to surfaces, both of which depend on the nature of the pollutant but also its evolution in the marine environment;
- the characteristics of the coastline: i.e. the nature of the substrate, the site's morphology and exposure, the presence of various types of debris on the coast, the season or more precisely the stage in the coastal sedimentary cycle;
- the prevailing sea and weather conditions, in particular the sea state and the temperature.

This wide range of parameters explains the different appearances of oil when it is washed up on the shoreline and emphasises the importance of surveys and pollution assessments in order to identify the priority sites for clean-up operations and to define the most appropriate response techniques and equipment.

The type of pollutant and its evolution

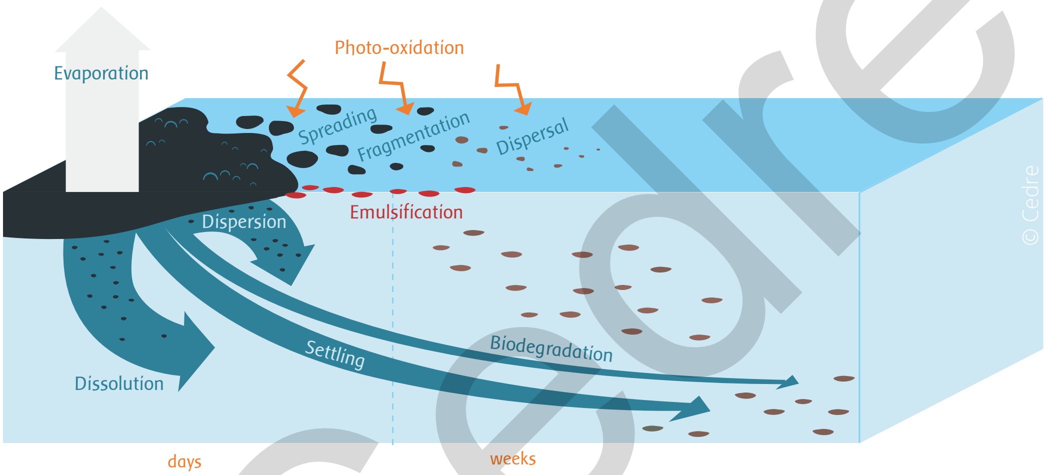
Crude oils and refined products are mixtures of oil and various other components that have a significant influence on their behaviour, fate and impact, as well as on the choice of response techniques.

When spilled at sea, oil undergoes various processes that bring about changes to its general appearance and its physical and chemical characteristics. These processes are mainly:

- **spreading,** which is the most significant process immediately after the spill and depends on the viscosity of the oil;
- **evaporation**, which will affect a varying proportion of the spill, depending on the type of oil, from almost the entire spill to an insignificant share;
- **emulsification**: micro-droplets of seawater can be incorporated into the oil, in variable quantities (up to 70 or 80% of its initial volume), depending in particular on its asphaltene content; emulsified oil resembles "chocolate mousse" and is more viscous and can be sticky;
- **natural dispersion** (a trend that varies greatly depending on the type of oil), which exposes organisms in open water and on the seabed to concentrations that can be lethal;
- **dissolution**, which mainly concerns aromatic fractions, which are the most toxic, and can have a significant ecological impact in the water column; it concerns some of the same fractions as evapora-

tion, with one or other of these phenomena becoming predominant depending on the conditions;
- **settling**, which is a long-term process in which some of the oil sinks to the bottom;
- **natural degradation** of the oil.

These evolutionary processes do not all occur at the same time, for the same duration, or with the same intensity.



Fate of the pollutant

Oil classification

Given the multitude of petroleum products that exist, a simplified classification into a limited number of categories is required. The proposed four-category classification (highly volatile oils, light oils, medium oils, heavy oils) is based on the pollutant characteristics that significantly influence the choice of response strategies and techniques, primarily viscosity and the tendency to adhere to surfaces.

The fate and effects of oil vary according to its nature and its evolution at sea. Table 2 puts forward a classification of oil products according to their behaviour and impact on the shoreline.

Oil type	Behaviour	Impact
Highly volatile oil (kerosene, petrol, distillates)	- low viscosity - complete evaporation in 1 or 2 days or even less - very rapid spreading - tendency to naturally disperse	- high capacity to penetrate/infiltrate substrates - very high toxicity in the water column and on the foreshore• (very high proportion of soluble aromatic fractions)
Light oil (diesel, home heating oil, marine diesel, biodiesel, light crude oil)	- low to moderate viscosity - relatively rapid evaporation, can concern 2/3 of the initial volume after a few days - rapid spreading - moderate solubility	- variable capacity to penetrate substrates - high persistence• - variable toxicity according to the proportion of soluble aromatic fractions but can be high to very high - possible long term chronic effects
Medium oil (most crudes, light lubricating oil, refined residues)	- moderate to high viscosity - moderate evaporation (1/3 in 24h) - moderate spreading - low solubility - high tendency to form stable emulsions ("chocolate mousse") - tendency to sink after weathering or adherence to fine particles	- variable capacity to penetrate substrates according to the porosity and particle size - very high persistence• - high impact (direct toxicity, coating, smothering) - possible chronic effects
Heavy oil (heavy crude, heavy fuel oil, heavy residue, weathered emulsion)	- high to very high viscosity - little to no evaporation - little to very little spreading - very low solubility - potential emulsification - very slow alteration - possible refluidisation in the sun	- major accumulations on the foreshore• - high to very high persistence• on the upper foreshore• - high impact (smothering, coating) but low toxicity to non-toxic for semi-solid products
VLSFO/ULSFO (Very/Ultra Low Sulphur Fuel Oil)	- moderate to very 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	- variable capacity to penetrate substrates according to viscosity - high to very high persistence• on the upper foreshore• - high impact (smothering, coating) but low toxicity to non-toxic for semi-solid products

Table 2: Classification of oils according to their behaviour and impact on the shoreline

Types of deposits

The oil will reach the coast in various forms, which can be classified as follows:

- **large-scale oilings**, in the form of relatively thick, uniform slicks (several mm to several cm) or slicks spread more or less continuously over a large surface area (several hundred m²); on hard vertical surfaces, the oil forms a horizontal band.
- **scattered oilings**, which can vary in appearance and can be divided into two main categories depending on whether they:
  - are deposited on the surface in the form of:
    - patches several millimetres thick and more than one metre in diameter;
    - patties with a diameter of less than one metre;
    - tarballs with a diameter of less than 10 cm;
    - trails or ribbons of oil representing small quantities deposited along the high-water mark as the tide goes out;
    - brownish, airy foam or scum deposited on highly exposed foreshores•, generated by intense mixing, due to wave action, of sheen (heavy or light) that has been driven towards the coast. This foam only represents a very small quantity of oil;
    - stains, smears or speckles caused by oil being projected onto hard surfaces;
    - sheen (on water) or oily film on the foreshore•.
  - have penetrated into the substrate (or been naturally buried) in the form of:
    - a layer of oiled sediment, either on the surface or covered by clean sediment, varying in thickness from a few centimetres to several tens of centimetres;
    - relatively thick (0.5 to 10 cm) alternate layers of oil/oiled sand and clean sand, over a variable depth.

The oil can also be deposited on various natural or anthropogenic• debris/litter or become trapped in large volumes of plant matter deposited on the shoreline (seaweed, eelgrass, seagrass).

Pollution surveys

Surveys constitute an important stage in the response process, as they offer a relatively accurate assessment of the extent of the pollution, and thus enable the response effort to be organised in an appropriate and rational manner.

The aim is therefore to gather as much relevant information as possible in a relatively short timeframe in order to meet these two objectives. To do so, it is strongly recommended that observers are trained to ensure that field observations are reported in an appropriate, consistent format (digital or paper forms), keeping inaccurate, and therefore unreliable, subjective observations to a minimum.

FOR MORE INFORMATION

Procedures for conducting surveys are detailed in a specific guide produced by Cedre:

"Surveying Sites Polluted by Oil" Operational Guide

A3

The response

Response on the shoreline involves a number of actions:

- prior measures taken before the spill reaches the coast to limit the spread of the pollution, in particular by protecting certain sensitive sites (in addition to deploying containment booms) and mitigating the impacts, particularly onshore, of response operations;
- site clean-up;
- worksite management, including personal safety measures, site security, organisation and monitoring of operations, including the immediate management of recovered waste (evacuation and storage on the upper foreshore or nearby).

Shoreline response therefore consists of a series of closely interlinked operations that must be compatible. The notion of a worksite encompasses all these operations; the different tasks must be perfectly organised in order to ensure an efficient worksite.

Clean-up phases

In the event of heavy pollution, clean-up begins with phase 1 or initial clean-up operations, followed by phase 2 or final clean-up operations.

Initial clean-up (phase 1)

This initial phase involves removing, as a priority and as rapidly as possible, large accumulations of oil and various oiled materials (floating debris, seaweed etc.). The aim is twofold:

- to limit the spread of the pollution, by mitigating the risks of stranded oil being remobilised, by the sea or wind, and
- to curb the ecological impact, by reducing the time for which the oil is in contact with the environment, as well as of course using techniques that are the least harmful for the environment.

Final clean-up (phase 2)

Final clean-up fulfils the need to restore sites for their previous uses and to enable the affected environment to recover normal ecological functioning. This phase should not begin until the bulk of the oil has been removed and all threats of major new deposits has been eliminated. This involves deploying techniques with a varying degree of sophistication to remove residual oil which is detrimental either to economic or leisure activies, or to the ecological or the landscape function of the affected sites.

Choice of techniques

Each case of pollution is unique and there is no miracle technique or cure-all solution. However, there are basic clean-up principles that can be adapted according to the situation and how it evolves.

There exists a wide range of techniques available for responders to implement each of these two phases. They differ according to:

- **the spill characteristics:** its extent (volume), whether it is scattered or concentrated in space or time, the nature of the pollutant (viscosity, adhesion, persistence) and the types of deposits (slicks, tarballs, buried oil, etc.);
- **the site characteristics:** its accessibility, exposure, the nature of the substrates, the presence of debris, etc.

In some cases, clean-up requires technical worksites to be set up, necessitating specific equipment and skills; it is preferable in terms of efficiency, safety and possibly environmental preservation to contract specialised clean-up companies.

The different types of shores are generally divided into 3 main categories—based on similarities in terms of environmental sensitivity, how the oil is trapped and the clean-up techniques to be used—according to the nature of the dominant substrate:

- sediment beaches (sand and pebbles),
- hard substrates (rocks, boulders and port or erosion defence structures),
- intertidal areas colonised, or in the process of being colonised, by higher plants (mudflats, marshes and estuary banks).

Response organisation

Those in charge must have a **constant overview** of the situation in terms of changes to the oil (viscosity, weathering), the pollution (spread, release, new deposits), sea and weather conditions and, of course, clean-up worksites (required and available equipment and logistics). Based on this information, they are able to (re) define the response priorities and ensure that the chosen techniques are compatible with the available resources and the timeframe.

Clean-up operations

The **quality of the response** will depend on:

- the predefined organisation and its implementation;
- the available resources;
- the people involved, at different levels, both for decision-making (authorities) and in the field (expertise, supervision and implementation). An efficient response means having the right people with the right equipment in the right place at the right time. This requires training and experience, but also a sense of anticipation, initiative and adaptability. With the same equipment, two teams can achieve very different results;
- the teams' working conditions.

The **health and safety of response teams** is the number one priority. The health risks associated with the toxicity of the pollutant, extreme temperatures, harsh weather conditions, working in dangerous environments (at heights or near water) or with certain equipment must be constantly assessed. Personal protective equipment suited to the exposure to these risks must be provided. The best possible health and safety conditions, adapted according to the site environment, must be ensured (balanced meals, drinking water, hot drinks; decontamination area; breaks, shelters and toilets in the uncontaminated zone, etc.).

Potential impacts of the response

Response operations can cause greater harm to the environment than the presence of the oil itself. The **impact of clean-up techniques** must therefore be as low as possible (and most importantly lower than that of the oil alone).

At certain ecologically sensitive sites, it is sometimes preferable to **"do nothing"** and let nature do the clean-up work: this is the case, for example, for light pollution in a marsh. The same applies to certain lightly oiled wave-exposed sites, particularly in winter.

If, due to poor choice or lack of expertise, a clean-up operation is poorly suited to the site or spill characteristics, or if it is poorly implemented, it can have harmful effects on the environment. It is therefore important that operations are defined by technical and environmental experts.

In addition, in order to avoid transferring the pollution to land and to keep further impacts to a minimum, it is important to take specific precautions, in addition to the precautions required for certain techniques, in relation to worksites, storage sites, access points and routes, in terms of their selection (absence of rare or protected plants) and protection (waterproofing, channelling, decontamination site, etc.).

Clean-up endpoints

The **level of clean-up** required mainly depends on the site's ecological sensitivity and its socio-economic uses (industry, fishing, aquaculture, tourism, leisure, nature, etc.). These two aspects, which also dictate the priorities, or even the need for clean-up at all, fluctuate tremendously with the seasons.

It is now widely accepted that, in the event of a spill, the first question to answer is whether or not it is appropriate to implement response operations, which means carefully assessing the advantages and disadvantages of any possible strategy or technique and considering natural cleaning as a potential solution.

In the event of a major to moderate spill, the bare minimum consists in removing the oil wherever and whenever this is technically and ecologically possible and economically acceptable. Whether the oil is floating or deposited, the fact that it may be remobilised makes it a potential source of (re)contamination; it is therefore a hazard for the environment in the broadest sense. The lower this risk is perceived to be (or as it diminishes), the more we must question the need to respond (or to continue to respond).

The aim of response operations is not to attempt to remove all traces of oil, but rather to provide the most favourable conditions for the environment to return to normal functioning in the long term, while allowing local socio-economic activities to resume. This means that, at the end of the clean-up process, some oil may remain but at concentrations that will no longer disrupt the functioning or recovery of the biotope, or the socio-economic uses of the site.

It is essential to have solid knowledge of response techniques in terms of their efficiency and their potential impact (physical, biological) on the environment.

Decision-making

Spill response should aim to accommodate both ecological and socio-economic constraints, however there are often diverging interests which can be sources of conflict. The different stakeholders must therefore accept the fact that, in most cases, an optimal response cannot overcome all drawbacks.

Should clean-up be conducted? When should it be stopped? Opinions on these points naturally tend to diverge between the polluter, the insurer, victims, politicians, scientists, ecologists, the media, the general public, etc. The solution most often resides in seeking a consensus between the different operators on what is acceptable in terms of pollution from an ecological, economic and political point of view, and what is feasible in terms of clean-up from a technical, financial and ecological point of view.

It is therefore necessary to define an organisation that will take into account all the opinions and concerns of the people and organisations affected by the spill, in particular by:

- **seeking the best technology available**, drawing on past experience and technical and scientific knowledge;
- **setting up advisory, assessment and control committees**: technical committees put forward technical response recommendations, monitor the pollution and control the implementation of decisions. Committees with a more local and political remit validate the decisions made by the technical committees, particularly with regard to the achievement of agreed objectives;
- **implementing survey, monitoring and control procedures**.

Worksite visit

Once the aims and limits of the response have been established, the clean-up techniques defined and accepted, and responder safety guaranteed, clean-up operations can begin.

Response: what to do

Shoreline protection techniques (other than booms)

Time and circumstances permitting, certain measures should be taken before the oil reaches the shore, so as to facilitate subsequent clean-up operations on the shoreline and to reduce the potential impact.

This section covers all protection techniques other than containment booms* that will:

- limit the spread of the pollution, by setting up various systems;
- protect channels and streams: straight nets, filter dams, sealing with an earthen bund, with or without flap gates, or with sand-filled big bags•;
- remove oil from the water on the foreshore• (mop nets, sorbent pom-poms on a floating rope for example);
- cover the substrate (protective sheeting);
- reduce the volume of waste, by collecting litter and natural elements washed up on the shore (seaweed, posidonia, eelgrass) or at least moving them to beyond the reach of the sea.

FOR MORE INFORMATION
*For protection techniques using containment booms:
"Manufactured Spill Response Booms" Operational Guide

B1

Protecting channels and streams

The idea of closing off **channels and streams using containment booms** is generally illusory due to strong currents sweeping across their entrances. However, in the case of viscous pollutants, certain systems across channels can be devised to prevent or at least limit upstream pollution.

The system installed will vary according to the size of the channel; some of the main options are:

- ballasted straight nets or vertical filtering geotextiles for small channels ▶Tech Sheet P 01
- custom-made filtering barriers for larger channels; such systems require ongoing maintenance and have a limited lifetime ▶Tech Sheet P 01
- dams made of earth and other materials, which are more effective but more complex and costly to build ▶Tech Sheet P 02
- filtration units at water intakes for salt or aquaculture ponds for instance ▶Tech Sheet P 03

To ensure such protection solutions are effective, a series of these systems is generally constructed at different points along the channel and at different heights in the water column.

The references "▶Tech Sheet XX" found in this section refer to the descriptive sheets in the third section of this guide.

These systems are high maintenance (to ensure durability and when removing the trapped oil and oiled materials).

Filtration units

Filter barrier

▶Tech Sheet P 03

Sophisticated systems can be designed and adapted according to the characteristics of the water intake (dimensions, flow rate) and the quality of filtration required, depending on the sensitivity of the facility (oyster, salt or aquaculture pond).

The basic system for an individual water intake with a diameter of 20 to 50 cm is a filter cartridge composed of a mesh casing (metal wire or plastic netting) designed to fit the size and shape of the water intake. This casing is filled with materials with filtration and sorption capacities suited to the risks (straw, crushed oyster shells or polypropylene sorbents). To prevent clogging of the filtration unit (litter, seaweed, etc.), a net should be installed in front of the water intake.

Capturing oil in the water from the lower foreshore

Oil floating on or below the surface can be trapped in the water column, to prevent it from washing up on the shore, using fine-mesh nets installed in a feathered position on the foreshore•.

Mop nets ▶Tech Sheet P 04 are low-cost fine-mesh nets (scaffold, hail or potato netting) that are anchored at one end on the foreshore• to capture clusters of viscous pollutant drifting at high tide. This recovery system was developed during the *Erika* spill, and was used in addition to surfwashing• operations (see initial clean-up ▶Tech Sheet N 10).

The use of this technique during the *Erika* spill showed that it is effective for short-term operations (a few tides) as a curative measure (associated with surfwashing•) or as a preventive measure (on a newly cleaned site, to capture any tarballs from other sites that are still contaminated). Under these conditions (short timeframe and relatively small area), it is easy to install the nets according to the prevailing tidal characteristics and to ensure the necessary maintenance: replacement of oiled nets, repositioning according to the tide, checking nets are firmly attached, etc.

The experience of the *Prestige* spill, on the other hand, has shown that this technique is unsuitable as a large-scale, long-term protection strategy (at least on tidal coasts), and is even less effective if the pollution is very scattered and is washed up haphazardly. As a protective technique, it should be reserved for small beaches or coves that are inaccessible to vehicles, or on beaches that are poorly suited to the use of beach cleaners (e.g. strewn with shellfish debris or pebbles on the upper beach). On large sites with dunes, they should only be installed in areas of oil accumulation (e.g. groynes). On a microtidal• coastline (with no tides or a very low tidal range), two techniques can be used: shorter nets attached to a floating rope positioned a few metres from the water's edge, or, as implemented during the *Deepwater Horizon* spill (2010), a floating rope fitted with sorbent pom-poms held in place at the water's edge using stakes.

Trapping oil using mop nets

Protecting the upper foreshore with plastic sheeting or geotextile

▶Tech Sheet P 05

The upper section of a site (beach, cove, riprap or quay) can be temporarily protected by wrapping or covering with plastic sheeting or geotextile. Any deposited oil can be scraped off or subsequently removed together with the protective lining.

On beaches, this process is primarily applied to mesotidal• and microtidal• shores. On quays, it is particularly useful on sites with a risk of oil pollution (quays, terminal, etc.).

It is a temporary protective measure which, in order to be effective, must be constantly maintained (checking that it is securely attached and watertight, remplacement of any torn sections, etc.).

This technique can also be used temporarily on a cleaned site (high-level riprap, for example), if there is a risk of more oil reaching the site.

Removing litter and natural debris

Before the oil reaches the shore, it may be worthwhile removing any litter and natural debris from the beaches, especially if there are large quantities. The aim of this operation is to reduce the quantities of oiled materials and to facilitate initial clean-up operations. Depending on the amount of litter and debris present, it may be collected manually, with mechanised support for evacuation, or mechanically using earthmoving equipment with forks or grabs (particularly for large items such as tree trunks or logs) or open-work buckets, or using specialised machinery such as raking or sifting beach cleaners•, seaweed rakes, etc.

The collection process must of course be as selective (without removing sand) and methodical as possible, to meet the eligibility criteria for the different recycling and recovery streams (wood, plastic, glass, seaweed). Natural debris can sometimes, if the site permits, simply be brought up to very top of the beach so as to be temporarily out of the reach of the oil, and later be brought back down the foreshore•.

Phase 1: initial clean-up

There exist different techniques for recovering the bulk of the pollutant, whether it is still floating at the water's edge or washed up on the shoreline. The most commonly used and most effective techniques are as follows:

- pumping, either directly or by skimming, of slicks and patches that are floating or have washed up, operating from the shore using skimmers, pumps and vacuum systems;
- mechanical collection on the beach, using conventional equipment (earthmoving equipment) but also specialised equipment;
- manual recovery.

The initial clean-up phase can include other techniques, with a lower recovery rate, in particular the dislodging of clusters of trapped pollutant, either using low-pressure water jets (a technique known as flushing•), or by moving heavily oiled pebbles down the beach into the surf zone (a technique known as surfwashing•).

On water, specialised equipment, such as oil skimmers, is often used to recover the pollutant. This is generally not the case for recovery on the beach, which is usually carried out using traditional equipment commonly used in other fields, for instance for public works, agriculture or wastewater treatment.

However, certain devices have been adapted or developed to ensure good selectivity and a high recovery rate.

Finally, manual collection remains essential, whatever the scale or type of pollution, and may be the only possible option for certain sites that are difficult to access or ecologically sensitive.

Skimming, pumping and vacuum systems

Vacuum truck

Skimming•, pumping and suction are the main recovery methods in the case of a spill of a fluid pollutant ▶Tech Sheets N 02 and 03

These techniques involve equipment that is generally used in agriculture, wastewater treatment and public works. However, specialised equipment also exists.

These operations encompass both the actual collection of the pollutant and the transfer of the collected products, via an integrated tank or a discharge line, to a primary storage facility located at the top of the beach or in the immediate vicinity.

Pumping is not always possible. Various factors determine the feasibility of this technique, as well as the equipment and procedures:

- the **nature of the pollutant**, in particular its viscosity: a fluid product is pumpable, a viscous product much less so, if at all;
- the **agitation** of the water body, which reduces the recovery rate and selectivity and often prevents the equipment from being deployed;
- the **size of pollutant accumulations**, and more specifically their thickness. The thicker the slick, the more efficient and selective the recovery operation will be. The pollutant should therefore be contained and channelled towards the suction heads. Various techniques can be used for this, both at the water's edge (using a light worksite boom and hoses, for example) and on the foreshore• (by scraping towards a collection point or using hoses, for instance);
- the **presence of solid debris**, which can hinder the supply of oil to the pumps or even damage them;
- the **site morphology**, such as any height constraints or simply the possibilities it offers in terms of access, deployment or movement;
- the **storage capacities** that can be brought on site or created (pits, etc.) in the immediate vicinity.

Different equipment may be used, depending on whether the pollutant is floating in the open water or next to the beach, or whether it has washed up on the shore.

Skimmers

Skimmers are specialised devices designed to skim the pollutant from the surface of the water. They are composed of a floating skimming head and a pump.

Skimmer and integrated pump during trials at Cedre

There are different types of skimmers, divided into two main categories according to their operating principle: mechanical skimmers and oleophilic• skimmers. Mechanical skimmers are less selective and are better suited to working with viscous pollutants, while oleophilic skimmers are more effective on fluid pollutants. Oleophilic• skimmers are more selective, meaning that smaller storage capacities are required than in the case of mechanical skimmers, which, on the other hand, have higher recovery rates.

Pumps

The pump can either be integrated in the skimmer or separate. Pumps can also be used with a simple floating suction head or even a simple flat fan-shaped nozzle.

Different pumps operate based on different principles; some work well with fluid oil products without solids, while others are compatible with highly viscous pollutants, possible containing solids (sediment, debris a few centimetres in diameter, seaweed). In coastal areas, the most commonly used types are screw pumps, lobe pumps, peristaltic pumps and eccentric rotor pumps (Moineau principle). The pumps are powered by a thermal, hydraulic or pneumatic power pack designed to allow a certain degree of mobility. On the beach, fitting a pump to the power take-off shaft of a tractor equipped with a three-point linkage will make the recovery system more readily mobile.

Vacuum systems

Vacuum systems operate by suction thanks to the vacuum created in the reception tank.

The end of the suction hose is immersed in the liquid to be pumped. To be selective, the suction nozzle must be kept immersed just below the surface of the oil: if it is immersed too deeply, it will only suck up water; if it is not immersed deeply enough, it is likely to take in a lot of air which will ultimately "break" the vacuum. These systems should therefore only be used on slicks that are thick enough (implement containment and feeding). It is strongly recommended to connect a floating suction head and fit the vacuum system with a manual control valve.

Direction suction of a slick

- **Conventional vacuum systems**. Conventional systems from the agriculture or water treatment sectors are often used. During the *Amoco Cadiz* spill for instance, hundreds of slurry tankers were deployed on Brittany's beaches. Vacuum sanitation trucks, which are less robust and less mobile on beaches, are sometimes used.

Direct suction and settling in a sanitation truck

- ✓ autonomy and versatility: can be used for pumping, storage, settling and transfer;
- ✓ very readily available: rapid mobilisation of trucks and, to a lesser extent depending on the region, of farm machinery (especially in pig and cattle farming regions);
- ✓ high suction rate, average suction height of 5 to 6 m;
- ✓ tolerance to small solid debris (however, in the case of viscous substances or a high proportion of solids, choose vacuum trucks that can be opened to be emptied);
- ✓ little or no increase in the emulsification of the pollutant;
- ✓ possibility of injecting an emulsion breaker•;
- ✓ possibility of primary separation (evacuation of free water on site inside a boom, for example, after a few minutes of settling).
- ✗ use limited to sites that are accessible to tractors; even more limited access for trucks;
- ✗ efficiency reduced due to downtime required for settling and releasing water;
- ✗ slow return to optimal operating pressure when a lot of air has entered the system;
- ✗ low selectivity (significant proportion of water collected with the oil) except in skimming mode;
- ✗ suction hose difficult to handle (rigid, heavy), especially when oiled.

- **Specialised vacuum systems**. Various types of vacuum systems have been specially developed for spill response applications: vacuum tanks mounted on a chassis, with or without wheels, generally equipped with a floating suction head (selectivity) and a transfer pump to discharge the recovered mixture. These systems are relatively heavy and their use is generally limited to certain accessible sites with a good bearing capacity (such as quays).

Pneumatic conveying systems

The operating principle of pneumatic conveying systems is based more on the creation of a very high flow rate and high velocity air flow than on vacuum. This air inflow is created by a vacuum unit. The vacuum initially generates suction, but it is the flow that transports the oil, water and debris to the system's reception tank.

- **conventional pneumatic conveying systems**. On these vehicles, such as sanitation or industrial cleaning trucks, the suction hose is large enough (diameter of 125 to 300 mm) to make it virtually impossible for the pumped products to block it. Air flow must be present at all times for the system to work; the suction hose must therefore always be held slightly above the oil, and never be immersed, so that air can always enter the hose.
  - ✓ good efficiency on all viscosities of oil (simultaneous suction of water appears necessary for highly viscous products);
  - ✓ tolerance of virtually all types of debris;
  - ✓ little or no increase in the emulsification of the product;

- ✓ greater suction height than any other suction system (over 10 m); some units used for cleaning out the bilge of a vessel have a suction height of 25 m;
- ✓ autonomy and versatility: can be used for pumping, storage, settling and transfer;
- ✓ possible primary separation by settling.
- ✗ large, heavy machinery that is difficult to manoeuvre and requires a good bearing capacity (truck);
- ✗ low selectivity;
- ✗ difficult to repair on site.

- **Specialised pneumatic conveying systems.** These systems are used increasingly often on the shoreline, as they are particularly well suited to recovering fuel oil and contaminated sediments between boulders and in riprap. They are either small industrial vacuum systems, which are very powerful but require a large-capacity pneumatic compressor, meaning that they cannot be deployed on certain coastal sites, or less powerful systems in the form of small mobile units comprising:
  - a vacuum unit;
  - a cyclonic head mounted on a receiving tank (an interchangeable 200-litre or, more conveniently, 50-litre drum) or on a cylindrical hopper fitted with a drain valve at its base and mounted on a tripod to sit on top of a receiving tank;
  - a suction hose fitted with a suction nozzle.

Double drum vacuum system

- ✓ selective recovery of oil and oiled debris washed up on the shore;
- ✓ possible use on sites that are difficult to access and to manoeuvre on (but be careful of the weight and bulk of the motor pump unit or compressor and the limited length of the pipes);
- ✓ no increase in the emulsification of the pollutant;
- ✓ all viscosities.
- ✗ low recovery rate in most cases (frequent stops to change/empty the reception tank).

Mechanical recovery using earthmoving equipment

►Tech Sheet N 04

Mechanical recovery

Conventional equipment—mainly earthmoving equipment but also agricultural machinery—is widely used in the event of an oil spill. Very widely available, robust and manoeuvrable even on difficult terrain, these vehicles perform several functions: collection and transfer from the beach of large quantities of pollutant and polluted materials, scraping of a layer of more or less fluid pollutant, excavation of clean sediment or support for manual operations.

- ✓ very high recovery rate
- ✗ low selectivity on moderate to low levels of pollution (the materials removed can have oil contents of < 5%)
- ✗ potentially high ecological impact: excessive removal of clean sediment; burial and mixing of the pollutant in clean sand; degradation of access points; destructuring then erosion of the substrate.

Two aspects call for particular vigilance:

Organisation: in order to be as selective as possible, drivers should be well informed and a traffic system should be set up to prevent the oil from being buried and spread by erratic traffic.

Safety: particular care should be taken to ensure site safety, especially given that during the initial clean-up phase not all the people on site are used to working in the presence of heavy equipment.

Direct collection

In the case of large-scale arrivals (particularly of slightly fluid to highly viscous products), heavy equipment such as front-end loaders can remove the pollutant directly at the water's edge with a very high recovery rate.

This equipment is ideally suited to direct collection, as long as the slicks are thick enough. However, very quickly, as the volume of oil decreases, their use becomes less appropriate as their selectivity decreases and excessive quantities of clean sediment are removed. At that point, they should then only be used to support more selective operations, such as manual recovery.

Other conventional equipment, such as agricultural machinery, is also widely used. These machines can collect seaweed or oiled debris, but also large clusters of viscous oil, thanks to a range of existing equipment that prevents the removal of large quantities of sand with the debris: perforated front bucket, mesh bucket, agricultural fork, stump grinder, etc.

When sites are cluttered with bulky floating debris (branches and tree trunks, drums, plastics, ropes, etc.), it is important to move them out of the reach of the pollution; very often it is worth conducting a specific removal operation before the oil reaches the shore.

Concentrating and scraping the pollutant

When the oil forms a more or less fluid layer deposited on the foreshore•, mechanical equipment can be used to concentrate the oil on the beach as a preliminary measure.

This operation involves scraping the oil layer on the beach, while removing as little sand as possible. Graders have often been used for this purpose in the past. Alternatively a slurry plane or loader whose front blade is fitted with a rubber edge to scrape less sediment can be used.

This type of operation can be conducted on beaches with firm saturated sand. On beaches with ripple marks, this technique is not sufficiently precise.

Evacuation

The loader can transport the contents of its bucket directly to a storage area on the upper beach if it is nearby; if the storage area is further away, the loader will load the contents into a suitable vehicle.

In the case of manual recovery operations, the collected waste can be loaded manually into the loader bucket, either loose (by shovel) or in packaged form, in bags or bins, which can then be emptied or deposited for transfer.

A range of different earthmoving or agricultural vehicles (tippers, dumpers, flatbeds, trailers) can be used, provided they are suited to the pollutant and the site. If the site is easily accessible and passable, 6x4 tippers or semi-trailers can be used, loaded by earthmoving equipment.

Mechanical recovery using specialised equipment

In order to overcome the limitations and drawbacks of both earthmoving equipment (potential ecological impact) and manual recovery (low recovery rate), attempts have been made to develop specialised machinery that would be effective in terms of selectivity and recovery rate, particularly for moderate to light scattered pollution.

On sandy beaches, two main recovery principles have been tested: sand screening and adhesion. The first most commonly involves the use of beach cleaners•; the second, using rollers, was widely employed during the *Prestige* spill (2002) on the beaches of Aquitaine. On rocks, there have been very few attempts to develop mechanical solutions. Those that exist mainly involve suction using small industrial vacuum systems. Scraping can also be carried out using a brush tool fitted with a vacuum system.

- ✓ good recovery rate and selectivity;
- ✓ relatively widely available (beach cleaners•).
- ✗ use limited to beaches with easy access and circulation;
- ✗ narrow window of use, limited to certain characteristics of the pollutant and the substrate which are not always encountered or are encountered for too short a timeframe;
- ✗ tendency to fragment oil clusters (beach cleaners•).

Beach cleaners•

▶Tech Sheet N 05

Beach cleaner•

These machines were developed several decades ago to remove litter and debris that had been washed up or left on beaches: cigarette butts, various types of plastic and glass packaging, plant debris, etc. There are a number of different models, ranging from large beach cleaners• (towed, mounted or self-propelled) to small walk-behind beach cleaners•. Most operate on the same principle: the surface layer of sand is removed by an adjustable (0 to 20 cm), sometimes vibrating, blade, then the sand is lifted (often by a rotating claw or pick-up device) onto an endless screening belt (with mesh sizes ranging from 15 mm to 28 mm) which sifts the sand, and finally the debris is deposited in a hopper at the end of the belt.

First tested during the *Tanio* spill (1980), these machines have proved to be very effective, on dry to slightly damp sand, at recovering clusters of viscous oil such as tarballs, patties and small patches, and only these, with certain adaptations to reduce the fragmentation of tarballs by the cleaners (e.g. removal of the pick-up blade, replaced with flexible flaps) and to improve selectivity (e.g. offsetting the belt's axis of rotation to facilitate screening). While the performance of different models varies, the quality of screening does not depend solely on the machine itself. The tractor, which requires certain characteristics (120 hp minimum, ability to operate at very low speeds, suitable tyres) and, perhaps most importantly, the driver, who must coordinate the appropriate settings (tractor speed and rotation speed of the pick-up and belt, working depth, etc.), play an equally decisive role.

Like all response equipment, beach cleaners• have their limitations and drawbacks:

- they are not suitable for sloping ground (jamming);
- they are ideal on homogeneous, fine-grain, dry sand, but not suitable for hard-packed, wet sand (oil clusters are crushed), for sediment that is too heterogeneous (poor selectivity, large quantities of sediment removed), or for coarse-grain sediment (bearing capacity and selectivity issues);
- they can have a potentially significant ecological impact if overused and especially if their use is not limited and supervised, particularly in certain sensitive areas (near the foot of dunes, for example).

Rollers

▶Tech Sheet N 06

The concept of the adhesion of clusters of oil to or within a specific coating also attracted a great deal of interest during the *Prestige* spill (2002), when different models of rollers were used to recover freshly deposited tarballs from beaches. Different models of rollers have been developed, in terms of their dimensions and the adhesion coating. The performance, advantages and limitations vary from one model to another.

These devices are mainly effective on fresh oil with little sand mixed in, and on hard ground (lower foreshore• , for example).

One of the very first rollers (covered with carpet) was built by Cedre in the early 1980s, but it never made it past the prototype stage. During the *Erika* spill (1999), a private company put forward another prototype, comprising a strip of geotextile and driven by a quad bike, but it was never properly put to use as it was finalised just as the arrivals of tarballs began to peter out. This illustrates the difficulties encountered by all these specialised devices, which have too narrow a window of use in terms of compatibility with the pollutant and the site to be developed industrially, except in particularly favourable circumstances, as was the case during the *Prestige* spill (2002), with tarballs (from the wreck) regularly washing up on the shoreline over a period of several months.

Oleophilic roller•

Manual recovery

Manual recovery operation

Manual recovery is unavoidable: it is carried out whatever the extent of the pollution, the type of pollutant or the type of site. It is often the main, or even the only, method used, particularly in the case of small-scale or scattered pollution, and it remains one of the key solutions in the event of an oil spill. Given its precision, low impact and flexibility, manual recovery can be preferable to mechanical recovery in the event of heavy localised pollution. Manual recovery is inevitably implemented wherever mechanical collection is not feasible, particularly at sites where access and circulation are difficult. Paradoxically, manual recovery is often remarkably effective on such sites, generally thanks to the organisation of a human chain. Generally speaking, however, and especially in the case of light, scattered or residual pollution, manual recovery operations have low recovery rates. ▶Tech Sheet N 07

- ✓ high flexibility
- ✓ very high selectivity
- ✓ limited ecological impact (but potential impact in marshes and mudflats)
- ✗ low recovery rate
- ✗ tiring work with slow progress
- ✗ large workforce required

Two aspects call for particular vigilance:

Organisation: define the different positions (containment, collection, evacuation, etc.), plan team rotations and organise mechanised support.

Safety/comfort: schedule breaks (rest, coffee), provide protective clothing suited to the pollution, weather conditions and extreme temperatures.

Concentration and collection

The pollutant is collected using a variety of tools that should be adapted to requirements. In order to keep sand removal to a minimum, shovels and other equipment should be angled at a tangent to the surface of the ground, and deep removal should be avoided as far as possible. For the same reason, the use of forks is recommended in the presence of oiled debris (vegetation or other). In the case of scattered pollution, the oil should be concentrated using rakes, brushes, leaf rakes, etc. The work may be facilitated by building makeshift tools (picks, forks covered with wire mesh, rock scrapers, etc.).

Oiled materials are deposited in piles or windrows•. In the case of low viscosity oil, these materials are herded, using a variety of brooms or swine manure scrapers for example, towards a collection point (in a shore-sealing boom, a bund• or a natural or dug-out depression) to carry out more selective recovery, possibly by pumping.

Oiled floating debris should be systematically collected as it causes the pollution to spread and can hinder the smooth running of other operations such as pumping or screening.

Evacuation

When the beach is accessible to earthmoving equipment and when quick action is required, the piles of waste may be collected by mechanical equipment (usually loaders), taking care to minimise the removal of clean sand.

Packaged waste (bags, bins, big bags•, for which precautions must be taken to avoid tearing and spillage) may be removed using light mechanised vehicles such as quad bikes, which are highly manoeuvrable, particularly on sites where tractors fitted with buckets, for example, cannot operate due to the accessibility or practicability of the terrain. Thanks to their drive wheels and low-pressure tyres, quad bikes can operate on ground with a low bearing capacity, even on sensitive sites (subject to certain rules, however: low speed, particularly when turning, compliance with traffic lanes, etc.). Otherwise, waste must be evacuated manually. To do so, it is packaged in plastic bags, bins or buckets, which are then transported by hand, on stretchers or on people's backs.

Other initial clean-up techniques

Flushing •

▶Tech Sheet N 08

Flushing• operation on riprap

Low pressure hoses can be used to implement a technique known as flushing, whereby fresh clusters of oil deposited on surfaces (beaches, rocks, etc.) or trapped in cracks in rocks and gaps between boulders are remobilised and channelled towards a collection point.

The pressure must be adapted to the nature of the site and the pollutant. Care should be taken not to scour• the base of riprap or unstable boulders, or the inside of certain structures composed of small stones and gravel (e.g. old marsh dykes). In some cases, pressurised water can cause the oil to emulsify, rendering it increasingly viscous and less mobile. The water jet can also cause surface pollutant to penetrate deep into the sediment. To prevent this, the water jet should be set at an oblique or tangential angle. Penetration of the pollutant into the sediment can be further restricted by creating a water flow upstream (or saturation of the sediment, see below).

The working pressure should be between 3 and 10 bar. The equipment used must be robust (traditional fire-fighting equipment or Venturi• effect hose ("Impact hose")), light and unsophisticated (small individual pumps of 25 to 30 m^3/h) to be easily moved around the clean-up area. This type of equipment must be capable of operating with seawater. Supplying water to the pump can sometimes be problematic, particularly at certain tidal sites or in rough water, where it is not always possible to protect and continuously immerse the suction strainer (prime loss, blocking with seaweed or sand, etc.).

On some sites, instead of small standalone pumps, a large pumping unit, with a capacity of over 100 m^3/h, can be used, equipped with a distribution manifold to supply several hoses.

- ✓ limited ecological impact
- ✓ no hazards for operators
- ✓ common, widely available equipment required
- ✗ ineffective on weathered oil
- ✗ destructive effect on soft substrates and old stone structures
- ✗ possible formation of quicksand (loosening by solid jets)

Flooding•

▶Tech Sheet N 09

In the case of a fluid pollutant deposited on a shingle bar, it is recommended to artificially saturate the shingle bar with water, in order to reduce oil penetration into the sediment during flushing• operations and to allow drainage. This is achieved by creating a laminar flow within the shingle bar via a perforated pipe at the top of the bar, supplied by a very high capacity pump at low pressure.

During the *Exxon Valdez* spill (1989), hot water pressure washing was carried out

"Omnibarges" used following the Exxon Valdez spill

partly using specially developed "Omnibarge" pontoons, fitted with all the equipment (pumps, hoses, booms, sorbents, skimmers, fuel tanks, etc.) needed to autonomously carry out a large-scale clean-up operation at remote, difficult access sites. Heat-exchanger boilers (providing 8 million BTU/h) supplied hot water to several fire hoses, then to a 20 m-long remote-controlled articulated arm, fitted with 6 high-pressure spray nozzles. These boilers supplied hot seawater (60°C) at a flow rate of around 120 m^3/h, almost half of which was for a deluge system used simultaneously to saturate the beach sediment.

Surfwashing•

▶Tech Sheet N 10

Surfwashing• involves using loaders to move oiled sediment (pebbles or sand) down to the surf zone, where it is deposited in piles or windrows• to be exposed to wave energy. The waves destroy these piles and in doing so separate the oil from the sediment and redistribute the sediment across the beach.

In the case of heavy pollution, the main purpose of this operation is the separation of oil from the sediment. The released oil tends to be deposited on the beach, especially in the case of a viscous pollutant; it is therefore important to recover it quickly at the next tide (using rollers, for example) or, better still, to trap it before it is redeposited along the strandline•.

This recovery system was developed following the *Erika* spill (1999). It involves using fine-mesh nets: initially eel nets, then later less expensive netting such as scaffold, hail or potato netting. However, eel nets are more effective due to their rigidity, which holds them open in the waves, whereas other nets tend to twist.

These nets are installed individually on the foreshore• with one end anchored to a mooring (big bag• filled with sand), partially buried in the sand using a excavator. They vary in size according to the type of net and the site configuration: from 5 to around 20 metres long by 1.5 to 5 metres wide. They are positioned above the mid-tide level (at a variable height depending on the height of the day's tide), as well as further up the shore and sometimes on either side of the oiled sediment moved down the beach for surfwashing•.

This system is very effective on sticky, viscous pollutants such as heavy fuel oil. It is significantly less effective on light pollutants (lack of adherence, and also self-adherence), or even completely ineffective on relatively exposed sites.

Surfwashing operation•

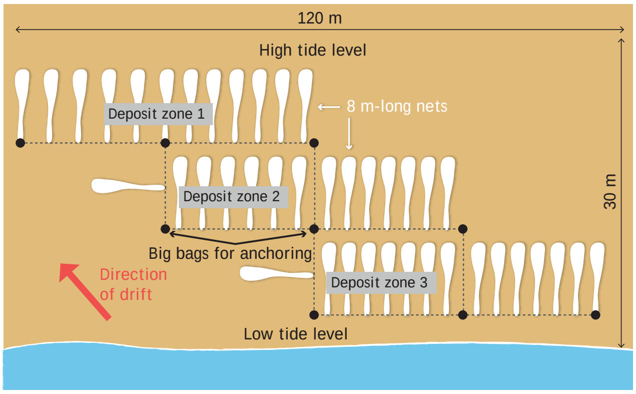


Diagram showing the layout of a system to recover oil released by surfwashing•

Rows of mop nets prepared at low tide for a surfwashing• operation at the next ebb tide

A variant of this technique was developed following the *TK Bremen* spill (2011), when surfwashing• operations were carried out on a sandy beach in the immediate vicinity of an oyster farming estuary, at ebb tide, to prevent the plume of released oil from moving up the river with the flood tide•. It consists in attaching several mop nets to a single 60-metre floating rope anchored to three partially buried big bags•. The system can comprise several parallel lines of ropes, positioned longitudinally along the beach.

Surfwashing• operations can look dramatic because of the heavy equipment (loader, trucks) involved and the momentarily chaotic appearance of the beach. However, the disruption to the beach is only temporary: the sea will ultimately return the sediments back to their original level with subsequent tides. This level corresponds to a state of equilibrium between the characteristics of the sediment (shape, size, weight) and of the prevailing hydrodynamic forces (intensity, direction) on the site.

The sea washes the sediments naturally, through impact and abrasion as they are redistributed back up the foreshore•. Surfwashing• can therefore also be used in phase 2 (final clean-up) to clean lightly oiled pebbles, or as an alternative to screening fine-grain sand containing micro-tarballs for example.

This technique, based on natural dynamic processes, has some very strong advantages, but also entails obvious geomorphological risks if conducted incorrectly. It should therefore only be implemented during favourable tidal periods (preferably with low or moderate tidal coefficients, especially in the case of large volumes) and only under the supervision of an expert in coastal geomorphology. Only such an expert can assess the feasibility of the technique on a case-by-case basis and define the methods to be used according to local sediment characteristics, wave energy and the direction of longshore drift.

- ✓ very selective technique
- ✓ avoids the need to permanently remove large volumes of sediment, which would lead to subsequent coastal erosion due to the resulting sediment deficit.
- ✓ relatively low cost (earthmoving equipment and, possibly, purchase and disposal of nets, sorbents, etc.)

- temporary disruption to beach profile
- possible (re)contamination of surrounding areas in the case of a large quantity of pollutant
- obvious geomorphological risks (coastal erosion) if conducted incorrectly:

If the sediment is moved too far down the beach: risk of sediment being temporarily or even definitively exported from the beach system. This will lead to a sediment deficit at the scale of the beach, which the sea will attempt to compensate for, to the detriment of the upper beach.

If the operation has been scheduled for a period of adverse tidal or weather conditions (gales, storms): the temporary absence of pebbles on the upper shore means that they will no longer perform their wave-damping role during upcoming storms.

Tilling technique

Tilling

▶Tech Sheet N 16

This technique, used in phase 2, can also be used in phase 1 to support sand screening. More precisely, it consists in a ploughing operation. In the case of large patches buried under a thick layer (more than 20 cm) of clean sand, the passage of a ploughshare (or several spaced apart) at low speed can bring the oil to the surface, without overly fragmenting it, where it can be recovered using beach cleaners•, as was the case occasionally following the *Erika* (1999) and *Prestige* (2002) spills.

Phase 2: final clean-up

Once the bulk of the oil has been definitively removed and all risks of new arrivals of pollutant eliminated, the final clean-up phase can be planned.

As a general rule, the sea finalises the clean-up process, sometimes with remarkable efficiency. However, for ecological as well as economic and aesthetic reasons, final clean-up is very often justified, in particular:

- when, in view of the persistence of the pollutant and the limited exposure of the site, natural cleaning proves insufficient and means that the expected time required for cleaning is incompatible with the site's economic or aesthetic requirements: for example, a tourism area affected during the (pre)summer period;
- or when there is a high probability of the pollution having a clear impact on living, natural or cultivated resources, or becoming a source of chronic contamination.

A wide range of final clean-up techniques exists (some of which are also used for initial clean-up). They cannot be systematically applied to all substrates; rather they must be defined according to the site characteristics, the extent and state of the pollutant (fluid, viscous), the types of arrivals (clusters or slicks on the surface or buried pollutant) and, of course, the level of clean-up required. It is essential to take into account the ecological sensitivity of the site and its immediate surroundings when determining the technique and the level of clean-up to be achieved.

The basic principle for the final clean-up phase is to take full advantage of natural cleaning processes, or to recreate these processes where they are absent or insufficient.

The main natural cleaning processes, based on mechanical and biochemical phenomena, are:

- cleaning by wave action, whose direct effect removes fresh oil from surfaces and, on highly exposed sites (pebbles, cobbles and rocks), removes residual oil by abrasion.
- sediment reworking by wave action, which separates oil previously trapped in the sediment by hydraulic sorting and resuspension, but also forms oil aggregates with fine mineral particles, accelerating the removal of the pollutant from the beach;
- leaching, by forced percolation of fluid oil through the sediment, when the wave recedes or at ebb tide;
- the action of indigenous bacteria and micro-organisms, which are omnipresent and specialised in oil degradation;
- the effect of UV rays, which destroy oil films.

Natural agent	Action	Effects	Final clean-up techniques
waves	- pressure	- removal from surfaces	- flushing
strong waves (breakers)	- reworking of the sediment	- release of trapped oil - separation - hydraulic sorting	- underwater tilling - underwater agitation (flushing•) - surfwashing• - sand screening
strong waves (breakers) + sediment	- strong pressure - abrasion/impact	- blasting - spraying	- pressure washing - surfwashing•
water mass	- water flow - leaching - percolation	- saturation - movement of oil - removal of oil	- saturation (flooding•) - agitation (flushing•) - drainage
fine mineral particles	- oil-fine sediment aggregates	- adhesion + removal of oil	- surfwashing• - tilling and underwater agitation
bacteria and organisms	- biodegradation	- oil biodegradation	- bioremediation
air, UV	- deterioration	- oil biodegradation	- onshore tilling (resurfacing)

Table 3: similarities between natural cleaning and final clean-up

As the table above suggests, the majority of restoration techniques are directly inspired by these natural clean-up processes. The use of specific products can facilitate certain techniques and improve their performance.

Clean-up techniques applicable to different substrates

Flushing

(sand, pebbles, cobbles, rocks, marshes)

Low-pressure water jets are used either to dislodge residual clusters of oil trapped on rocks, boulders, riprap, walls, etc. and then wash and rinse these hard surfaces, or to extract oil trapped and buried in sediment (pebbles, sand); in the latter case, this technique is referred to as underwater agitation ▶ Tech Sheet N 11, which consists in energetically mixing underwater sediment to release the oil.

In addition to underwater agitation, water jets can be used for other final clean-up operations, such as herding effluent towards a collection point, removing sand from the foot of rocks, or subsurface inspections to identify buried oil, etc.

All these operations can be carried out using low-pressure pumps (3 to 8 bar) with a moderate flow rate (at least 25 m^3/h) together with a fire hose or, if possible, an Impact hose.

Effluent recovery

▶ Tech Sheets N 12 and 13

(all substrates)

This is an important step in clean-up operations. Clean-up should not be a case of transferring pollution from the shore into the sea; it is important that oil removed during clean-up operations does not go on to contaminate neighbouring sites unaffected by the pollution or already cleaned. Effluents from washing operations must be recovered, whatever the washing technique, whatever the substrate, whatever the pollutant.

Recovery is a full-blown operation within the clean-up process. It should be set up before the actual clean-up operation begins.

Recovering washing effluents from riprap

Effluents can be contained by gravity, drainage or water jets, at one or two points conducive to collection. The system used will depend on the configuration of the site and the nature of the substrate: trenches and pits, either natural (rocks) or dug out (sediment). It is useful to take advantage of the relief of the ground, to identify natural drainage channels and receptacles, to make use of them but also, if necessary, to adapt them. The use of a shore-sealing boom can also be considered on certain beaches.

Effluents can be recovered by pumping, sorption (sorbents suited to the pollutant, most commonly in the form of pads, mats, socks, pom-poms), or filtration (sieves, scoop nets, etc.).

The experience of the *Erika* spill (1999) revealed the benefits of using geotextile such as a winter cover (used in horticulture to protect shrubs in winter). This material has a relatively high filtration capacity, is flexible enough to fit into the contours of the ground, and is strong enough to be (re) used on a clean-up site. During rock washing operations, such a lining, laid at the foot of the rocks and covering the run-off route up to the collection point, will considerably reduce the penetration of effluent into the sediment as it travels along the beach.

When the surfaces to be cleaned are partially submerged or located in the immediate vicinity (a few metres) of the sea, the effluents may be recovered on the water, inside a lightweight containment boom, by skimming, pumping or even using mop nets or sorbents.

Use of sorbents
(all substrates)

Containment system with sorbent pads

During this phase of the response, the main purpose of using sorbents is to recover the oil released during washing operations. In the case of small quantities of oil, this technique is more selective than pumping. Sorbents, preferably in conditioned form, are positioned either in the trenches dug for washing effluents, or inside a containment boom on the water. Oiled sorbents can be recovered along the wave front using forks or picks (for conditioned sorbents), scoop nets or special shovels with holes (for bulk sorbents or absorbent plant matter).

Sediment removal
▶Tech Sheet N 14
(sand, pebbles, rocks)

As a result of beach growth, oiled rocky areas (foot of rocks, etc.) and patches of oil can often become buried under a layer of clean sediment (sand, pebbles). This layer of clean sediment must be removed to reveal the buried oil. This can be done manually (using a shovel), with pressurised water (using a hose) or mechanically (using an excavator).

Botanical worksites
▶Tech Sheet N 24
(sand, pebbles, rocks)

Monitoring a botanical worksite

Areas of vegetation, in dunes and on rocks, may be oiled to a varying extent. The decision may be made to implement response actions. These are delicate operations that require a specific decision-making process and specialised recommendations by botanical experts. Such operations, on what are referred to as 'botanical worksites', supervised by environmentalists, were organised following the *Erika* spill. This term encompasses scraping, brushing, vacuuming, cutting, washing, collecting and manual sand screening, sometimes requiring almost surgical precision. The aim is to remove as much oil as possible without further damaging the plant cover or the soil. For rocks covered with lichen, washing should only be carried out surgically on the main stains; the surrounding rocks should be protected from splashes and run-off from washing operations using sorbent materials and geotextile. In cracks, certain plants may be cut back, but the soil, even if skeletal, must not be removed. The sensitivity of these diverse environments means they require special care; clean-up operations must comply with strict recommendations made by experts.

Clean-up techniques for sediment substrates

Sand screening

▶ Tech Sheet N 05
(sand)

Walk-behind beach cleaners• in series

Phase 2 sand screening operations differ slightly from those conducted during phase 1. The same beach cleaners• are used (adaptations are still relevant, but are not systematically required), this time equipped with finer screens. However, a large proportion of the work is carried out using walk-behind beach cleaners• which screen the sand more finely (5 mm mesh or less, but often with an excessively small mesh size, down to 2 mm, as was the case on certain beaches in the Gironde area during the *Prestige* spill (2002)).

Because of the tendency to overuse these machines in phase 2, it is even more important than in phase 1 that the limitations and recommendations relating to mechanical screening are meticulously applied.

Drainage

▶ Tech Sheet N 15
(sand)

Highly fluid oil (and washing effluents) tends to percolate into the sediment. After a few days, the pollutant may therefore no longer be visible at the surface, however it may still be present under a layer of sand at groundwater level. If you dig a hole in this type of beach, it quickly fills up with water—and oil in the case of pollution. Drainage is a solution which consists in channelling underlying oil towards a trench dug in the open air, where it is contained and subsequently recovered. This technique involves digging oblique, parallel or radiating trenches on the foreshore• using shovels or ploughs. These trenches converge at a low collection point which may be a simple bund•, a crosswise trench (sand deposited along the seaward edge of the trench), a system of planks, a shore-sealing boom or, on the water, a containment boom.

According to the volume of oil accumulated, it may be recovered by skimming/pumping (vacuum truck, pump, skimming head) or using sorbents. The technique is easy to implement, however the process is relatively slow and needs to be repeated. In the presence of coarse sediments, water jets or fountains at the top of the beach can enhance the process by increasing water circulation, thereby facilitating the release of oil.

Underwater agitation

▶Tech Sheet N 11
(sand and pebbles)

Underwater agitation

This technique is used to remove oil buried in sediment (sand, pebbles). It is carried out underwater, in water at least 5 cm deep. It involves scouring• the sediment using water jets to release the oil, which is then recovered at the water surface using skimmers or sorbents. This technique is mainly applicable to fluid products; however it can be used to break up sunken patches of heavy fuel oil, as was the case following the *Erika* spill (1999), in an attempt to form fragments that will rise to the surface where they can be recovered using scoop nets.

A fire hose or, better still, a Venturi• effect hose ("Impact hose") is sufficient for small areas, which are scoured by several operators standing in the water. The hoses are supplied by small, lightweight, portable pumps with a flow rate of around 30 m^3/h at a pressure of 3 to 8 bar. Supplying water to the pump can sometimes be problematic, particularly at certain tidal sites or in rough water (prime loss, blocking with seaweed or sand, etc.).

A mechanised version of the technique may be implemented by attaching several hoses to a mobile platform in order to optimise the recovery rate. A few years ago, Cedre developed a mechanised underwater agitation prototype comprising a series of hoses mounted on a mobile floating pontoon and later took part in the development of other motorised prototypes during response operations in the Middle East. The main difficulty lies in providing a permanent water supply and sufficient power to operate the hoses while ensuring compatibility with the system's mobility and with oil recovery. According to the circumstances, the feasibility of mechanisation may need to be reassessed.

Tilling

▶Tech Sheet N 16
(sand)

Tilling

This technique is implemented in the presence of water and serves the same purpose as underwater agitation, however in this case an agricultural harrow or rotavator is used to overturn the sand. Water jets can also be used simultaneously with tilling.

Tilling can also be carried out for another purpose: to facilitate the natural degradation of the oil by increasing both aeration and UV exposure. In this case, it is conducted on beaches contaminated by a light pollutant that is no longer present in the form of mobilisable accumulations but as a more or less pronounced, homogeneous staining of the sand. It is particularly well suited to the upper beach, which is less regularly reached by the sea, and, similarly, to the parts of Mediterranean beaches only reached during surges. It requires to be repeated several times.

Surfwashing•

▶Tech Sheets N 10 and P 04
(sand and pebbles)

Surfwashing• is a technique which involves moving sediments down to the lower foreshore to be cleaned by natural wave action. They will gradually be returned to their initial level by the waves.

In phase 2, this technique is used for various purposes:

- for pebbles, whatever the type of pollutant, to complete preliminary washing or as the best solution when they are only lightly oiled;
- for sand, as an alternative to screening (in the case of micro-tarballs of heavy fuel oil) or to speed up agitation (in the case of contamination by light crude oil).

In the first case, there is often no need for an oil recovery system, whereas in the second case, oil is often released in the form of clusters of various sizes (possibly larger than their initial size) or high concentrations of sheen. The released oil can be recovered either manually or using mop nets, sorbents or vertical geotextile (filtration).

This technique entails geomorphological risks if it involves large volumes of sediment or if it is conducted on a site where the shingle bar plays an important local role in preventing coastal erosion by the sea. In this case, prior consent from a geomorphological expert is required.

A prior survey of the pollution should be carried out in order to accurately determine the volume to be treated and the operating method best suited to the site (plan of operations, timing and location of deposits, etc.). Sediment removal must be closely monitored and limited to what is strictly necessary. Heavy, powerful, mobile equipment is required, such as bulldozers or loaders on wheels, quarry trucks, etc., which can be operated with precision as long as they are well supervised.

There is a less energetic variant of surfwashing• which aims only to implement phase separation, using the sea's natural hydraulic sorting and redistribution processes, even at sites with low agitation. This action is used for instance to treat piles of sand and decomposed seaweed containing a few clusters of fuel oil. In this case, the piles are simply deposited in the wave front at ebb tide. Thanks to the near-instantaneous selective redistribution by the sea, the released clusters of oil can be recovered simultaneously, either manually or using mechanical equipment (rollers) on the beach.

Washing pebbles at specialised installations

Various techniques can be used to wash pebbles, depending on the volumes to be treated and the accessibility and size of the site. It is not always necessary to use a cleaning agent (not used, for example, following the *Erika* (1999) and *Prestige* (2002) spills to clean heavy fuel oil): the use of a cleaning agent entails an additional cost and greatly penalises oil recovery operations by reducing their efficiency (even if it is a solvent, the share of oil that is momentarily dispersed does not enter the recovery system) and increasing the volume of effluent to be treated (due to additional rinsing).

• **Washing in booths**

▶Tech Sheet N 19

Equipment for washing in booths

This technique, developed during the *Erika* (1999), is an improved version of the pressure washing technique (▶Tech Sheet N 17) applied to pebbles over a wire mesh tank (▶Tech Sheet N 18) or on a raised perforated sheet of metal. This "booth" is a light metal frame with a strong openwork base (wire or sheet metal), on which the pebbles are washed, and three lateral sides, covered with geotextile, to contain the spray of effluents and oil. All the washing effluents pass through the base and are collected in a recovery device set up under the booth (drainage ditch protected with geotextile, with filtering and absorption materials, etc.). To wash small pebbles without them being projected out of the booth, they can be placed in plastic mesh bags, such as oyster bags, which are turned over during washing.

• **Washing in a concrete mixer**

▶Tech Sheet N 20

Pebbles can also be washed using a small concrete mixer installed on the beach, with a recovery system installed below. Different variants of this method exist and should be tested according to the nature

Washing in a concrete mixer

of the pollutant: dry mixing, possibly with sand as an abrasive material, or with water, possibly, if considered necessary, following prior mixing with a pure solvent, followed by rinsing. The pebbles are mixed in the concrete mixer for a short duration (a few minutes, to be assessed on a case-by-case basis).

• **Washing in a concrete mixing truck**

▶Tech Sheet N 21

With this off-site washing process using a concrete mixing truck, equipment that is generally readily available, sediment is washed satisfactorily with relatively limited material, human and financial resources. This concept, tested in the United Kingdom several years ago by the Warren Spring Laboratory, has since been improved and widely used internationally, notably on Cedre's recommendations. The pebbles are removed from the beach, washed on the backshore and returned to their original site as soon as washing is complete. Such an operation cannot be improvised, as it is essential to ensure that the temporary removal of pebbles will not cause any harm to the sediment balance of the beach (risk of coastal erosion in the event of a storm) and that a suitable area, in terms of access, bearing capacity and environmental impact (ecological impact and noise), is available in the immediate vicinity of the site. As with concrete mixers, the washing method will vary depending on the pollutant. With this technique, however, the use of a cleaning agent, which appears to be necessary in most cases, involves greater constraints and more complex logistics. The oiled pebbles are mixed for a few minutes with the neat cleaning agent, then water is gradually introduced during the mixing process. The mixer is then stopped and water is added to allow the supernatant oil to be discharged by overflow into a specific tank. The discharged pebbles are then rinsed over a wire mesh tank by hot water pressure washing ▶Tech Sheet N 18. Oil is regularly skimmed from the surface of the settled water and the water is reused.

- **Washing at a cleaning station**
  ▶Tech Sheet N 22

Industrial washing facilities have sometimes been used to wash contaminated sand and pebbles (for example: *Tanio* (1980); *Amazzone* (1988); *Deepwater Horizon* (2010). Installed in the immediate vicinity of the beaches to be cleaned, this type of facility offers a high washing rate (several tens of m³/h) while offering the comfort and safety conditions required for long-lasting operations. These facilities are generally originally designed to wash quarry aggregates and are adapted to treat oil; in particular, they ensure closed-circuit management of liquids (hot water, cleaning agent and possibly other liquids) in order to limit their consumption and the volume of effluent to be treated. Such stations are sizeable and require a large area for logistics; the installation of such a facility should therefore only be considered in the case of very heavy pollution and where sufficient space is available in the immediate vicinity of the shoreline.

High pressure hot water washing

Clean-up techniques for rocks and other hard surfaces

Hot water pressure washing
▶Tech Sheet N 17

For health and safety reasons, operators must wear appropriate protective equipment (disposable suit, full waterproofs, boots, gloves, goggles, balaclava, etc.).

Final clean-up of hard surfaces is carried out using a standard hot water pressure washer, whose operating pressure ranges from 20 bar to 150/200 bar and temperature from 0°C to 90°C. The values displayed on the washer's gauges are higher than the actual output temperature and pressure, because of losses (especially in winter) in the machine and the pipes, and especially in the first few centimetres beyond the nozzle. Nevertheless, these machines can have a significant destructive effect on the physical environment (shattering of rock or damage to grout for example), as well as the biological environment (scorching of vegetation or sterilisation of surfaces, for example). It is therefore important not only to seek the optimum settings to ensure a good compromise between efficiency and impact (by adjusting the temperature and more importantly the pressure depending on the nature and fragility of the substrate), but also to clean only what is necessary (for instance, do not mistake the black lichen *Verucaria maura* for oil) and comply with any specific instructions that may be issued for certain ecologically sensitive sites.

The pressure washers should be capable of operating with seawater, which in addition to being more economical and environmentally friendly than using mains water, also avoids the need for the logistics involved in supplying fresh water. They must also be easy to use (thermal power source with electric start-up) and mobile (compact models on individual skid mounts so they can be transported, but also crane- or helicopter-lifted).

Emergency maintenance and repair of this type of equipment require on-site intervention (on average one mechanic for 10 machines). In the case of a major spill, it is recommended to concentrate the machines in a single area rather than spread them out. This ensures a better maintenance and repair service and more effective cleaning.

Final clean-up using pressure washers requires prior removal (by scraping then flushing•) of the bulk of the oil, followed by the laying of linings to protect unoiled surfaces from splashes (frost protection covers) and the installation of an effluent recovery system.

Using cleaning agents

The aim is to soften the oil in order to remove it from the rocks more easily. The use of a cleaning agent does not prevent prior scraping of excess oil or the use of pressurised hot water.

Based on the experience of the *Erika* spill (1999) and the *Prestige* spill (2002), the use of cleaning agents is not systematically necessary, even on weathered heavy fuel oil; however, it may be worthwhile assessing the benefits of such products on other pollutants. There are two types of cleaning agents in France:

- solvents, or petroleum fractions, which simply remove the oil from its substrate, without subsequently dispersing it. In terms of toxicity, recommended solvents have a low aromatic content (< 5%). Recovery of the released oil is of course a priority: solvents are the only type of cleaning agent with which this is possible;
- cleaning agents comprising a solvent phase and a surfactant phase: the surfactant has an emulsifying effect, i.e. it disperses the released oil and facilitates its penetration into the sediment. Due to the harmful effects of dispersed oil on flora and fauna, the use of products containing surfactants should be limited, or even prohibited, in the presence of sensitive marine resources, whether exploited or not, on the site or in the immediate vicinity. Consequently, their use should only be authorised under exceptional circumstances, and only on sites where the hydrodynamic forces (waves, tides, currents) are sufficiently intense to ensure rapid dilution of the effluents.

Whatever type of cleaning agent is selected, it must have undergone prior toxicity, biodegradability and efficiency tests (carried out by recognised organisations). Cedre keeps an up-to-date list of products that can be used on the shoreline. In addition, controlled field tests should be carried out to confirm that the selected product is effective on the specific pollutant.

The optimal method of using these products is to spray them undiluted onto the polluted surface 15 to 30 minutes (depending on ambient temperature) prior to washing. This contact time promotes the action of the cleaning product; it should not exceed 30 minutes due to the risk of the solvent evaporating. The solvent dosage is approximately 1 volume of product for up to 3 volumes of pollutant.

Dismantling riprap

Coastal protection structures such as riprap, positioned as groynes or breakwaters, are real oil traps. Due to difficulties in cleaning them, they sometimes need to be dismantled, at least partially, in order to be completely cleaned.

Specific methods for difficult access sites

When response operations on cliffs are deemed necessary, specific measures must be taken in terms of the equipment to be installed and the operators to be called in. To deploy operators and equipment at the foot of a cliff, or to remove waste from a cove, highly qualified professional rope access technicians are required; only such operators are qualified to install specific equipment such as zip-lines, lifelines (steel wires and ropes fixed to a wall) and all other facilities required for on-site safety.

Clean-up on a difficult access site

Choices, constraints and procedures for implementing techniques

Decision matrices

The choice of techniques will depend on the extent of the pollution, the nature of the pollutant and the type of coastline.

There is no single, universally applicable technique. Some can be used, sometimes with variations, on different substrates and different pollutants. Others are only applicable to a specific pollutant, pollution or substrate and therefore have a much narrower window of use. Finally, some techniques are more effective on tidal coasts than on coasts with a very small tidal range.

The main techniques applicable in phase 1 and phase 2 are described in specific summary sheets or "Tech Sheets".

Because of the wide variety of techniques and pollution scenarios, it is impossible to detail here all the solutions to be applied to the different situations. However, some indications must be provided to guide the choice of techniques to be used.

For this purpose, the following pages feature:

- “decision matrices” to help with the selection of one or more techniques for each of the two clean-up phases, according to the type of pollutant, the type of substrate and the presence or absence of tides;
- “summary tables" for response operations, from phase 1 to phase 2, on each of the main types of substrate.

Decision matrices

Decision matrices for choosing the appropriate response technique(s) have been drawn up for typical pollution scenarios on two main types of coastline: macrotidal (e.g. the English Channel and French Atlantic coastline) and microtidal (e.g. The Mediterranean coastline). These scenarios result from the combination of three factors—pollution, pollutant and substrate—simplified into broad categories:

- two types of pollution: heavy and light (or residual) pollution, corresponding to phase 1 and phase 2 respectively;
- two types of pollutant: fluid pollutants (in reality, fluid to slightly viscous) and viscous pollutants (in reality, viscous to highly viscous);
- around twenty typical environments defined according to their substrate (rocks, artificial structures, boulders, cobbles/pebbles, fine-grain sand, coarse-grain sand, mud, marshes) and their exposure to wave energy (exposed or sheltered).

The following table summarises the different matrices:

		Coastline/tidal range	
Pollution	**Pollutant**	Channel - Atlantic	Mediterranean
Heavy or phase 1	Fluid	**Matrix 1**	**Matrix 5**
	Viscous	**Matrix 2**	**Matrix 6**
Light or residual or phase 2	Fluid	**Matrix 3**	**Matrix 7**
	Viscous	**Matrix 4**	**Matrix 8**

The techniques are listed according to their relevance as follows:

- "Recommended": technique to be considered generally without any specific restrictions;
- "May be useful": technique that can be applied possibly under certain favourable conditions (pollutant, site);
- “Can be considered under certain conditions”: technique only to be considered if the various conditions related to its use are fulfilled in terms of ecological sensitivity, safety or feasibility of implementation;
- "Not applicable": incompatible with the substrate.

In addition, a reference to a "Tech Sheet" is systematically provided to ensure a better understanding of the procedures and restrictions.

Matrix 1			Macrotidal shore				Phase 1: initial clean-up				Fluid to slightly viscous pollutant				
Substrate			Leave alone	Pumping			Collection				Additional recovery			Protection	
				At the water's edge		On the fore-shore	Earthmoving equipment (scraping)	Manual collection	Specialised equipment		Flushing	Flooding	Surf washing	Mop nets/ sorbents on ropes	Protective sheet-ing
Type		Expo-sure		Skimming	Pumping	Pumping			Beach cleaner	Roller					
Port infra-structures	Dock	+	May be useful	May be useful	May be useful	May be useful	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Not applicable
		-	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	May be useful	Not applicable	Not applicable	May be useful	Not applicable	Not applicable	Not applicable	Can be considered under certain conditions
	Riprap	+	Recommended	May be useful	May be useful	May be useful	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Recommended	May be useful	Not applicable	Not applicable	Not applicable
		-	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	Recommended	Recommended	Not applicable	Not applicable	Can be considered under certain conditions
Rocks	Cliffs	+	Recommended	Not applicable	Not applicable	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Not applicable
		-	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Not applicable	Recommended	Not applicable	Not applicable	May be useful	Not applicable	Not applicable	Not applicable	Not applicable
	Wave-cut plat-form	+	Can be considered under certain conditions	May be useful	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	Recommended	Not applicable	Not applicable	Not applicable	Not applicable
		-	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	Recommended	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable
	Boul-ders	+	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	Recommended	Not applicable	Not applicable	Not applicable	Not applicable
		-	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	Recommended	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable
Sediment beaches	Cobbles	+	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	Recommended	Recommended	Recommended	Not applicable	Not applicable
		-	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	Recommended	Recommended	Recommended	Can be considered under certain conditions	Not applicable
	Coarse sand	+	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	May be useful	Recommended	Recommended	Not applicable	Not applicable
		-	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	May be useful	Recommended	May be useful	Can be considered under certain conditions	Can be considered under certain conditions
	Fine sand	+	Can be considered under certain conditions	Recommended	Recommended	Recommended	May be useful	Recommended	Not applicable	Can be considered under certain conditions	May be useful	Not applicable	Recommended	Not applicable	Not applicable
		-	Can be considered under certain conditions	Recommended	Recommended	Recommended	May be useful	Recommended	Not applicable	Can be considered under certain conditions	May be useful	Not applicable	Can be considered under certain conditions	Can be considered under certain conditions	Can be considered under certain conditions
Mudflats		-	Recommended	Can be considered under certain conditions	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable
Marshland		-	Recommended	Can be considered under certain conditions	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable
See Tech Sheet no.			N 01	N 02	N 02	N 03	N 06	N 07	N 05	N 06	N 8	N 9	N 10 - P 04	P 04	P 05

Recommended   May be useful   Can be considered under certain conditions   Not applicable

Matrix 2			Macrotidal shore				Stage 1: initial clean-up				Fluid to slightly viscous pollutant				
				Pumping			Collection				Additional recovery			Protection	
Natural			Leave alone	At the water's edge		On the foreshore	Earthmoving equipment (scraping)	Manual collection	Specialised equipment		Flushing	Flooding	Surf washing	Mop nets/ sorbents on ropes	Protective sheeting
Type		Exposure		Skimming	Pumping	Pumping			Beach cleaner	Roller					
Port infrastructures	Dock	+	🟩	🟩	🟩	🟩	🟧	🟧	⬜	⬜	🟧	⬜	⬜	⬜	⬜
		-	🟧	🟦	🟦	🟦	🟧	🟦	⬜	⬜	🟩	⬜	⬜	⬜	🟧
	Riprap	+	🟦	🟧	🟧	🟧	🟧	🟧	⬜	⬜	🟩	🟧	⬜	⬜	⬜
		-	🟧	🟦	🟦	🟦	🟧	🟦	⬜	⬜	🟦	🟩	⬜	⬜	🟧
Rocks	Cliffs	+	🟦	⬜	⬜	⬜	⬜	🟧	⬜	⬜	🟧	⬜	⬜	⬜	⬜
		-	🟧	⬜	⬜	⬜	⬜	🟦	⬜	⬜	🟩	⬜	⬜	⬜	⬜
	Wave-cut platform	+	🟧	🟩	🟦	🟦	⬜	🟦	⬜	⬜	🟦	⬜	⬜	⬜	⬜
		-	🟧	🟦	🟦	🟦	⬜	🟦	⬜	⬜	🟦	⬜	⬜	🟧	⬜
	Boulders	+	🟧	🟩	🟦	🟦	⬜	🟦	⬜	⬜	🟦	⬜	⬜	⬜	⬜
		-	🟧	🟩	🟦	🟦	⬜	🟦	⬜	⬜	🟦	⬜	⬜	🟧	⬜
Sediment beaches	Cobbles	+	🟧	🟦	🟦	🟦	🟧	🟦	⬜	⬜	🟩	🟩	🟦	🟩	⬜
		-	🟧	🟦	🟦	🟦	🟩	🟦	⬜	⬜	🟩	🟩	🟦	🟩	⬜
	Coarse sand	+	🟧	🟦	🟦	🟦	🟩	🟦	🟧	🟧	🟧	🟧	🟦	🟩	⬜
		-	🟧	🟦	🟦	🟦	🟩	🟦	🟧	🟧	🟧	🟧	🟩	🟩	🟧
	Fine sand	+	🟧	🟦	🟦	🟦	🟩	🟦	🟦	🟦	🟧	⬜	🟦	🟩	⬜
		-	🟧	🟦	🟦	🟦	🟩	🟦	🟦	🟦	🟧	⬜	🟧	🟩	🟧
Mudflats		-	🟦	🟧	🟧	🟧	⬜	🟧	⬜	⬜	🟧	⬜	⬜	🟧	⬜
Marshland		-	🟦	🟧	🟧	🟧	⬜	🟧	⬜	⬜	🟧	⬜	⬜	🟧	⬜
See Tech sheet no.			N 01	N 02	N 02	N 03	N 06	N 07	N 05	N 06	N 8	N 9	N 10 - P 04	P 04	P 05

🟦 Recommended 🟩 May be useful 🟧 Can be considered under certain conditions ⬜ Not applicable

Matrix 3 — Macrotidal shore — Phase 2: final clean-up — Fluid to slightly viscous pollutant

Natural: Type		Exposure	Collection: Manual recovery	Collection: Flushing	Collection: Drainage	Collection: Tilling	Collection: Underwater agitation	Collection: Mechanical sand screening	Collection: Cutting	Washing: Surf washing	Washing: Hot water high pressure washing	Washing: Cleaning station, concrete mixing truck or concrete mixer	Washing: Effluent recovery	Degradation: Leave alone	Degradation: Bioremediation	Degradation: Scarification
Port infrastructures	Dock	+	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered under certain conditions	Not applicable	Not applicable
	Dock	-	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered under certain conditions	Not applicable	Not applicable
	Riprap	+	Can be considered under certain conditions	May be useful	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered under certain conditions	Not applicable	Not applicable
	Riprap	-	May be useful	Recommended	Not applicable	Not applicable	May be useful	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered under certain conditions	Not applicable	Not applicable
Rocks	Cliffs	+	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Recommended	Can be considered under certain conditions	Not applicable	Not applicable
	Cliffs	-	May be useful	May be useful	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Recommended	Can be considered under certain conditions	Not applicable	Not applicable
	Wave-cut platform	+	May be useful	May be useful	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered under certain conditions	Not applicable	Not applicable
	Wave-cut platform	-	May be useful	Recommended	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable
	Boulders	+	May be useful	May be useful	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered under certain conditions	Not applicable	Not applicable
	Boulders	-	May be useful	Recommended	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable
Sediment beaches	Cobbles	+	May be useful	Recommended	Not applicable	Not applicable	May be useful	Not applicable	Not applicable	May be useful	May be useful	May be useful	Recommended	Can be considered under certain conditions	Not applicable	Not applicable
	Cobbles	-	May be useful	Recommended	Not applicable	Not applicable	May be useful	Not applicable	Not applicable	May be useful	May be useful	May be useful	Recommended	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable
	Coarse sand	+	May be useful	May be useful	May be useful	May be useful	May be useful	Not applicable	Not applicable	May be useful	Not applicable	Can be considered under certain conditions	Recommended	Can be considered under certain conditions	Not applicable	Not applicable
	Coarse sand	-	May be useful	May be useful	May be useful	May be useful	May be useful	Not applicable	Not applicable	May be useful	Not applicable	Can be considered under certain conditions	Recommended	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable
	Fine sand	+	May be useful	May be useful	May be useful	May be useful	May be useful	Not applicable	Not applicable	May be useful	Not applicable	Can be considered under certain conditions	Recommended	Can be considered under certain conditions	Not applicable	Not applicable
	Fine sand	-	May be useful	May be useful	May be useful	May be useful	May be useful	Not applicable	Not applicable	May be useful	Not applicable	Can be considered under certain conditions	Recommended	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable
Mudflats		-	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Recommended	Recommended	Not applicable	Not applicable
Marshland		-	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Recommended	Recommended	Not applicable	Can be considered under certain conditions
See Tech sheet no.			N 07	N 08	N 15	N 16	N 11	N 05	N 25	N 10 P 04	N 17 N 18 N 19	N 20 N 21 N 22	N 12 N 13	N 01	N 27	N 26

Recommended — May be useful — Can be considered under certain conditions — Not applicable

Matrix 4			Macrotidal shore				Phase 2: final clean-up				Fluid to highly viscous pollutant			
			Collection							Washing				Degradation
Natural														
Type		Exposure	Manual recovery	Flushing	Drainage	Tilling	Underwater agitation	Mechanical sand screening	Cutting	Surf washing	Hot water high pressure washing	Cleaning station, concrete mixing truck or concrete mixer	Effluent recovery	Leave alone	Scarification
Port infrastructures	Dock	+	Can be considered under certain conditions	Can be considered under certain conditions							May be useful		Recommended	Can be considered under certain conditions	
		-	Can be considered under certain conditions	Can be considered under certain conditions							May be useful		Recommended	Can be considered under certain conditions	
	Riprap	+	Can be considered under certain conditions	Can be considered under certain conditions							May be useful		Recommended	Can be considered under certain conditions	
		-	May be useful	May be useful			Can be considered under certain conditions				May be useful		Recommended	Can be considered under certain conditions	
Rocks	Cliffs	+	Can be considered under certain conditions	Can be considered under certain conditions							Can be considered under certain conditions		Recommended	Can be considered under certain conditions	
		-	May be useful	May be useful							Can be considered under certain conditions		Recommended	Can be considered under certain conditions	
	Wave-cut platform	+	May be useful	Can be considered under certain conditions							May be useful		Recommended	Can be considered under certain conditions	
		-	Recommended	May be useful							Recommended		Recommended	Can be considered under certain conditions	
	Boulders	+	May be useful	May be useful							May be useful		Recommended	Can be considered under certain conditions	
		-	Recommended	May be useful			Can be considered under certain conditions				Recommended		Recommended	Can be considered under certain conditions	
Sediment beaches	Cobbles	+	Recommended	May be useful			Can be considered under certain conditions			May be useful	Recommended	May be useful	Recommended	Can be considered under certain conditions	
		-	Recommended	May be useful			Can be considered under certain conditions			Can be considered under certain conditions	Recommended	May be useful	Recommended	Can be considered under certain conditions	
	Coarse sand	+	Recommended	May be useful		Can be considered under certain conditions	Can be considered under certain conditions	Can be considered under certain conditions		May be useful			Recommended	Can be considered under certain conditions	
		-	Recommended	May be useful		Can be considered under certain conditions	Can be considered under certain conditions	Can be considered under certain conditions		Can be considered under certain conditions			Recommended	Can be considered under certain conditions	
	Fine sand	+	Recommended	Can be considered under certain conditions		Can be considered under certain conditions	Can be considered under certain conditions	Recommended		May be useful			Recommended	Can be considered under certain conditions	
		-	Recommended	Can be considered under certain conditions		Can be considered under certain conditions	Can be considered under certain conditions	Recommended		Can be considered under certain conditions			Recommended	Can be considered under certain conditions	
Mudflats		-	Can be considered under certain conditions	Can be considered under certain conditions									Recommended	Recommended	
Marshland		-	Can be considered under certain conditions	Can be considered under certain conditions					Can be considered under certain conditions				Recommended	Recommended	Can be considered under certain conditions
See Tech Sheet no.			N 07	N 08	N 15	N 16	N 11	N 05	N 25	N 10 P 04	N 17 N 18 N 19	N 20 N 21 N 22	N 12 N 13	N 01	N 26

Recommended
May be useful
Can be considered under certain conditions
Not applicable

Matrix 5			Microtidal shore				Phase 1: initial clean-up				Fluid to slightly viscous pollutant				
Natural			Leave alone	Pumping			Collection				Additional recovery			Protection	
				At the water's edge		On the fore-shore	Earthmoving equipment (scraping)	Manual collection	Specialised equipment		Flushing	Flooding	Surf washing	Mop nets/ sorbents on ropes	Protective sheeting
Type		Expo-sure		Skimming	Pumping	Pumping			Beach cleaner	Roller					
Port infra-structures	Dock	+	May be useful	May be useful	May be useful	May be useful	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Not applicable
		-	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	May be useful	Not applicable	Not applicable	Not applicable	May be useful
	Riprap	+	Recommended	May be useful	May be useful	May be useful	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Recommended	May be useful	Not applicable	Not applicable	Not applicable
		-	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	Recommended	Recommended	Not applicable	Not applicable	May be useful
Rocks	Cliffs	+	Recommended	Not applicable	Not applicable	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Not applicable
		-	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Not applicable	Recommended	Not applicable	Not applicable	May be useful	Not applicable	Not applicable	Not applicable	Can be considered under certain conditions
	Wave-cut plat-form	+	Can be considered under certain conditions	May be useful	May be useful	Recommended	Not applicable	Recommended	Not applicable	Not applicable	Recommended	Not applicable	Not applicable	Not applicable	Not applicable
		-	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	Recommended	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable
	Boul-ders	+	Can be considered under certain conditions	May be useful	May be useful	Recommended	Not applicable	Recommended	Not applicable	Not applicable	Recommended	Not applicable	Not applicable	Not applicable	Not applicable
		-	Can be considered under certain conditions	May be useful	May be useful	Recommended	Not applicable	Recommended	Not applicable	Not applicable	Recommended	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable
Sediment beaches	Cobbles	+	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	Recommended	Recommended	Can be considered under certain conditions	Not applicable	Not applicable
		-	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	Recommended	Recommended	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable
	Coarse sand	+	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	May be useful	Recommended	Can be considered under certain conditions	Not applicable	Not applicable
		-	Can be considered under certain conditions	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	May be useful	Recommended	Can be considered under certain conditions	Can be considered under certain conditions	Can be considered under certain conditions
	Fine sand	+	Can be considered under certain conditions	Recommended	Recommended	Recommended	Can be considered under certain conditions	Recommended	Not applicable	Can be considered under certain conditions	May be useful	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable
		-	Can be considered under certain conditions	Recommended	Recommended	Recommended	Can be considered under certain conditions	Recommended	Not applicable	Can be considered under certain conditions	May be useful	Not applicable	Can be considered under certain conditions	Can be considered under certain conditions	Can be considered under certain conditions
Marshland		-	Recommended	Can be considered under certain conditions	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable
See Tech Sheet no.			N 01	N 02	N 02	N 03	N 06	N 09	N 08	N 07	N 12	N 13	N 10 - P 04	P 04	P 05

Recommended | May be useful | Can be considered under certain conditions | Not applicable

Matrix 6			Microtidal shore				Phase 1: initial clean-up				Viscous to highly viscous pollutant				
Natural			Leave alone	Pumping			Collection				Additional recovery			Protection	
				At the water's edge		On the foreshore	Earthmoving equipment (direct collection)	Manual collection	Specialised equipment		Flushing	Flooding	Surf washing	Mop nets/ sorbents on ropes	Protective sheeting
Type		Exposure		Skimming	Pumping	Pumping			Beach cleaner	Roller					
Port infrastructures	Dock	+	May be useful	Can be considered	Can be considered	Can be considered	Can be considered	Can be considered	Not applicable	Not applicable	Can be considered	Not applicable	Not applicable	Not applicable	Not applicable
		-	Can be considered	Recommended	Recommended	Recommended	Can be considered	Recommended	Not applicable	Not applicable	May be useful	Not applicable	Not applicable	Not applicable	May be useful
	Riprap	+	Recommended	Can be considered	Can be considered	Can be considered	Can be considered	Can be considered	Not applicable	Not applicable	May be useful	Can be considered	Not applicable	Not applicable	Not applicable
		-	Can be considered	Recommended	Recommended	Recommended	Can be considered	Recommended	Not applicable	Not applicable	Recommended	May be useful	Not applicable	Not applicable	May be useful
Rocks	Cliffs	+	Recommended	Not applicable	Not applicable	Not applicable	Not applicable	Can be considered	Not applicable	Not applicable	Can be considered	Not applicable	Not applicable	Not applicable	Not applicable
		-	Can be considered	Not applicable	Not applicable	Not applicable	Not applicable	Recommended	Not applicable	Not applicable	May be useful	Not applicable	Not applicable	Not applicable	Can be considered
	Wave-cut platform	+	May be useful	May be useful	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	May be useful	Not applicable	Not applicable	Not applicable	Not applicable
		-	Can be considered	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	May be useful	Not applicable	Not applicable	Can be considered	Not applicable
	Boulders	+	Can be considered	May be useful	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	May be useful	Not applicable	Not applicable	Not applicable	Not applicable
		-	Can be considered	May be useful	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	May be useful	Not applicable	Not applicable	Can be considered	Not applicable
Sediment beaches	Cobbles	+	Can be considered	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	May be useful	May be useful	Can be considered	Not applicable	Not applicable
		-	Can be considered	Recommended	Recommended	Recommended	Not applicable	Recommended	Not applicable	Not applicable	May be useful	May be useful	Can be considered	Can be considered	Not applicable
	Coarse sand	+	Can be considered	Recommended	Recommended	Recommended	May be useful	Recommended	Can be considered	Can be considered	Can be considered	Not applicable	Can be considered	Can be considered	Not applicable
		-	Can be considered	Recommended	Recommended	Recommended	May be useful	Recommended	Can be considered	Can be considered	Can be considered	Not applicable	Can be considered	Can be considered	Can be considered
	Fine sand	+	Can be considered	Recommended	Recommended	Recommended	May be useful	Recommended	May be useful	May be useful	Can be considered	Not applicable	Can be considered	Can be considered	Not applicable
		-	Can be considered	Recommended	Recommended	Recommended	May be useful	Recommended	May be useful	May be useful	Can be considered	Not applicable	Can be considered	Can be considered	Can be considered
Marshland		-	Recommended	Can be considered	Can be considered	Can be considered	Not applicable	Can be considered	Not applicable	Not applicable	Can be considered	Not applicable	Not applicable	Can be considered	Not applicable
See Tech Sheet no.			N 01	N 02	N 02	N 03	N 06	N 07	N 05	N 06	N 08	N 09	N 10 - P 04	P 04	P 05

Recommended · May be useful · Can be considered under certain conditions · Not applicable

Matrix 7			Microtidal shore			Phase 2: final clean-up				Fluid to slightly viscous pollutant					
			Collection							Washing				Degradation	
Natural															
Type		Exposure	Manual recovery	Flushing	Drainage	Tilling	Underwater agitation	Mechanical sand screening	Cutting	Surf washing	Hot water high pressure washing	Cleaning station, concrete mixing truck or concrete mixer	Effluent recovery	Leave alone	Scarification
Port infrastructures	Dock	+	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered under certain conditions	Not applicable
		-	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered under certain conditions	Not applicable
	Riprap	+	Can be considered under certain conditions	May be useful	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered under certain conditions	Not applicable
		-	May be useful	May be useful	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered under certain conditions	Not applicable
Rocks	Cliffs	+	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Recommended	Can be considered under certain conditions	Not applicable
		-	May be useful	May be useful	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Recommended	Can be considered under certain conditions	Not applicable
	Wave-cut platform	+	May be useful	May be useful	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered under certain conditions	Not applicable
		-	Recommended	May be useful	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Recommended	Not applicable	Recommended	Can be considered under certain conditions	Not applicable
	Boulders	+	May be useful	May be useful	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered under certain conditions	Not applicable
		-	Recommended	May be useful	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Recommended	Not applicable	Recommended	Can be considered under certain conditions	Not applicable
Sediment beaches	Cobbles	+	May be useful	Recommended	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Can be considered under certain conditions	Recommended	May be useful	Recommended	Can be considered under certain conditions	Not applicable
		-	Recommended	Recommended	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Can be considered under certain conditions	Recommended	May be useful	Recommended	Can be considered under certain conditions	Not applicable
	Coarse sand	+	May be useful	Can be considered under certain conditions	Not applicable	Can be considered under certain conditions	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Recommended	Can be considered under certain conditions	Not applicable
		-	Recommended	Can be considered under certain conditions	Not applicable	Can be considered under certain conditions	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Recommended	Can be considered under certain conditions	Not applicable
	Fine sand	+	May be useful	Can be considered under certain conditions	Not applicable	Can be considered under certain conditions	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Recommended	Can be considered under certain conditions	Not applicable
		-	Recommended	Can be considered under certain conditions	Not applicable	Can be considered under certain conditions	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Recommended	Can be considered under certain conditions	Not applicable
Marshland		-	Can be considered under certain conditions	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Not applicable	Can be considered under certain conditions	Not applicable	Not applicable	Not applicable	Recommended	Recommended	Can be considered under certain conditions
See Tech Sheet no.			N 07	N 08	N 15	N 16	N 11	N 05	N 25	N 10 P 04	N 17 N 18 N 19	N 20 N 21 N 22	N 12 N 13	N 01	N 26

Recommended — May be useful — Can be considered under certain conditions — Not applicable

Matrix 8 — Microtidal shore — Phase 2: final clean-up — Fluid to highly viscous pollutant

Natural			Collection							Washing				Degradation	
Type		Exposure	Manual recovery	Flushing	Drainage	Tilling	Underwater agitation	Mechanical sand screening	Cutting	Surf washing	Hot water high pressure washing	Cleaning station, concrete mixing truck or concrete mixer	Effluent recovery	Leave alone	Scarification
Port infrastructures	Dock	+	Can be considered	Can be considered	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered	Not applicable
		-	Can be considered	Can be considered	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered	Not applicable
	Riprap	+	Can be considered	Can be considered	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered	Not applicable
		-	May be useful	Can be considered	Not applicable	Not applicable	Can be considered	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered	Not applicable
Rocks	Cliffs	+	Can be considered	Can be considered	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Can be considered	Not applicable	Recommended	Can be considered	Not applicable
		-	May be useful	Can be considered	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered	Not applicable
	Wave-cut platform	+	May be useful	Can be considered	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered	Not applicable
		-	Recommended	Can be considered	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Recommended	Not applicable	Recommended	Can be considered	Not applicable
	Boulders	+	May be useful	Can be considered	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	May be useful	Not applicable	Recommended	Can be considered	Not applicable
		-	Recommended	Can be considered	Not applicable	Not applicable	Can be considered	Not applicable	Not applicable	Not applicable	Recommended	Not applicable	Recommended	Can be considered	Not applicable
Sediment beaches	Cobbles	+	Recommended	Can be considered	Not applicable	Not applicable	Can be considered	Not applicable	Not applicable	Can be considered	Recommended	May be useful	Recommended	Can be considered	Not applicable
		-	Recommended	Can be considered	Not applicable	Not applicable	Can be considered	Not applicable	Not applicable	Can be considered	Recommended	May be useful	Recommended	Can be considered	Not applicable
	Coarse sand	+	Recommended	Can be considered	Not applicable	Not applicable	Can be considered	Can be considered	Not applicable	Can be considered	Not applicable	Not applicable	Recommended	Can be considered	Not applicable
		-	Recommended	Can be considered	Not applicable	Not applicable	Can be considered	Can be considered	Not applicable	Can be considered	Not applicable	Not applicable	Recommended	Can be considered	Not applicable
	Fine sand	+	Recommended	Can be considered	Not applicable	Not applicable	Can be considered	Can be considered	Not applicable	Can be considered	Not applicable	Not applicable	Recommended	Can be considered	Not applicable
		-	Recommended	Can be considered	Not applicable	Not applicable	Can be considered	Can be considered	Not applicable	Can be considered	Not applicable	Not applicable	Recommended	Can be considered	Not applicable
Marshland		-	Can be considered	Can be considered	Not applicable	Not applicable	Not applicable	Not applicable	Can be considered	Not applicable	Not applicable	Not applicable	Recommended	Recommended	Can be considered
See Tech Sheet no.			N 07	N 08	N 15	N 16	N 11	N 05	N 25	N 10 P 04	N 17 N 18 N 19	N 20 N 21 N 22	N 12 N 13	N 01	N 26

Recommended — May be useful — Can be considered under certain conditions — Not applicable

Response according to the substrate (summary tables)

To clean a site, several complementary techniques may be required and should not necessarily be implemented simultaneously. However, this assumes that the different steps have been clearly defined and that any implications they may have in relation to the other techniques have been assessed.

To facilitate this process, sites are categorised into 5 main types of substrate or shoreline:

- rocks and infrastructures;
- pebbles/cobbles;
- sand;
- mudflats;
- marshes.

There are two summary tables for each type of shoreline: one for phase 1 and the other for phase 2. These summary tables outline the sequence of possible operations (with references to the various Tech Sheets), the procedures and the various factors to be taken into account at the different stages of implementation.

Decision matrices

Decision matrices for choosing the appropriate response technique(s) have been drawn up for typical pollution scenarios on two main types of coastline: macrotidal (e.g. the English Channel and French Atlantic coastline) and microtidal (e.g. The Mediterranean coastline). These scenarios result from the combination of three factors—pollution, pollutant and substrate—simplified into broad categories:

- two types of pollution: heavy and light (or residual) pollution to phase 1 and phase 2 respectively;
- two types of pollutant: fluid pollutants (in reality, fluid to slightly viscous) and viscous pollutants (in reality, viscous to highly viscous);
- around twenty typical environments defined according to their substrate (rocks, artificial structures, boulders, cobbles/pebbles, fine-grain sand, coarse-grain sand, mud, marshes) and their exposure to wave energy (exposed or sheltered).

Phase 1: Initial clean-up (1/2)

Techniques - objectives - procedures	Equipment required	Factors to be considered
Pumping at the water's edge ▶Tech Sheet N02 ➞ recover accumulations by enhancing their concentration and improving recovery rate and selectivity		
(a) Prepare storage site (liquid to slightly viscous pollutants) - facilitate sorting - reduce volumes for evacuation - restrict the spread of the pollution	(should be adapted to suit the pollutant and the site) - areas, trenches, bunds•, skips, (watertight) tanks - drainage (rainwater overflow) - screening, sorting - earthmoving equipment (digging) - protective membranes and geotextile	- ecological sensitivity - site accessibility - transfer of the pollution (watertight storage, decontamination of trucks) - traffic (should be channelled) - site hazards (height, rockfall, falling, slipping, exposure to waves, etc.) - personal health and safety (protective clothing, life jackets, masks) - accessibility of the shore - agitation of the water body (currents, swell, wind) - tidal range - nature (emulsion, viscosity) and evolution of the pollutant according to the temperature - presence of solid debris - draught of skimmers and compatibility with depth of water - recovery of liquids from settling - traffic lanes
(b) Concentrate slicks - where possible, contain the pollutant trapped in coves (retention boom)	- containment booms - shore-sealing booms	
(C) Contain and reconstitute the slick in front of the pumping/skimming equipment: - by trawling (worksite booms, sorbent booms) - by scraping (planks, scrapers, brushes) - by hosing	- worksite booms - conditioned sorbents - planks, scrapers, hoses - small boat	
(d) Pump - prevent clogging of the pumps: use a screen or another system to retain debris	- skimming/pumping equipment (skimmer, pump, vacuum truck or other transfer system) - grating, filter baskets - storage capacities and transfer means	
(e) Separate - promote the separation of oil and water: emulsion breaking, settling - evacuate the products recovered	- settling tanks/separator - transfer pumps - emulsion breaker• - trucks suited to the pollutant	

ROCKS and INFRASTRUCTURES *2/3*

Phase 1: Initial clean-up (2/2)

Techniques - objectives - procedures	Equipment required	Factors to be considered
Manual recovery ▶ Tech Sheet N 07 ➞ remove mobilisable clusters of pollutant and heavily polluted diverse materials (sediment, seaweed, floating debris) - direct collection (use mechanical support wherever possible: vehicles, crane, etc.) - scraping - concentration (containment) - sorption - evacuation	- shovels, forks, scrapers, brushes, brooms, trowels, etc. - worksite booms, sorbents - bins, bags	- site hazards (height, rockfall, falling, slipping, exposure to waves, etc.) - personal safety: permanent supervision and protective equipment - mechanical equipment can rarely operate on such sites - organisation of teams
Flushing• ▶ Tech Sheet N 08 ➞ dislodge layers of oil deposited on rocks or trapped in crevices (cracks, boulders etc.) and move the pollutant towards a collection area	- pump unit (3 to 8 bar individual pump, 25 to 30 m^3/h) - low pressure hoses: fire or Impact hose with Venturi effect• - pipes, connectors	- site hazards (height, rockfall, falling, slipping, exposure to waves, etc.) - personal safety: permanent supervision and protective equipment - organisation of teams
• systematically recover effluents to stop the pollution from spreading by installing a recovery system: - prepare a collection area, channel the effluents - on the water ▶ Tech Sheet N 12 - on the foreshore• ▶ Tech Sheet N 13	(should be adapted to suit the pollutant and the site) - containment equipment: containment or shore-sealing booms, bunds•, pits, etc. - recovery and evacuation means: pump, sorbents, etc. - settling and storage capacities	- tides - agitation of the water body

Phase 2: Final clean-up (1/1)

Techniques - objectives - procedures	Equipment required	Factors to be considered
Flushing• ▶Tech Sheet N 08 ➞ wash surfaces with a large quantity of water to dislodge residual oil and recover it at a collection point - prepare a collection area, channel the effluents - wash - recover freed waste	- pump unit (3 to 8 bar individual pump, 25 to 30 m³/h) - fire or Impact hose - pipes, connectors - shovels - worksite boom (containment, shore-sealing) - skimmer, pump, sorbents - storage tanks, settling of recovered products	- nature and evolution of the oil, viscosity, weathering, thickness of the layer, adherence, etc. - site hazards (height, rockfall, falling, slipping, exposure to waves, etc.) - accessibility of the shore - tidal range (take equipment off site every day) - limited efficiency of washing using cold water on sticky or overly weathered oil
High pressure washing using hot or cold water (with or without a cleaning agent) ➞ remove oil from polluted surfaces using hoses under high pressure. Always comply with environmental and safety instructions. **Prior operations:** • **manual scraping** ➞ remove the bulk of residual layers (viscous pollutant) before pressure washing to increase effectiveness • **protection against spray** ➞ protect unoiled rocky areas from being polluted by the projection of contaminated effluents and aerosols • **Hot water pressure washing** ▶Tech Sheet N17 Hot water is generally needed, while the use of a washing agent (for preference a solvent) is not systematically necessary.	- scrapers, brushes - bags, bins, etc. - flexible geotextile sheeting, possibly with stakes - hot water pressure washer (50 to 150 bars, 0 to 90 °C) - hoses, pipes, connectors - selected washing agents - horticultural spreading equipment	- nature and evolution of the oil, viscosity, weathering, thickness of the layer, adherence, etc. - site hazards (height, rockfall, falling, slipping, exposure to waves, etc.) - accessibility of the shore - tidal range (take equipment off site every day) - limited efficiency of washing using cold water on sticky or overly weathered oil - potentially high impact of clean-up on the environment (cracking of rocks, destruction of unoiled flora and fauna, removal of biological film, etc.) - accept the temporary presence of an oily film after washing (destroyed in the long term by the sun's UV rays) - adjust pressure and temperature according to the requirements and objectives set - possible spread of the pollution: by projection and migration into the sediment - possible recontamination by released oil - toxicity of the cleaning agent: choose a product tested by a recognised organisation (Cedre keeps an up-to-date list) - effectiveness of selected product: conduct an on-site test

ROCKS and INFRASTRUCTURES *3/3*

Phase 2: Final clean-up (1/1)

Techniques - objectives - procedures	Equipment required	Factors to be considered
• systematically recover effluents to stop the pollution from spreading by installing a recovery system: - use or prepare natural run-off channels - should be set up before washing begins - on the water ▶Tech Sheet N 12 - on the foreshore• ▶Tech Sheet N 13	(should be adapted to suit the pollutant and the site) - shovels, etc. - containment equipment: worksite booms, containment or shore-sealing booms, bunds•, pits, etc. - recovery and evacuation means: pump, sorbents, etc. - settling and storage capacities	- tides - agitation of the water body

COBBLES/PEBBLES 1/4

Phase 1: Initial clean-up (1/2)

Techniques - objectives - procedures	Equipment required	Factors to be considered
Prior operations: • **storage site preparation** - facilitate sorting - reduce volumes for evacuation - prevent transfer of the pollution (overflow, leaks, infiltration, etc.)	(should be adapted to suit the pollutant and the site) - area, trenches, (watertight) bunds•, skips, tanks - drainage (rainwater overflow) - screening, sorting - earthmoving equipment (digging) - protective membranes and geotextile	- ecological sensitivity and accessibility of the site - transfer of the pollution (watertight storage, decontamination of trucks) - traffic (should be channelled)
• **litter collection** (removal or temporary movement to the upper beach where it will be out of the reach of the sea) - mechanical recovery - manual recovery - evacuation	- farm machinery (e.g. forks), earthmoving equipment (loader, excavator, bulldozer...) - forks, rakes, brushes, bins, bags. - farm, earthmoving and mining equipment (loaders, skips, dumpers, trailers, etc.)	- accessibility of beach to mechanical equipment - organisation of workforce (very large number of responders) - selectivity
Skimming•/pumping ▶Tech Sheet N 02 and ▶Tech Sheet N 03 ➡ recover large accumulations of pollutant by promoting its concentration and improving recovery rate and selectivity - concentrate the slick using booms: prevent slicks from reaching pebble beaches at all costs - if a slick has washed up on a pebble beach, try to herd the oil to certain areas to facilitate pumping - contain and reconstitute the slick in front of the pumping/skimming means (trawling with sorbent booms, hosing, manual tools) - pump - store and transfer	- floating booms - shore-sealing booms - worksite booms - conditioned sorbents - small boats (where necessary) - planks, scrapers, hoses - very powerful pump, compatible with great lengths of pipe - skimming/pumping equipment (skimmer, pump, vacuum truck or other transfer system) - grating, filter baskets - storage capacities and transfer means	- personal health and safety (protective clothing, masks) - nature and evolution of the oil, viscosity, weathering, thickness of the layer, adherence, etc. - site hazards: often exposed (waves, swell) - accessibility of the shore: areas are often unworkable for ordinary machinery - tidal range (take equipment off site every day)
Manual recovery ▶Tech Sheet N 07 ➡ recover large accumulations of pollutant by promoting its concentration and improving output and selectivity - mainly manual recovery of accumulations and waste - mechanical support where possible	- shovels, buckets - earthmoving equipment, quad bikes	- selectivity - potential presence of the pollutant under the surface: infiltration (fluid pollutant) and/or burying (viscous pollutant)

COBBLES/PEBBLES 2/4

Phase 1: Initial clean-up (2/2)

Techniques - objectives - procedures	Equipment required	Factors to be considered
Surfwashing• ▶ Tech Sheet N 10 ➡ use the sea's energy to separate the pollutant from the pebbles and ensure initial clean-up - move polluted pebbles down to the lower foreshore - recover the freed pollutant in the water or on the upper foreshore•	- earthmoving equipment: tractor loader, loader, bulldozer, trucks - recovery equipment: nets (heavy fuel oil) + mooring, sorbent materials, manual recovery, rollers	- accessibility of beach to mechanical equipment - geomorphological risks (erosion): sensitivity of backshore in the absence of temporary protection (consult an expert geomorphologist) - tidal conditions
Flushing• ▶ Tech Sheet N 08 ➡ dislodge clusters of pollutant stuck to surfaces or trapped in crevices or under boulders - low pressure, high capacity washing with water	- pump unit (3 to 8 bar individual pump, 25 to 25 30 m³/h) - pipes, connectors	- seawater supply: tidal range, agitation of the water body - solidity of substrates (especially old stonework), risk of scouring• - risk of emulsification of the pollutant - risk of penetration of the pollutant into the depths of the substrate
Flooding• ▶ Tech Sheet N 09 ➡ flood a section of the shingle bar in order reduce the vertical infiltration of the pollutant into the sediment during flushing• - create a laminar flow	- perforated pipe - high capacity transfer pump (approximately 100 m³ per hour)	- seawater supply: tidal range, agitation of the water body
Systematic complementary operation: • systematically recover effluents to stop the pollution from spreading by installing a recovery system - on the water ▶ Tech Sheet N 12 - on the foreshore• ▶ Tech Sheet N 13	(should be adapted to suit the pollutant and the site) - containment equipment: containment or shore-sealing booms, bunds•, pits, etc. - recovery and evacuation means: pump, sorbents, etc. - storage equipment	- selectivity - potential presence of the pollutant under the surface: infiltration (fluid pollutant) and/or burying (viscous pollutant)

COBBLES/PEBBLES 3/4

Phase 1: Final clean-up (1/2)

Techniques - objectives - procedures	Equipment required	Factors to be considered
Flushing• ▶ Tech Sheet N 08 ➞ wash the shingle bar in a large quantity of water to dislodge residual pollutant (liquid pollutant) and recover it at a collection point - prepare a collection area, channel the effluents - wash - recover freed waste	- **pump unit** (3 to 8 bar individual pump, 25 to 30 m³/h), - fire or Impact hose - pipes, connectors - shovels - worksite boom (containment, shore-sealing) - skimmer, pump, sorbents - storage tanks, settling of recovered products	- site hazards: often exposed (waves, swell) - ecological sensitivity of site - accessibility of the shore - water supply - tidal range (take equipment off site every day) - nature and evolution of the oil (viscosity, weathering, thickness of the layer, adherence etc.)
Washing at a facility ➞ remove oil from polluted pebbles **Operations prior to washing:** • **manual scraping** ➞remove the bulk of residual layers (viscous pollutant) before pressure washing to increase effectiveness • **effluent recovery** ➞ recover effluents at a collection point, to prevent the pollution from spreading to the lower beach ▶ Tech Sheet N 12 and ▶ Tech Sheet N 13 - system to be installed at the washing site, before the washing operation begins - use or prepare natural run-off channels, line them wherever possible	- scrapers, brushes - bags, bins, etc. - flexible geotextile sheeting, possibly with stakes - boom, skimmer, sorbents, filter - shovels - filtering geotextile - recovery equipment (pumping, sorbents, scoop nets, etc.)	- possible spread of the pollution: migration into the sediment - possible recontamination by remobilised oil - potential presence of the pollutant under the surface: infiltration (fluid pollutant) and/or burying (viscous pollutant)
washing in booths ▶ Tech Sheet N 19 - hot water is needed whereas use of a cleaning agent (for preference a solvent) is not systematically necessary. - adjust pressure according to the size of the pebbles; possibly use mesh bags (such as oyster bags) for small pebbles	- thermal pressure washer (50 to 150 bar, 0 to 90 °C) which can operate with seawater - washing booth (wire mesh structure mounted on a stand) - hoses, pipes, connectors - (possibly) selected cleaning agents (solvents), with horticultural spreading equipment	- recovery is easier in the absence of a cleaning agent - accept the temporary presence of an oily film after washing (destroyed in the long term by UV rays) - choose a product tested by a recognised organisation and conduct a test to confirm effectiveness on-site - fragility of pebbles

COBBLES/PEBBLES 4/4

Phase 1: Final clean-up (2/2)

Techniques - objectives - procedures	Equipment required	Factors to be considered
Washing in a concrete mixer ▶ Tech Sheet N 20 - hot water is needed whereas use of a cleaning agent (for preference a solvent) is not systematically necessary **Washing in a concrete mixing truck** ▶ **Tech Sheet N 21** - hot water is needed whereas use of a cleaning agent (for preference a solvent) is not systematically necessary - the use of a cleaning agent (for preference a solvent) is not generally necessary	• **concrete mixer** - system for rinsing over grating (optional) - effluent recovery system - hot water (pressure washers) • **concrete mixing truck** - cleaning agent (solvent) - hot water (pressure washers) - system for rinsing over grating - effluent recovery and settling system - storage of effluents and pollutants	- sensitivity of the backshore in the temporary absence of protection, previously provided by the pebbles - available surface area - efficiency and toxicity of the cleaning agent - return the pebbles to the extraction site
Surfwashing• ▶ Tech Sheet N 10 ➡ use the sea's cleaning power to complete the washing of pebbles or to clean lightly polluted pebbles - deposit washed pebbles on the lower foreshore - pollutant recovery system not normally necessary - NB: in the case of small-scale scattered pollution, simply throw lightly oiled pebbles into the waves by hand	- loader, tipper trucks, wheelbarrows - mop nets if necessary (in the case of tarballs)	- sensitivity of the backshore in the temporary absence of protection, previously provided by the pebbles - check that there is no pollutant along the strandline•
Bioremediation ▶ Tech Sheet N 27 ➡ accelerate natural breakdown of oil by bacteria and other microorganisms - assess the possibility of implementing this technique - spread bioremediation agents - set up monitoring	- expert - bioremediation agent + spreader	- only on very light or residual pollution on a sheltered site - feasibility (assess according to procedures defined by experts) - efficiency and toxicity of the product

Phase 1: Initial clean-up (1/3)

Techniques - objectives - procedures	Equipment required	Factors to be considered
Pumping at the water's edge ▶ Tech Sheet N 02 ➞ recover accumulations by enhancing their concentration and improving recovery rate and selectivity		
(a) Prepare storage site (liquid to slightly viscous pollutants) - facilitate sorting - reduce volumes for evacuation - restrict the spread of the pollution	(should be adapted to suit the pollutant and the site) - areas, trenches, bunds•, skips, (watertight) tanks - drainage (rainwater overflow) - screening, sorting - earthmoving equipment (digging) - protective membranes and geo-textile	- ecological sensitivity - site accessibility - transfer of the pollution (watertight storage, decontamination of trucks) - traffic (should be channelled)
(b) Concentrate slicks on the beach - deflect the pollutant towards the beach (floating boom in a staggered configuration along large beaches positioned against the flow of long-shore drift) - contain the pollutant trapped in coves (retention boom) - stop the slick from stranding (case of low tidal range) using a longitudinal boom positioned at the water's edge (pump pollutant over the boom)	- floating booms - shore-sealing booms	- personal health and safety (protective clothing, masks), decontamination - accessibility of the shore - agitation of the water body (currents, swell, wind) - tidal range
(C) Contain and reconstitute the slick in front of the pumping/skimming equipment: - by trawling (worksite booms, sorbent booms) - by scraping (planks, scrapers, brushes) - by hosing	- worksite booms - conditioned sorbents - planks, scrapers, hoses - small boat	- accessibility of the shore - agitation of the water body (currents, swell, wind) - tidal range
(d) Pump - prevent clogging of the pumps: use a screen or another system to retain debris	- skimming/pumping equipment (skimmer, pump, vacuum truck or other transfer system) - grating, filter baskets - storage capacities and transfer means	- nature (emulsion, viscosity) and evolution of the pollutant according to the temperature - presence of solid debris - draught of skimmers and compatibility with depth of water
(e) Separate - promote the separation of oil and water: emulsion breaking, settling - evacuate the products recovered	- settling tanks/separator - transfer pumps - emulsion breaker• - trucks suited to the pollutant	- recovery of liquids from settling - sensitivity and accessibility of the site - traffic lanes

Phase 1: Initial clean-up (2/3)

Techniques - objectives - procedures	Equipment required	Factors to be considered
Recovery on beaches (1/2) ➞ recover accumulations by enhancing their concentration and improving recovery rate and selectivity		
Prior operations: • **storage site preparation** - facilitate sorting - reduce volumes for evacuation - prevent transfer of the pollution (overflow, leaks, infiltration, etc.)	(should be adapted to suit the pollutant and the site) - area, trenches, bunds•, skips - (watertight) - tanks, containers, etc. - drainage (rainwater overflow) - screening, sorting - earthmoving equipment (digging) - protective membranes and geotextile	- ecological sensitivity and accessibility of the site - transfer of the pollution (watertight storage, decontamination of trucks) - traffic (should be channelled)
• **litter collection** (removal or temporary transfer to the upper beach where it will be out of the reach of the sea) - mechanical recovery - manual recovery - evacuation	- farm machinery (forks.) earthmoving equipment (loader, shovel, bulldozer...), specialised means (sifting and raking beach cleaners•, mechanical rakes...) - rakes, brushes, bins, bags - farm, earthmoving and mining equipment (loaders, skips, dumpers, trailers, etc.)	- accessibility of beach to mechanical equipment - organisation of workforce (very large number of responders) - selectivity: avoid removing too much sand in a bid to immediately obtain an apparently clean beach
Scraping the layer of oil deposited on the sand ▶ Tech Sheet N 04 (towards accumulation areas, then pumping or recovery using shovels)	- earthmoving equipment: loader or rubber blade - manual tools: planks, scrapers (as used in pig sties), hoses	- personal health and safety (protective clothing, masks) - selectivity (layer thickness) - procedure: methodical progression
Pumping on the foreshore• ▶ Tech Sheet N 03 - promote the concentration of slicks and improve recovery rate - prevent clogging of the pumps: use a screen or another system to retain debris - reduce volumes for evacuation: promote the separation of oil and water (emulsion breaking, settling)	- worksite booms - skimming/pumping equipment (skimmer, pump, vacuum truck or other transfer system) - screens, filters, etc. - storage capacities and transfer means - settling tanks/separator - transfer pumps - emulsion breaker• (+ injector) - trucks suited to the pollutant	- personal health and safety (protective clothing, masks) - nature (emulsion, viscosity) and evolution of the pollutant according to the temperature - agitation of the water body and tidal range - presence of solid debris - draught of skimmers and compatibility with depth of water - recovery of liquids obtained after settling - sensitivity and accessibility of the site - traffic lanes
Sand screening ▶ Tech Sheet N 05 ➞ screen the sand to extract the clusters of viscous pollutant - follow procedures (selectivity) and environmental recommendations	- beach cleaners•: adaptations required - tractor with loader for waste evacuation	- litter (to be removed prior to operations) - sand must be suited to operation: dry, fine and homogeneous - potentially high impact at the foot of dunes

Phase 1: Initial clean-up (3/3)

Techniques - objectives - procedures	Equipment required	Factors to be considered
Recovery on beaches (2/2) ➞ recover large accumulations of pollutant by promoting its concentration and improving recovery rate and selectivity		
Removal using rollers ▶ Tech Sheet N 06 ➞ selectively remove the pollutant stranded on the surface of the beach	- rollers (various models with various types of tractors)	- litter (to be removed prior to operations) - sand must be suited to operation: saturated with water, hard and homogeneous - sufficiently viscous, sticky, fresh oil
Manual recovery ▶ Tech Sheet N 07 ➞ selectively remove the pollutant stranded on the surface of the beach - by direct collection - concentration: scraping and raking - by screening	- manual tools: forks, different rakes and brushes (leaf rake, garden brush), picks, sieves, etc. - bins, bags - mechanical support: farm machinery, earthmoving equipment (loaders, skips, dumpers, trailers, etc.), quad bikes	- personal safety: protective equipment - organisation of workforce (very large number of responders) - selectivity: avoid removing too much sand in a bid to immediately obtain an apparently clean beach - accessibility of beach to mechanical equipment
Flushing• ▶ Tech Sheet N 08 ➞ displace fluid pollutant stranded on the beach - low pressure, high capacity washing with water	- fire or Impact hose - pumps (3 to 8 bars, 25 to 30 m^3/h) - flat rather than solid water jet	- seawater supply: tidal range, agitation of the water body - risk of penetration of the pollutant into the depths of the substrate
Systematic complementary operation: • systematically recover effluents to stop the pollution from spreading by installing a recovery system - on the water ▶ Tech Sheet N 12 - on the foreshore• ▶ Tech Sheet N 13	- (should be adapted to suit the pollutant and the site) - containment equipment: containment or shore-sealing booms, bunds•, pits, etc. - recovery and evacuation means: pump, sorbents, etc. - settling and storage capacities	- tides - agitation of the water body

Phase 2: Final clean-up (1/1)

Techniques - objectives - procedures	Equipment required	Factors to be considered
Surfwashing• ▶Tech Sheet N 10 ➞ complete clean-up or separate residual pollutant either in the form of micro-tarballs (as an alternative to screening) or fluid pollutant (stained sand) - move polluted sediment down to the lower foreshore (pebbles and sand) - recovery of any freed clusters of pollutant	- tracto-loader, loader on wheels, bulldozer, trucks - recovery equipment: nets (viscous pollutant), sorbent materials, manual recovery, rollers	- ecological sensitivity: geomorphological characteristics (consult a geomorphologist) - tidal conditions
Flushing ▶Tech Sheet N 08 ➞ wash surfaces with a large quantity of water - move residual fluid oil towards a collection point - recover effluents	- fire hose, Impact hose + low pressure pump - light boom, sorbent + pumps, skimmers, sorbents	- water supply - direction and pressure of water jet (avoid solid water jets, position the jet at an angle) - temporary quicksand
Drainage ▶Tech Sheet N 15 ➞ promote the run-off of pollutant in areas of ground water emergence - dig oblique draining trenches, towards a ditch at the lower end of the beach - recover effluents	- tractor + plough with 2 ploughshares for drainage trenches	- emergence of ground water - fluidity of the oil - repetition of the operation
Tilling ▶Tech Sheet N 16 ➞ case 1 - in water: cause fluid oil trapped in the sand to be placed in suspension and recovered at the water surface - operation conducted in shallow waters at flood tide• (20 to 30 cm) - recovery of floating effluents ➞ case 2 - out of the water: promote the aeration of sand contaminated by a fluid pollutant (stained sand)	- tractor + harrow or claw, or scarifier or rotovator (cases 1 and 2) - recovery of effluents on water (worksite boom, sorbents, scoop nets, skimming) (case 1)	- tidal conditions - homogeneous sediment - repetition of the operation

Phase 2: Final clean-up (1/2)

Techniques - objectives - procedures	Equipment required	Factors to be considered
Underwater agitation ▶Tech Sheet N 11 ➞ cause fluid oil trapped in sand or stones to be placed in suspension and recovered at the water surface - scour• the polluted sand at high tide - recover floating effluents	- fire or Impact hose - low pressure pump - light boom, sorbent - pumps, skimmers, sorbents	- repetition of the operation - fluidity of the oil - temporary quicksand
Sand screening ▶Tech Sheet N 05 ➞ remove residual small tarballs - proceed methodically by slowly screening in strips (beach cleaner•)	- large and small beach cleaners• - manual screening (may be necessary in vegetated areas): sieves, nets, etc.	beach cleaner•: - nature of substrate: fine-grain, dry, homogeneous sand, slight slope - potential ecological impact for vegetation at the foot of dunes - selectivity: risk of large-scale removal of clean sand, if operation is poorly implemented
Bioremediation ▶Tech Sheet N 27 ➞ accelerate natural breakdown of oil by bacteria and other microorganisms - spread bioremediation agents	- bioremediation agents - spreader	- implementation: only on very light or residual pollution on a sheltered site (assess according to procedures defined by experts) - efficiency and toxicity of the product - set up monitoring

Initial clean-up (1/1)

Techniques - objectives - procedures	Equipment required	Factors to be considered
Leave alone ▶ Tech Sheet N 01 ➞ do not generate additional environmental damage by conducting unnecessary operations - site surveying To be considered as a priority especially in the case of a small or moderate spill	- small flat-bottomed boat - possibly hovercraft	- high ecological sensitivity - the ecological impact of response can be more harmful than that of the oil itself - very low bearing capacity: response difficulties - pollutant unlikely to remain on site - intervention should only be considered in the case of deposits of large slicks of heavy fuel oil or in the case of buried pollutant
Manual recovery ▶ Tech Sheet N 07 ➞ remove clusters of polluted debris and large accumulations of oil, especially when easily accessible (generally only during phase 1) - on foot - from small boats	- manual tools: forks, shovels, scrapers, rakes, etc. - bins, stretchers, etc. - artificial pathways (duckboard, driving tracks, grating, geotextile) - small flat-bottomed boat, floating pontoon, etc.	- personal health and safety (protective clothing and rescue measures) - very low bearing capacity - selectivity - team organisation: accurately define the response procedure and the different positions
Flushing ➞ move accumulations of mobilisable pollutant towards a collection point at low tide - case 1: flushing• at very low pressure ▶ Tech Sheet N 08 - case 2: flooding by laminar flow ▶ Tech Sheet N 09	- fire or Venturi• effect hose - supply: small pump, possibly floating, or high capacity transfer pump supplying several hoses via a manifold - perforated tube ("fountain") - artificial pathways - floating pontoon, small boats - containment (floating boom), recovery (pumping or sorption, scoop nets) and storage equipment	- water supply is very often problematic: contain water in trenches or seawater reservoirs - destructive effect on the ground if the pressure is too high
Resurfacing ➞ detach accumulations of pollutant so that they float, in order to recover them at the (sub)surface (skimming, sorption, scoop nets, etc.) - case 1: via slight surface agitation ▶ Tech Sheet N 11 - case 2: via any other low intensity mechanical agitation: - either of the water at the (sub) surface: using an agitator, propeller, ventilator or by bubbling - or of the pollutant: using light equipment vibrating on the bottom (chains, etc.)	Assess in accordance with the consistency of the mud/silt and the viscosity of the pollutant - flat-bottomed boat - small supply pump, possibly floating pump - fire or Impact hose - compressor - agitator, propeller, ventilator - chain - containment (floating boom), recovery (pumping or sorption, scoop nets) and storage equipment	- personal health and safety (protective clothing and rescue measures) - destructive effect on the ground if the pressure is too high: create low to very low pressure or agitation on the water body - resource organisation: accurately define the response procedure and the different positions

Initial clean-up (1/1)

Techniques - objectives - procedures	Equipment required	Factors to be considered
Leave alone ▶Tech Sheet N 01 ➙ do not generate additional environmental damage by conducting unnecessary operations - site surveying - monitor evolution/regular surveying of the marsh and the pollution To be considered as a priority especially in the case of a small or moderate spill	- small flat-bottomed boat (optional)	- high ecological sensitivity of this type of site - low bearing capacity - the ecological impact of the response is potentially more harmful than that of the oil - intervention should only be considered in the case of major deposits of viscous oil or in the case of buried pollutant - call upon the services of an expert botanist
Prior operations: • **Preparation of pathways and storage points** ➙ limit the harmful effects of intervention especially due to pedestrian and vehicle traffic: reduce and channel traffic, define, cordon off and protect pathways and storage sites	- stakes, tape, etc. - ground protection (pathways and storage points): geotextile, sheeting, wickerwork fencing, planks, etc.	- ecological sensitivity - definition according to the sensitivity of the vegetation (ask an expert botanist)
Manual recovery ▶Tech Sheet N 07 ➙ remove polluted debris and large accumulations of oil, especially when easily accessible (this is generally the only phase): - on foot - from small boats	- manual tools: forks, shovels, scrapers, rakes, etc. - bins, stretchers, etc. - artificial pathways: duckboard, driving tracks, grating, geotextile - small flat-bottomed boat, floating pontoon, etc. - possibly quad bike for support	- personal health and safety - team organisation: accurately define the response procedure and the different positions - sensitivity to trampling - selectivity - supervision by a botanist
Flushing ➙ move accumulations of mobilisable pollutant towards a collection point, either in the form of a depression (pool, channel) or on the water (containment boom) - case 1: flushing at low pressure ▶Tech Sheet N 08 - case 2: flooding• by laminar flow ▶Tech Sheet N 09	- small supply pump, possibly floating, or high capacity transfer pump supplying several hoses via a manifold - fire hose - perforated tube ("fountain") - artificial pathways - small flat-bottomed boat, floating pontoon, etc. - light containment boom - containment (floating boom), recovery (pumping or sorption, scoop nets) and storage equipment	- water supply is very often problematic: contain water in trenches or seawater reservoirs - potentially destructive effect of hosing (pressure)
Cutting vegetation ▶Tech Sheet N 25 ➙ cut back and remove the above-ground parts of heavily oiled or smothered plants, in order to reduce the impact and remove the source of chronic contamination - on foot - from the water	- manual cutting tools (sickle, scythe, pruning sheers, backpack brushcutter, etc.) - weed-cutting launch• - big bags• - artificial pathways - small flat-bottomed boat - evacuation means (stretchers, boat, quad bikes for support, etc.)	- only in the case of heavy pollution and upon recommendation by a botanist (who supervises and oversees the worksite) - variable effects (beneficial to harmful) according to the species and the seasons - potential new arrivals of pollutant - site frequented or not by birds - safety and organisation of personnel

Final clean-up (1/1)

Techniques - objectives - procedures	Equipment required	Factors to be considered
Drainage ▶Tech Sheet N 15 ➙ free the pollutant trapped in the ground and the vegetation by digging small trenches converging at a lower collection point (pool, channel) or on the water (containment boom) Possible use of hoses: - case 1: flushing at low pressure ▶Tech Sheet N 08 - case 2: flooding• by laminar flow ▶Tech Sheet N 09 • systematically recover effluents to stop the pollution from spreading by installing a recovery system - on the water ▶Tech Sheet N 12 - on the foreshore• ▶Tech Sheet N 13	- shovels, spades, etc. - containment system (light sorbent booms, improvised filter dams in channels, etc.) - recovery means (sorption, pumping) - small supply pump, possibly floating pump - fire or Impact hose - high capacity transfer pump supplying several hoses - perforated tube ("fountain") Should be adapted to suit the pollutant and the site - containment equipment: containment or shore-sealing booms, pits, etc. - recovery and evacuation means: pump, sorbents, etc. - settling and storage capacities	- only on marshes heavily polluted by fluid oil - water supply is very often problematic: contain water in trenches or seawater reservoirs - destructive effect on the ground if the pressure is too high - tides - agitation of the water body
Resurfacing ➙ detach major accumulations of pollutant so that they float, in order to recover them at the (sub)surface: - case 1: via slight surface agitation ▶Tech Sheet N 11 - case 2: via any other low intensity mechanical agitation of the water at the (sub)surface, using an agitator, propeller, ventilator or by bubbling	Assess in accordance with the type of marsh and the viscosity of the pollutant - flat-bottomed boat, pontoon - small supply pump, possibly floating pump - fire or Venturi• effect hose - compressor - agitator, propeller, ventilator - containment and recovery equipment (pumping, skimming or sorption, scoop nets) and storage capacities	- personal health and safety (protective clothing and rescue measures) - destructive effect on the ground and vegetation if the pressure is too high: create low to very low pressure or agitation on the water body - resource organisation: accurately define the response procedure and the different positions
Scarification ▶Tech Sheet N 26 ➙ facilitate natural degradation of the oil - breaking of crusts	- manual tools: rakes, scarifiers	- presupposes intervention several months after the spill
Bioremediation ▶Tech Sheet N 27 ➙ accelerate natural breakdown of oil by micro-organisms - spread bioremediation agents	- bioremediation agents - spreader	- only on light or residual pollution - suitability (assess according to the procedures defined by experts) - efficiency and toxicity of the product - monitoring must be organised

Assessing techniques

Assessing the recovery rate of each technique

The indicated daily performance of each technique is liable to vary considerably according to the information source and the calculation method. The daily recovery rate will vary according to the pollution and of course the operators mobilised. There are many influencing factors, in particular:

- the characteristics of the pollution (extent, types of deposits, evolution): the performance towards the end of operations (or in the case of scattered pollution) will be considerably lower than that observed at the start of operations (or in the case of heavy pollution). When the oil becomes more scattered and forms thinner layers, it is more difficult to recover and requires more movements by operators and/or machinery, which means more unproductive time for ultimately a smaller volume of waste;
- the site characteristics:
  - accessibility and practicability for pedestrians and vehicles: possibility of a lot of downtime, for instance pending the arrival of equipment on the beach, during movements around the site, waste evacuation, etc.;
  - the tidal range: on a non-tidal coast, clean-up operations may focus on a narrow strip of shoreline, whereas on a coast with a high tidal range, the pollution will affect a wider section of foreshore•, up to several tens of metres, to varying degrees;
  - the weather conditions: high or low temperatures, strong winds, rain, etc. create difficult working conditions and penalise the recovery rate;
  - season and latitude, which determine the daylight hours and weather conditions.
- disparities between clean-up teams (motivation, supervision, adequate resources, experience, training) and, over time, within the same team (discouragement, fatigue).

In addition, the recovery rate varies according to the assessment methods used, depending on whether they are based on:

- potential gross performance, either given by the manufacturer or extrapolated from short-term observations (< 1 hour);
- performance calculated based on the number of hours actually worked (minus downtime) or not;
- gross performance calculated based on the entire clean-up chain and the entire workforce in the field (i.e. collection plus transfer to the intermediate storage site, including operators assigned to tasks other than collection).

It is therefore difficult to compare the recovery rate of operations that would appear to be equivalent and to provide precise values for recovery rates. The figures given in this guide are therefore orders of magnitude.

Assessing the cost of operations

Any a priori assessment of clean-up costs must be taken with caution. To assess the cost of a technique, several parameters must be taken into consideration, in particular the nature, origin, number and time period of operators and equipment on site, as well as the specificities of the sites.

The experience, motivation and efficiency (in terms of recovery rate and selectivity) of clean-up teams will largely determine the cost of operations. It is therefore impossible to determine in advance the precise cost of any given operation, due to the wide variety of operators involved in shoreline clean-up: military personnel, fire-fighters, government employees, local authority employees, private companies, volunteers.

In the context of a public procurement contract, the reference framework will vary tremendously depending on whether the obligation is one of means or of result. The reference area may be either a linear distance (a linear metre), or a surface area or volume (m^2, m^3); it may be defined either as the surface area actually oiled or as the overall surface area affected. The cost may also be calculated based on a time period (man-day or team-day), including or excluding equipment costs.

A private contractor will tend to adjust its unit price according to the quantities to be cleaned (effect of scale), logistical difficulties (access, environmental constraints) and organisational difficulties which, for identical substrates, differ from one site to another and one season to another for the same site (adverse weather conditions, daylight hours, accommodation facilities, for example).

Aside from any profit considerations, the evaluation of these various parameters for the same sites by different service providers can vary fourfold, and sometimes even more.

In addition, clean-up costs sometimes include the cost of processing the collected waste (including transport): this cost generally represents a non-negligible, sometimes major, proportion of the overall cost of the response. This cost must be taken into account when comparing different teams, as the volume and type of waste recovered greatly depend on the recovery technique used (selectivity).

Estimating resource requirements

The volume of resources required and the duration of operations are two elements that are difficult to accurately estimate in advance for a given site and a specific spill. However, in order to estimate requirements and allocate the available resources as effectively as possible, the following data can be used as a rule of thumb (see box on page 88); the figures should be adjusted as soon as more information is available on the characteristics of the pollution and the site, as well as on the operators' skills.

Guideline for estimating resource requirements

- **basic unit**: 10-person team with a team leader;
- **pumping/skimming equipment**: hourly rate: take an average expected rate of 1/4 or even 1/5 of the theoretical instantaneous rate to account for downtime for various reasons (breakdowns, movements around the site, etc.).;
- **traditional pumping/recovery equipment** (agriculture, public works, sanitation):
  - → personnel required: at least 2 operators per vehicle (driver + assistant) assigned exclusively to one specific vehicle;
  - → recovery rate: (pumping: see above) scraping/sediment removal: calculate as follows: swath width covered by the blade or bucket multipling the thickness of sediment removed (grader: 2-3 cm; bucket loader without flexible scraper: 10-25 cm; bulldozer: 20-50 cm; excavator: 25-50 cm) x vehicle speed (varying between 1 and 3 km/h). (The result obtained should be adjusted to take into account on-site downtime: the 1/4 or 1/5 rule can also be applied here);
- **rock washing**: the average area covered by an operator varies greatly, from 1 to around 50 m^2/h, depending on the nature of the pollutant and the site, and whether or not the calculation includes equipment and site preparation time, spraying of a cleaning agent and the installation of effluent recovery. Provide 3 to 5 pressure washers per 10-person team and rotate operators every hour or two as follows: 1 for washing, 1 for the containment and recovery system, 1 for monitoring and supplying water and for adjusting the machines;
- **manual recovery**: on average, a 10-person team operating on a sandy beach with no major obstacles to movement can cover, depending on the extent of the pollution and the width of the affected beach, approximately 100 to 300 linear metres of beach per day (including waste evacuation from the upper beach). The daily recovery rate per person varies between 0.5 m^3 and a maximum of 2 m^3, depending on the type of beach and pollution.

Worksite management

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Worksite definition

▶Tech Sheet G 01

This is a fundamental aspect of the response, designed primarily to ensure the safety of operators (and the general public) and to prevent damage to the environment and equipment.

In particular, it is important to prevent indirect damage from the spill, i.e. environmental damage caused by the response operations, by taking the necessary precautions to protect the soil from degradation and pollution transfer.

In addition to these preventive and protective measures, worksite management also encompasses all the necessary procedures to optimise the work and facilitate the smooth running of operations, particularly as regards the definition, organisation and monitoring of clean-up operations.

Worksite management also includes the demobilisation phase, which involves cleaning and, where necessary, restoring the various sites used and their surrounding area: the worksites themselves, waste storage sites, equipment storage points, site facilities (base camp or simple hut), etc., including any temporary developments (in particular for access) that could ultimately alter the function of the site.

All worksites must be well organised and methodical, however the working conditions (hygiene, comfort and safety), human and material resources, and logistical and environmental constraints will differ according to the type of worksite.

We can identify at least **three types of worksite**:

- **simple** worksites (manual recovery, for example): the worksite does not normally present any real risks in terms of access and movement. The work does not require any technical or mechanical skills, apart from logistical support;
- **technical** worksites (pumping or rock washing, for example): the work requires the use of specific techniques and special mechanical equipment; the site may present certain difficulties in terms of access or movement;
- **specialised** worksites (e.g. response on cliffs or submerged slicks): the site environment and working conditions present obvious risks that require specialised professionals qualified to work in these high-risk areas (e.g. rope access technicians or divers).

In order to optimise the response and reduce the environmental impact, it is necessary, before conducting clean-up operations, to precisely define:

- the appropriate clean-up techniques depending on the nature of the shoreline affected and the type of deposits;
- the limits of the response and the level of clean-up (the use of certain clean-up techniques in certain sensitive areas may be detrimental to the environment);
- the general organisation of the worksite, the location of access points and storage sites on the upper beach, especially when operating on a natural site.

In this case of simple worksites, this task is a simple formality; however the attention and skills needed to accomplish this task are proportional to how technical and specialised the worksite is. In most cases, it therefore requires the involvement of technical and environmental experts, and the presence of representatives of the local authority and the site manager (and possibly various other organisations, such as insurers) is also recommended. This same team will conduct the final site inspection.

Mechanical clean-up operation

Manual clean-up operation

Clean-up operation conducted by a rope access technician

Personal safety and worksite security

▶ **Tech Sheet G 02**

Awareness of risks and the associated prevention measures should be raised from the outset, and repeated as often as necessary, particularly during long-lasting operations, during team or operator handovers. This applies to all worksites, even non-technical ones, especially if they are located near heavy machinery, since on-foot operators, whether volunteers or hired staff, are generally not used to working in the presence of this type of machinery, which can move at high speed (and vice versa for machinery drivers).

▶ **Tech Sheet G 03**

Ensuring worksite safety greatly enhances the safety of both operators and the general public. It is important to:

- call on **specialised professional operators** for specialised operations;
- prevent **site access** to all unauthorised individuals;
- **mark out work areas and facilities**;
- comply with **safety rules** relating to general site conditions and those specific to the different machinery and techniques used.

National labour laws also apply to shoreline clean-up work, particularly when the situation is no longer considered an emergency, at which point an expert or a health and safety protection coordinator may need to be called in. In all these areas, they will be able to provide considerable assistance in terms of site safety during the design, preparation and operational phases.

To ensure operator safety, certain measures must be complied with, in particular:

- **Personal Protective Equipment** (PPE•) must be worn at all times, and reminders must be regularly given, especially for high-risk operations;
- clean, sheltered areas (breaks, meals, changing rooms);
- decontamination arrangements ▶ **Tech Sheet G 04**: create decontamination stations or simple scrub-down areas for operators, equipment and vehicles in order to reduce the transfer of oil off the beach and make conditions more comfortable for operators.

Worksite with clean area marked out

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Environmentally-friendly practices

▶ **Tech Sheet G 06**

It is essential to systematically prevent harmful effects generated by the response, i.e.:

- **soil degradation** and damage to sensitive biotopes (dunes, maritime grassland, etc.) due to poorly managed actions: intense, uncontrolled pedestrian and vehicle traffic; unnecessary and inappropriate developments (levelling of the ground); installation of worksite facilities (huts, fire-fighting equipment, tanks, etc.) or storage areas, in places of ecological interest (botanical, faunal, geological or hydrological);
- **soil contamination** due to transfer of oil from the beach via oiled equipment (boots, wheels, response equipment) or overflow or leaks from transfer and storage capacities.

To fit with the **environmental constraints**, certain actions should be implemented to reduce the impact of the response on the environment:

- preparation of storage sites and worksite facilities on the upper beach and the backshore:
    - select a location at a distance from any sites of ecological or heritage interest, taking into account the sensitivity of the vegetation, protection against oil spillages and leaks, etc.
    - have botanical or environmental experts identify worksite locations, taking into account the ecological sensitivity at the time: for instance, a worksite could be shifted a few metres to several dozen metres to avoid destroying protected or rare plant species, or postponed during bird migration or nesting periods.
- preparation of access routes and traffic lanes:
    - identify suitable, authorised access points for the different types of vehicles (sometimes requiring protective measures);
    - channel pedestrian and vehicle traffic to avoid contaminating initially unoiled areas, in particular the backshore but also sometimes the lower part of the beach, and to reduce degradation of the soil and plant cover, by laying an artificial track (simple geotextile, specific track or boards), as soon as necessary;
    - mark out areas of the beach to be protected from traffic: the foot of dunes, for example, to prevent beach cleaners• and other heavy machinery from destroying the embryonic dune;
    - draw up a traffic plan (with guidance and signposting) whenever operations on a site with restricted traffic capacity are set to last for a long time;
    - use light machines such as quad bikes with low-pressure tyres, while taking certain driving precautions (low speed, slow turning, etc.);
    - on sensitive natural sites that are

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inaccessible by land or sea, transport response equipment either by carrying it on operators' backs or by helicopter in the case of a combined operation (several sites, opportunity to bring in personnel);

- comply with any local guidelines for site protection and instructions provided by experts during the worksite definition phase;
- remove all waste generated by the worksite itself (packaging and miscellaneous rubbish);
- restore the site prior to demobilisation.

Ground protection and marking out vehicle tracks

Preparing an access path to the clean-up site

Equipment maintenance

▶**Tech Sheet G 06**

Operations will run considerably more smoothly if the equipment is and remains reliable, and if maintenance and repair operations can be carried out on site.

For operations to run smoothly, particular care must be given to the equipment. This means not only packing it away in a sheltered place, but also maintaining it.

It is crucial to organise regular checking and maintenance. A breakdown can severely penalise operations; repairs must be organised.

Logistics area adjacent to a clean-up site

Waste management

▶ **Tech Sheet G 07**

The size of primary storage facilities on the upper beach or backshore will vary with that of the clean-up sites. They can range from a simple daily deposit point for a few dozen to a few hundred kilos (in bulk or packaged in bags, big bags• or skips) to a larger site grouping together the waste from such deposit points, to constitute a primary buffer storage site.

All these primary buffer storage sites cannot be identified in contingency plans.

FOR MORE INFORMATION

For advice on this essential phase of the response, please refer to the guide published by Cedre:

"Oil Spill Waste Management"
Operational guide

Here, only the specificity of upper beach or backshore sites is addressed.

Primary storage site

Worksite records

▶ **Tech Sheet G 08 and annexes**

Worksite record-keeping involves logging the human resources and equipment used on the different worksites.

To do so, forms must be completed at the end of each day to summarise the operations carried out and record the resources deployed for each site (an example of such a form is provided as an appendix).

These daily documents are a key source of information for response management:

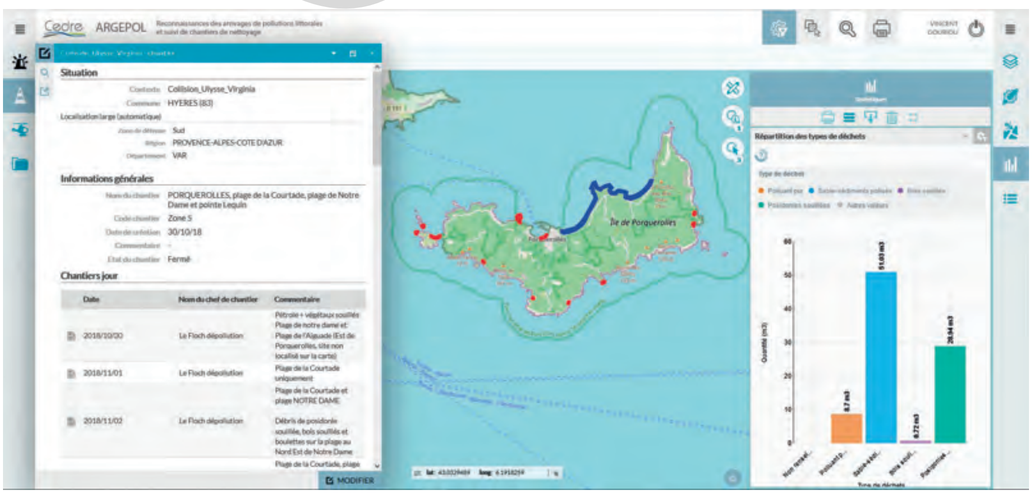
- **during the crisis**, they constitute a valuable management and communication tool, in that they offer a constant overview of human and material resources deployed on the worksites and provide a past history, either global or detailed, of the worksites (number, personnel and equipment used...).
- **after the crisis**, they are the basis for experience feedback, archiving and even compensation procedures.

In France, a computerised information feedback and processing system was developed by Cedre during the *Prestige* spill (2002).

With this system, dubbed ARGEPOL•, the situation can be monitored from the moment the pollution is first observed through to shoreline restoration and beyond.

It keeps precise daily records of the number of operators mobilised on a site, their organisation, the work carried out (clean-up techniques) and the equipment used (type of equipment, number, origin). Multimedia documents associated with a worksite or a pollution observation can be uploaded.

This system is able to automatically generate reports and maps based on the data entered. These documents can then be submitted to the authorities as attachments.



Screenshot of ARGEPOL•

Tech Sheets

The different techniques used in phase 1 and phase 2 are summarised in specific Tech Sheets. There are also Tech Sheets dedicated to the protective measures that should be taken before the spill reaches the shore and to the organisational and safety measures that should be taken to ensure that the worksite and the entire response operation run smoothly.

These sheets are organised into 3 categories:

- **P** Tech Sheets: **shoreline protection techniques** (other than containment booms) (▶**Tech Sheets P 01** to **P 05**);
- **N** Tech Sheets: phase 1 and phase 2 **clean-up techniques** (▶**Tech Sheets N 01** to **N 27**);
- **G** Tech Sheets: **worksite management measures** relating to personal safety, environmental protection, worksite organisation and waste management (▶**Tech Sheets G 01** to **G 08**).

For the clean-up techniques, the Tech Sheets outline the following key characteristics, procedures, limitations and constraints:

- **the scope of use**: the type(s) of substrate(s) concerned, the type(s) of pollution (extent) and pollutant (viscosity) and the type of shore (sea with or without tides);
- **the resources required**, specifying the basic equipment and additional resources that may be required or preferable for its deployment;
- **a presentation**, comprising the description, principles and purpose of the technique;
- **the conditions of use**, describing favourable or limiting factors, inherent to the characteristics of the pollution (and the pollutant), the substrate and the site (environmental conditions in the broadest sense);
- **impacts on the environment**: the potential detrimental physical and biological effects of the technique;
- **performance:** the average recovery rate, personnel required, types of waste generated;
- **any other comments to be taken into account**: observations, advice and recommendations relating to technical or organisational aspects.

Fact sheets

E

Main shoreline protection techniques (other than booms)

Protecting channels using nets and filter dams

Scope of use

Substrates: marsh, mudflat

Pollution: all types

Pollutant: viscous to highly viscous

Sea: with or without tides

Straw dam

Oyster shell dam

Resources required

➞ case 1: fine mesh nets, stakes

➞ case 2: mesh (chicken wire or plastic mesh) or a fine-mesh netting (eel nets, scaffold netting, etc.)

➞ case 3: filtering geotextile

- planks, stakes
- stiffeners (cables, etc.)
- absorbent materials (straw, shells, etc.)

Additional equipment:
- excavator
- water hoses (to loosen sediment before driving stakes into the seabed)
- winch

Description/Principle

Involves setting up makeshift systems to retain the largest clusters of pollutant in the water column to prevent marshes and especially production basins (salt production, oyster farming, etc.) from being polluted. The type of device varies according to the type of channel and the resources needing protected. According to the case in hand, the options are:

➞ case 1: narrow channel: system made of an ordinary straight or oblique fine-mesh (5 to 8 mm) net, fitted with floats and ballast, positioned obliquely (deflection mode), in chevron or herringbone mode depending on current speed. Nets can also be positioned successively at intervals along the river. A ballast chain along the lower edge of the net acts as a pressure release system: in the case of overpressure (increased current or clogging with diverse debris) it will temporarily lift up;

➞ case 2: wider channel: a filter dam made of a double framework (stakes, planks, metal stiffeners) incorporating filtering materials (straw, oyster shells etc.) held in place by netting and mesh (metal or plastic).

➞ case 3: Microtidal sites with low currents: selective filtering geotextiles (that let water through but not oil) maintained in position vertically with stakes
These systems are high maintenance (to ensure durability and when removing the trapped oil and oiled materials). The same channel can be blocked by a series of different types of devices.

Conditions of use

Pollution: viscous pollutant, heavy fuel oil
Substrate: load-bearing embankments
Site: marsh

Impact on the environment

Physical: temporary modification of hydrological conditions; possibly some turbulence in places perhaps with scouring• depending on current speed and the size of the watercourse
Biological: risk of fish being trapped in the system if the entire water column is boomed.

Performance

Recovery rate: variable depending on the type of protection and channel characteristics (width, current, distance, environmental sensitivity)
Implementation: variable depending on the type of protection (as is the case for maintaining the protective structure and recovering the oil)
Waste: pollutant, oiled nets and filtration materials

Comments

- effective on viscous pollutant, in particular heavy fuel oil; significantly less effective on light pollutant especially in strong currents; does not filter dissolved fractions.

Sealing off channels

Scope of use

Substrates: marsh, mudflat

Pollution: all types

Pollutant: fluid to highly viscous

Sea: with or without tides

Rockfill dam without openings

Gabion dam

Airlifting big bags of sand

Resources required

Basic equipment:
- sealing materials
- flap gates

Description/Principle

Consists in blocking off a channel to prevent the marsh and especially production basins from being polluted (salt production, oyster farming etc.). In tidal seas, such channels are exposed to strong currents, especially in the case of a large water body or network situated upstream.
The channel is closed off using various materials (silt, earth, stones, etc.), affecting the entire watercourse. The type of device varies according to the type of channel: complete closure is a possibility, but a dam with flap gates is generally preferable, especially on sensitive sites of ecological interest or economic importance (aquaculture) as it allows water to constantly flow through, thus maintaining the immersion/emersion cycle and the salinity.
These systems are high maintenance (to ensure durability and when removing the trapped oil and oiled materials).
The protection of large bodies of water requires more robust systems, built with sand-filled big bags•, juxtaposed or even stacked one on top of the other; they can be filled on site if it is accessible to heavy machinery, otherwise off site and airlifted by helicopter. There is an even more robust alternative: big bags• placed inside foldable metal gabions positioned side-by-side; they can be filled on site once the gabions have been put in position.
These systems require daily maintenance (systematic removal of pollutant and blocked debris).

Conditions of use

Pollution: pollutants of all viscosities

Substrate: load-bearing embankments

Site: marsh

Impact on the environment

Physical: temporary modification of hydrological conditions; possible creation of turbulence here and there depending on current speed and the size of the watercourse and the flap gates
Biological: alteration of local water conditions (immersion, salinity); risk of flooding behind the dam in the case of complete closure during periods of heavy rainfall or spates; obstructs the movements of fish.

Performance

Recovery rate: N/A
Implementation: variable depending on the type of protection (as is the case for maintaining the protective structure and recovering the oil)
Waste: pollutant, polluted debris and oiled materials

Comments

- effective on fluid to highly viscous pollutants.
- complete closure (without flap gates): cannot be envisaged for more that 5 or 6 days without leading to a risk of ecological impact in the marsh due to permanent immersion and decreasing salinity which can be harmful for flora and fauna. There are two possibilities to overcome this drawback: the regular destruction of the bund• (and then its reconstruction) or the use of a system of nozzles (flap gates)
- flap gates: the nozzles pass through the earth bund•; the number and diameter of the nozzles will be determined according to the flow rate. Such structures should only be considered for small channels, as they are costly for wide channels which require the intervention of specialist companies.
- In the case of a pollution risk, the necessary materials can be put in place before the pollution arrives.

Protecting water intakes by filtration

Scope of use

Substrates: marsh, mudflat

Pollution: all types

Pollutant: viscous to highly viscous

Sea: with or without tides

Filter cartridge (wire structure)

Resources required

Basic equipment:
- mesh (metal or plastic)
- synthetic oleophilic sorbents•
- crushed oyster shells, straw

Description/Principle

Involves fitting water intakes supplying (by gravitational convection) production basins (salt production, oyster farming, etc.) with a filter cartridge which acts as a filtering plug.
Sophisticated systems can be designed and adapted according to the characteristics of the water intake (dimensions, flow rate) and the quality of filtration required, depending on the sensitivity of the facility (oyster, salt or aquaculture pond).
The basic system for an individual water intake with a diameter of 20 to 50 cm is a filter cartridge. The casing is made of wire mesh (chicken wire or plastic mesh), and its size and shape are made to fit the nozzle or the water feed trough. It is filled with filtering and sorbent materials.
The filtering material should be suited to the resource needing protected (straw, oyster shells for coarse retention, oleophilic sorbents• for better filtration) and should be replaced as often as is necessary.
To prevent clogging of the downstream filtration unit (litter, seaweed, etc.), a straight net should be placed in front of the water intake.

Conditions of use

Pollution: moderately fluid to highly viscous pollutant

Substrates: N/A

Site: N/A

Impact on the environment

Physical: N/A
Biological: N/A

Performance

Recovery rate: N/A
Implementation: variable depending on the type of water intake (as is the case for maintaining the protective structure and recovering the oil)
Waste: pollutant, oiled filtration materials

Comments

- effective on viscous pollutant such as heavy fuel oil; considerably less effective on light pollutants, and completely ineffective for dissolved fractions.
- to facilitate the positioning and removal of the device at the water intake, and to prevent it from being sucked inside, design a cone-shaped filtering unit.

Trapping oil using mop nets or sorbent pom-poms on ropes

Scope of use

Substrates: all types

Pollution: light to heavy

Pollutant: viscous to highly viscous

Sea: with or without tides

Recovery nets installed on the foreshore• at low tide

Sorbent pom-poms on floating ropes

Resources required

Basic equipment:
- nets
- big bags• or boulders, breeze blocks

Additional equipment:
- excavator (to bury mooring points)

Description/Principle

This technique relies on the capacity of certain materials (fine-mesh nets, sorbent pom-poms) to capture clusters of viscous pollutant. Two processes can be considered (to be tested beforehand depending on the pollutant and the site).
Recovery nets or "mop nets": each net is anchored at one end and follows the water movements to recover tarballs as it sweeps through the water. The size will depend on how efficient the net is – which in turn is closely related to the rigidity of the material – and should be adapted according to the site: it will vary between 8 and 20 m long by 1 to 5 m wide. They are set up above the mid-tide line (which varies according to the height of the current tide), so that they partially emerge at high tide. They should be anchored at low tide using a makeshift mooring or, even better, a sand-filled big bag• buried using an excavator. This technique can be used in various ways:

➞ 1: as a remedial solution, to recover oil released during surfwashing operations•: the nets, positioned upstream of deposited piles of sediment, are removed after the following tide. This is the most effective method;

➞ 2: as a preventative solution, to trap any potential tarballs washing up on the shore. In this case, the system will need to be maintained over a longer time period: checking the solidity of moorings, repositioning the nets according to the tide, replacing oiled nets, etc. This effort may be disproportionate in view of the volume of pollutant collected and it can very quickly become difficult to manage when used for a long period of time on a large scale, on very scattered pollution with haphazard strandings. Such systems are not permanently effective (inadequate positioning due to tidal variations, nets becoming buried, leaching of oiled nets that have not be replaced in time). Finally, there may be a risk to navigation if a net is ripped from its mooring and drifting at sea.

➞ 3: on a microtidal• shoreline (no tide or very low tidal range), it is possible to mount this system of nets on ropes for preventive purposes: a single line of shorter nets, pre-assembled on the beach, can be anchored a few metres from the water's edge using big bags•.
Alternative: sorbent pom-poms (or snares) on a floating rope: a floating rope fitted with sorbent pom-poms is installed at the water's edge using stakes. Simple to implement but requires the permanent presence of operators; particularly suitable for microtidal• shores.

Conditions of use

Pollution: viscous pollutant, heavy fuel oil

Substrate: all

Site: macrotidal shores: mop nets (cases 1 and 2); microtidal shores: mop nets (case 3) and sorbent pom-poms on rope

Impact on the environment

Physical: none
Biological: none

Performance

Recovery rate: variable according to the method of use and the type of pollutant (low recovery rate for light oil).
Implementation: at least 2 to 3 people (same goes for maintenance).
Waste: very heavy to lightly oiled nets

Comments

- very effective on sticky, viscous pollutant such as heavy fuel oil
- significantly less effective on light pollutants, or even completely ineffective on relatively exposed sites

Laying protective sheeting

Scope of use

Substrates: all types (sheltered)

Pollution: moderate to heavy

Pollutant: moderate to high viscosity

Sea: with or without tides

Resources required

Basic equipment:
- nets, plastic sheeting, geomembrane

Additional equipment:
- tools and equipment for fixing sheeting in place: handgun, stakes, mallet, etc.

Description/Principle

Involves deploying geotextile membranes to protect the shore from the oil. It consists of setting up plastic sheeting or geotextiles at the high tide level in anticipation of the oil reaching the shore. Any deposited oil is thus scraped off, or subsequently removed with the membrane.

➞ On mesotidal• beaches: the sheeting is held in place using stakes and the edges are buried in the sediment (limited efficiency and hold). The seam between the different strips can be made by simply folding over the material. Requires considerable lengths to be effective.

➞ On quaysides: easier to install, particularly on microtidal• sites; it is particularly useful on sites at high risk of oil pollution (quay, terminal, etc.).
It is a temporary protective measure whose efficiency relies on constant maintenance (attaching sheeting, fixing rips and tears, watertightness, etc.)
This technique can also be used temporarily on a cleaned site (high-level riprap, for example), if there is a risk of more oil reaching the site.

Conditions of use

Pollution: moderate to heavy: all types of oil

Substrate: all types, vertical to sloping flat structure

Site: coast with a small tidal range for preference and relatively sheltered from wave action; compatible with easy deployment of tarpaulins

Impact on the environment

Physical and biological: very limited to none (temporary presence); prevents or greatly limits the contamination of the sediment

Performance

Recovery rate: variable deployment/installation time
Waste: fresh oil, oiled tarpaulins and geomembranes

Comments

- short lifespan
- high maintenance (attaching sheeting, ensuring system is watertight, repositioning, etc.)
- can only be used on sites with low exposure. It is totally unrealistic to try to directly protect wave-exposed riprap for example
- high risk of the sheeting being torn away by the sea, generating a navigational hazard (drifting tarpaulins)
- generates a large quantity of geomembranes, contaminated to varying extents, to be treated

Main clean-up techniques (phase 1 and phase 2)

“Leave alone” or natural cleaning

Scope of use

Substrates: all types

Pollution: light to moderate

Pollutant: all types

Sea: with or without tides

Cliffs

Resources required

Basic equipment:
N/A

Description/Principle

Natural cleaning is the result of natural physical and biochemical processes taking place along the coastline, especially involving wave and current energy, adhesion of oil to organic particles, bacterial and micro-organism activity, photo-oxidation, etc.
The so-called "leave alone" option, or non-response, should be considered in the same way as any other response technique. This option should be considered systematically in the event of a small spill in areas where response operations may be more harmful than the oil due entirely to biological biotope sensitivity (marshes for instance). It is all the more justified for a site that has not been heavily oiled and has a good self-cleaning potential, and that may present a safety hazard for responders (very wave-beaten rocky headland, for instance). The use and purpose of the site, how often it is used by humans and animals, at the time of the spill and in the immediate future, are all factors to be taken into account when deciding whether or not to respond.

Conditions of use

Pollution: all types of pollutant (as long as it is a small spill)

Substrate: all types

Site: very exposed, difficult to access, or ecologically fragile

Impact on the environment

Physical: in the event of major accumulations, risk of formation of a crust of pebbles, for instance, meaning that the pebbles are unable to absorb the shock of waves, and therefore no longer protect against erosion
Biological: persistence of the toxic effects of oil must not be underestimated; such effects will last for a variable amount of time and will need to be compared with the effects caused by response operations.

Performance

Recovery rate: N/A
Waste: N/A

The persistence of the pollutant is mainly dependent on its nature and the extent to which it becomes trapped, infiltrates or is buried in addition to the degree of exposure of the site to waves and other weathering agents

Comments

- often the best solution on certain sensitive sites
- only concerns small spills
- will require surveying of the affected size and monitoring of the pollution
- do not underestimate the persistence of certain pollutants or overestimate the efficiency of natural cleaning, especially if the oil has been sprayed to heights rarely reached by the sea.
- find out about the socio-economic uses (tourism, leisure, etc.) and any ecological functions (spawning, resting, nesting, etc.) of the site throughout the year (seasonality) and assess whether any of these are likely to be disrupted by the presence of traces of oil, even if only on an occasional basis

Skimming•/pumping at the water's edge

Scope of use

Substrates: all types

Pollution: heavy to very heavy

Pollutant: all types (pumpable)

Sea: with or without tides

Resources required

Basic equipment:
- skimmer, skimming head
- pump, vacuum truck
- storage capacities

Additional equipment:
- containment boom
- worksite boom, sorbent boom
- small boat (where necessary)

Description/Principle

This technique involves skimming/pumping large floating accumulations of oil at the water's edge, using pumping units (pumps, vacuum trucks) fitted with a floating skimmer, a floating suction head or a simple flat nozzle.
The oil will have to be contained by a boom, where necessary a shore-sealing boom. Containment may consist of a boom laid in herringbone mode to intercept drifting slicks (choose the right place depending on drift and storage facilities) or a containment boom to encircle the slick and stop it from leaving a cove, for instance. In places where tidal activity is low, laying a boom preventively along the water mark on a slightly exposed site can prevent the oil from being washed ashore and yet will allow pumping.
The oil should be herded towards the suction head using small worksite booms operated from a dinghy, if necessary.

Conditions of use

Pollution: pumpable oil; widespread deposits or heavy pollution

Substrate: good bearing capacity; accessibility for bringing equipment onto the beach

Site: accessible to farm tractors, earthmoving equipment, sanitation trucks. If possible, use the longshore drift to deflect the oil towards ditches or booms

Impact on the environment

Physical and biological: light to moderate, depending on circulation of machinery on the beach and to a possible transfer of the pollution; potentially serious impact if storage pits are dug on the upper foreshore or backshore

Performance

Recovery rate: variable (from a few m^3 to several dozen m^3 per hour) depending on the pumping/skimming equipment used and the viscosity of the pollutant. Count on between 1/4 and 1/5 of the theoretical pumping rate to take into account inevitable downtime (prime loss, blocking, litter, agitation of the water surface, etc.), in addition to pressure losses owing to the viscosity of the pollutant and the height and length of suction or delivery
Minimum workforce required: 2 to 3 people per recovery/storage unit
Waste: oil, emulsified to a varying extent; pollutant containing free water; sediment and diverse debris in varying quantities depending on the system used and the location.

Comments

- seek to be selective: concentrate slicks and apply suction at the thickest parts of the slicks
- the emulsion may be broken at this stage on the beach, by injecting an emulsion breaker• into the pollutant if tests prove that it is worthwhile (be aware of the possible toxicity of the product, including in settled water—in this case, do not discharge it into the environment)
- ensure that the pump is suited to the characteristics of the pollutant and the site
- install a protective liner for substrates (use tarpaulins) so as to mitigate the spread of the pollution
- consider the need to demobilise equipment and personnel every day from the scene of operations depending on prevailing local characteristics and tidal conditions during the response
- plan for the removal of storage capacities (specialised tanks are preferable to ditches)

Pumping on the foreshore• (in trenches or bunds•)

Scope of use

Substrates: sand

Pollution: heavy to very heavy

Pollutant: fluid to slightly viscous

Sea: with or without tides

Resources required

Basic equipment:
- pump
- vacuum tanker
- storage capacities

Additional equipment:
- excavator (digging trenches, constructing bunds•)
- plastic sheeting, geotextile (protection)
- machine with front rubber scraper blade
- manual scrapers (farming equipment)

Description/Principle

Consists of pumping up accumulations of oil concentrated at collection points on the foreshore•:

➞ case 1: on the mid-foreshore, in a shore-sealing boom or a bund• if the foreshore• is sloping, or in shallow pits if the foreshore is subhorizontal;

➞ case 2: on the upper foreshore, in a trench with a bund•.
In the first case, the fluid oil is scraped mechanically (rubber belt mounted on a blade or bucket, snow plough) or manually (manure scrapers) into ditches approximately 0.5 m deep (line base and sides with a tarpaulin).
In the second case, a trench is dug at low tide along the high tide mark of the day, the sand is removed to form a protective bund• on the landward side of the trench and the trench is lined with a tarpaulin.

Conditions of use

Pollution: pumpable oil with low to moderate viscosity – heavy pollution

Substrate: hard-packed, fine-grain sand, good bearing capacity, sufficiently thick sediment (for trenches/bunds•)

Site: accessible to earthmoving and agricultural equipment; very wide foreshore• (case 1); small relatively sheltered beach (case 2)

Impact on the environment

Physical: digging trenches: risk of temporary formation of quicksand after filling by the following tides.
Biological: toxic effects in the long term if the pollutant persists in the trenches after filling (due to the bunds collapsing – protect the pit as far as possible with a tarpaulin to limit this risk); otherwise temporary disturbance, recolonisation in the long term

Performance

Recovery rate: variable according to the pumping equipment used
Minimum workforce required: 2 to 3 workers per pumping unit; more if scraping is manual
Waste: pollutant mixed with varying quantities of sand

Comments

- case 1: should only be considered in the case of a major spill of a fluid pollutant and exclusively on a foreshore• where a large area is uncovered by the tides
- case 2: complex to implement: accurately assess the day's high tide level and the sea state; protect the bunds• and trenches using a tarpaulin in order to prevent the bunds from collapsing and to stop the sand and bunker fuel from mixing together in the trenches.
- clean out the trenches and remove the tarpaulins before leaving the worksite
- the best method involves pumping using vacuum trucks: choose vacuum trucks which can be opened to remove the sand
- the emulsion may be broken at this stage on the beach, by injecting an emulsion breaker• into the pollutant if tests prove that it is worthwhile (be aware of the possible toxicity of the product, including in settled water—in this case, do not discharge it into the environment)

Scraping using earthmoving equipment

Scope of use

Substrates: sand

Pollution: very heavy

Pollutant: fluid to slightly viscous

Sea: with tides

Resources required

Basic equipment:
- tractor or loader with front blade

Additional equipment:
- front-end loader (for removal)
- front blade fitted with a rubber scraper (snow plough design)

Description/Principle

Consists of concentrating the pollutant in order to facilitate its removal from the beach. Scraping is carried out using a tractor or earthmoving equipment fitted with a front blade in an oblique position. According to the viscosity of the pollutant, two options are available:

➞ case 1: fluid pollutant: scraping in radial or converging passes towards a collection point on the foreshore•; then removal by pumping/suction

➞ case 2: more viscous pollutant: concentration to form windrows•, by successive slightly overlapping passes parallel to the water line; removal of windrows using a loader.

Conditions of use

Pollution: heavy pollution, continuous slick, fluid to slightly viscous oil

Substrate: vast, flat foreshore• with wet fine-grain sand (very damp to saturated), and a good bearing capacity without ripple marks

Site: accessible to earthmoving equipment, large enough for vehicles to manoeuvre

Impact on the environment

Physical: normally only removes the pollutant, but some sediment may also be taken with it (if the operator is poorly supervised or inexperienced), especially if used on light pollution or an unsuitable site; high risk of disturbance due to traffic and mixing of oil with sediment
Biological: limited disturbance (except in the case of excessive removal of sediments or a high degree of oil and sediment mixing)

Performance

Recovery rate: variable
Minimum workforce required: 2 operators per vehicle (1 driver + 1 assistant)
Waste: oil mixed with varying quantities of sediment

Comments

- only carry out on heavy pollution; do not use on moderate to light pollution (not selective in this case)
- narrow window of use
- inform and supervise operators; use experienced drivers
- keep traffic on the beach to a minimum in order to limit oil and sediment mixing:
  - set up a traffic system on the beach
  - implement methodical scraping, using parallel longitudinal passes
- the bucket of the loader used to evacuate the pollutant should be filled no more than 2/3 full to prevent spillages during transportation
- ensure safety on the worksite

Sand screening with specialised machinery

Scope of use

Substrates: sand

Pollution: very heavy

Pollutant: fluid to slightly viscous

Sea: with tides

Resources required

Basic equipment:
- beach cleaners• (large and small)
- tractor

Additional equipment:
- tractor with loader (for removal)

Description/Principle

Involves screening the surface layer of the beach in order to selectively remove clusters of pollutant and various soiled debris. This technique is carried out using beach cleaners•, often used on popular tourist beaches. Two sizes of machines exist: large beach cleaners•, usually towed by a farm tractor, and small self-propelled beach cleaners. The operating principle of large beach cleaners• is as follows: a vibrating blade, possibly with a clawed pick-up, slices into the sediment and lifts up the surface layer, which is then pushed onto a perforated conveyor belt where it is screened; elements that are larger that the mesh size are deposited in the hopper at the end of the belt.
Walk-behind beach cleaners• operate in a similar way, with a lower recovery rate, with finer mesh (5 to 15 mm, instead of 15 to 28 mm for the large models) and they do not dig as deep (5 cm compared to 20 cm for large models). They allow finer screening operations, especially on sections of beach which cannot be accessed by large beach cleaners•.

Conditions of use

Pollution: only on clusters of viscous pollutant (tarballs to patties) and oiled debris; for use during final clean-up, but can also be adapted for use during initial clean-up.

Substrate: homogeneous sand, not too coarse, without too many large elements (pebbles, shells); not too compact (slightly humid to dry); good bearing capacity

Site: accessible to farm machinery; large enough and free of obstructions to allow easy manoeuvrability

Impact on the environment

Physical: in the event of poor usage: possibility of disproportionate removal of clean sediment; deconstruction and destabilisation of foot of dune (upper end of beach); erosion in the long term.
Biological: low impact on slightly sensitive psammophilous fauna in dry sand. Potentially great impact in the event of poor practices or overuse: destruction of the embryonic dune and the associated pioneer vegetation berm in front of the dune, decrease in biodiversity and fertility by reduction of the strandline•

Performance

Recovery rate: varies according to the site, pollution, machinery, drivers...; repeated runs are generally necessary; for large beach cleaners• : ¼ [(speed (0.3 to 3 km/h) x average working width (#2m) x operating depth set between 0 and 20 cm].
Minimum workforce required: 1 driver
Waste: various solid waste, tarballs, patties of oil with a small quantity of sand adhering to it; overall oil content: at least 20% (but far less in the case of poor practice).

Comments

- equipment is readily available, especially in popular tourist areas
- requires tractors which work at low speeds (0.3 km/h) and are powerful enough (min. 120 hp) and fitted with suitable tyres (sometimes hydro-inflated)
- can tend to fragment the pollutant in certain conditions
- the material must be adapted to optimise the equipment in the initial clean-up phase: pick-up claws can be replaced with flexible flaps
- requires brief training beforehand on the necessary adaptations to equipment (initial clean-up), specific operational modes and the potential ecological impact
- follow environmental guidelines, do not use at the foot of a dune, mark out the distance to be applied from the foot of the dune (5 to 10 m)

Removal/adherence using specialised equipment

Scope of use

Substrates: sand

Pollution: light to heavy

Pollutant: moderately to highly viscous

Sea: with (or without) tides

Resources required

Basic equipment:
- light roller (manual) or heavy roller (vehicle-mounted)

Additional equipment:
- tractor (variable depending on model): loader, farm tractor, self-propelled continuous tracked device
- loader for waste disposal

Description/Principle

Involves using specially designed rollers to take advantage of the adherence and trapping capacities of certain coatings for viscous pollutants. There are different sizes of rollers; the larger ones are pushed by farm or earthmoving machinery; the smaller ones are either on caterpillar tracks and are self-propelled or are pushed along by hand. The materials used to cover rollers range from geotextiles (*Bidim* or *Enkamat* types) to simple carpet. Some small models are not covered with material, but rather the oil is collected using nails or wire. A scraper automatically removes the pollutant from the surface of the cylinder, which is then transferred into a receptacle. This technique is particularly effective on scattered viscous pollutant.

Conditions of use

Pollution: moderate to very high viscosity; fresh oil; micro-tarballs to patties, or even small patches if using large rollers

Substrate: fine- to coarse-grain sand; flat surface with few ripple marks and without litter or debris (obstructing contact); firm ground saturated with water (at water table level).

Site: good bearing capacity and accessible to large machinery; slightly to moderately sloping

Impact on the environment

Physical/biological: none

Performance

Recovery rate: variable according to equipment, pollutant and pollution, sites, etc.
Minimum workforce required: 1 person (1 driver)
Waste: oil generally mixed with little sand (viscous pollutant); if the oil is relatively fluid: heavily contaminated sand containing at least 50% oil.

Comments

- very selective recovery
- on the lower beach, in addition to the use of beach cleaners (used higher up the beach)
- very narrow window of use (fresh pollutant; wet, hard, fine- to coarse-grain sand)
- this equipment is only available on the market in very limited quantities, but if it is effective given the type of pollution (tarballs washing up regularly over long periods, for instance from a leaking wreck) it is quick to design and build

Manual recovery

Scope of use

Substrate: all types

Pollution: very light to very heavy

Pollutant: all types

Sea: with or without tides

Resources required

Basic equipment:
- scrapers, rakes, brooms, brushes, forks; curved stable scrapers (fluid pollutants), etc.
- scoop nets, shovels etc.

Additional equipment:
- big bags•, bins, bags
- tractors with loader (for removal)

Description/Principle

Involves removing oiled sediment and debris by hand or using manual tools and storing it temporarily pending evacuation. This waste may be in bulk or packaged in bags, bins or big bags• (depending on the possibilities for transfer and intermediate storage) and then evacuated manually or, if possible, with the support of mechanical equipment.

Conditions of use

Pollution: all types; most often scattered pollution; on widespread pollution, only if use of other techniques is impossible

Substrate: all types; sufficient bearing capacity for pedestrians and possibly light machinery

Site: all types if they are sufficiently workable and providing they can cope with a high level of trampling

Impact on the environment

Physical: impact ranges from insignificant to high depending on the substrate. Risk of soil deconstruction on marshland. Erosion.
Biological: as above. Potentially destructive effects on flora (dunes, marshland).

Performance

Recovery rate: varies with the type of pollution and the site (from 0.2 to 2 m^3 at the most per person per day)
Minimum workforce required: (rough indication for an average sandy beach: 100 to 200 linear metres per day per team of 10 workers, including waste removal)
Waste: oiled debris and sediment with variable oil content: 10 to 30 % on scattered pollution but much more, especially during the first few days, in the case of a major fuel oil spill.

Comments

- very selective technique but requires a lot of time and personnel
- ensure operator safety:
  • safety measures on worksites: signposting, supervision, no isolated individuals out of sight, etc.
  • provide at least the minimum protective equipment: coveralls, waterproofs, boots, gloves, etc. depending on the nature of the pollutant, exposure and responder activity
- enhance comfort for personnel (difficult working conditions):
  • supplies (water, coffee, meals) for operators
  • logistics (shelter, clean areas, etc.)
  • tools (innovate if necessary)
- organise the response: give the responders well-defined responsibilities (collection, raking, piling in heaps, putting waste in bags/bin bags and disposal) and have teams rotate. The use of a loader partially replaces the latter two positions: the waste collected is directly placed in the loader and is then evacuated to an intermediate storage facility.
- organise a chain to evacuate waste from sites that are hard to reach.
- restrict the spreading of the pollution: set up traffic lanes, protect ground (geotextile), provide a decontamination area near the beach exit.
- always comply with environmental instructions.

Flushing•

Scope of use

Substrate: all types

Pollution: light to very heavy

Pollutant: all types

Sea: with or without tides

Resources required

Basic equipment:
- fire hose or Impact hose
- transfer pump (approx. 30 m^3/h; 4 to 8 bars)

Additional equipment:
- direct seawater supply, or alternatively via tanks
- small worksite booms, shore-sealing boom, planks, pump, sorbents

Description/Principle

Involves:
- removing the surface layer of thick accumulations on various hard surfaces (rocks, quays, etc.);
- dislodging clusters trapped in cavities of rocks, boulders, riprap, etc.
- displacing accumulations and effluents on the surface of the beach or water and channelling them to a collection point.

Conditions of use

Pollution: thick accumulations of freshly deposited oil, residual clusters and effluents

Substrate: (displacement) fine sediments, wet to saturated with water; (dislodgement) rocks, boulders, cobbles

Site: direct sea water supply available (possibly via channels) or accessible to machinery

Impact on the environment

Physical: can drive the oil into the sediment (if the jet is too powerful or incorrectly operated); temporary disturbance
Biological: can contaminate populations living in the underlying foreshore• if effluent recovery is not carried out properly

Performance

Recovery rate: varies considerably according to the site, pollutant, degree of pollution (a few tens to a few hundreds of m^2/h for displacement on the beach, from 1 to 5 m^2/h in the case of dislodgement)
Minimum workforce required: 5 to 6 hoses per team of 10 people
Waste: pumpable waste with high oil content; possibly saturated sorbents

Comments

- provide at least the minimum protective equipment: disposable suit, full waterproofs, boots, gloves, balaclava, goggles, mask. Operators are exposed to a lot of pollutant and effluent spray
- set up an effluent recovery system before beginning operations
- adjust the pressure according to the nature of the substrate and choose the most appropriate spraying mode: flat nozzle or solid water jet
- the spraying angle should be small, especially on sediments, in order to limit erosion (thin layer of sediment) and deep burying of oil. Consider additionally setting up a deluge system to saturate the sediment (shingle bar) with water.
- risk of emulsification with certain pollutants (factor which increases viscosity); use hot water hoses in parallel especially on pebbles
- operating a hose for an extended period of time is tiring: organise a rota (spraying/monitoring supply, pump and effluent recovery system)

Flooding•

Scope of use

Substrates: coarse sediment, pebbles, cobbles, boulders

Pollution: moderate to very heavy

Pollutant: fluid to slightly viscous

Sea: with or without tides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Resources required

Basic equipment:
- high capacity transfer pump (approximately 100 m³ per hour)
- drainage pipe or pierced tube

Additional equipment:
- direct water supply at sea: pontoons, support barge
- hoses (cold/hot water, high/low pressure)
- recovery: small worksite booms, shore-sealing boom, planks, pump, sorbents

Description/Principle

This technique involves saturation by flooding: it is carried out using a flexible perforated pipe (drainage pipe or pierced tube) which is laid longitudinally above the shingle bar and is supplied with seawater by a high capacity pump. The procedure involves setting up a laminar flow, from the upper end of the foreshore•, to flood the section of the shingle bar to be cleaned. This technique is used in conjunction with flushing• or washing operations to stop deep infiltration of pollutant due to the pressure of hoses and to improve drainage towards the lower end of the bar.

Conditions of use

Pollution: fresh oil, low to moderate viscosity; heavy pollution

Substrate: coarse sediment, pebbles

Site: particularly on narrow foreshores• with moderate slope; small shingle bar, on rocky substrate, at the foot of a rocky cove for example.

Impact on the environment

Physical: reworking of shingle bar to greater or lesser extent; subsequent regain of natural balance
Biological: slight risk of vertical infiltration of oil into shingle bar; possible contamination of lower beach if effluents are not immediately caught at the foot of the bar

Performance

Recovery rate: very variable (according to substrate, degree of pollution...)
Minimum workforce required: 10 people per worksite
Waste: oil emulsioned to a varying extent, possibly with fine sediment incorporated

Comments

- use a flexible pipe in order to best fit the relief of the beach
- avoid contaminating lower sections of the beach: set up an effluent recovery system at the foot of the shingle bar, contain effluent to prevent it from flowing down the foreshore•
- proceed methodically, section by section
- to be used in conjunction with washing with hot or cold water, using low or high pressure according to the case in hand

Surfwashing•

Scope of use

Substrates: sand, pebbles

Pollution: light to very heavy

Pollutant: various

Sea: preferably macro- or mesotidal• (but also possible on microtidal• sites)

Resources required

Basic equipment:
- earthmoving equipment: bulldozer, front-end loader, excavator
- recovery on the beach: nets, big bags• (for anchoring), ropes, etc.

Additional equipment:
- quarry truck
- on-water recovery system (sorbent boom and/or filter boom)

Description/Principle

Consists of moving sediment down the beach (and depositing it in piles or windrows•, not layers) to subject it to the natural cleaning action of the sea. Wave action breaks down the piles, separates the pollutant from the sediment, spreads out the sediment across the beach and cleans it by agitation and abrasion, while moving it back up to its original location. This technique can be used both during initial clean-up (phase 1) and final clean-up (phase 2).

In phase 1, the aim is to separate the pollutant from the sediment. The freed pollutant is deposited along the strandline•, where it should be recovered as quickly as possible. It can be recovered manually; sorbent material (straw, sorbents, etc.) may be spread along the upper beach beforehand to facilitate recovery. In the case of a viscous pollutant, recovery is best carried out using nets anchored at one end on the foreshore•, positioned upstream of the piles or windrows• (▶Tech Sheet P 04).

In phase 2, surfwashing• is used for different purposes:
- to directly clean slightly oiled pebbles or finish the previously undertaken washing operations (no recovery required);
- as an alternative to sand screening (for example, where beach cleaners• are no longer effective on micro-tarballs of heavy fuel oil): organise the recovery of any released oil (using nets or by manual recovery);
- to accelerate the washing of sand contaminated by a light crude oil: recovery is generally not possible (pollutant in the form of oiled foam or heavy sheen).

There are two possible options for implementing this technique: at ebb or flood tide•, depending on the specific issues and the site characteristics:

→ **flood tide• option**: at low tide, position the piles on the lower or mid foreshore• and stagger the nets behind the piles; remove the nets at the next ebb tide;

→ **ebb tide• option**: at low tide prior to the operation, position the recovery system longitudinally along the upper shore, in 2 or 3 parallel lines, staggered in the direction of the longshore drift just below the day's high water mark; at the following ebb tide, tip the oiled sand into the breakers, slightly upstream (in relation to the longshore drift) of the system which will gradually be uncovered as the tide goes out; remove the oiled nets once they have completely emerged. In addition, consider the use of an on-water recovery system using a sorbent boom or a geotextile filter barrier (either fixed or mobile), operated from a small boat with support from operators on the beach.

Conditions of use

Pollution: very light to very heavy

Substrate: pebbles and sand

Site: accessible to earthmoving equipment; strongly exposed to the sea's energy

Impact on the environment

Physical: temporary disruption to beach profile: obvious geomorphological risk (coastal erosion) in the event of poor assessment or implementation

Biological: limited except in the case of erosion; possible recontamination of the foreshore• by released oil

Performance

Recovery rate: depends on the beach's characteristics (size, manoeuvrability, exposure) and on the pollution

Minimum workforce required: Flood tide• option = vehicle (1 driver) + nets (at least 5 people – installation and removal); Ebb tide• option = vehicle (1 driver) + recovery system using nets (6 people minimum for installation and implementation on the beach + at least 2 people per boat)

Waste: variable depending on the response phase: clusters, nets polluted to varying extent, sorbents, etc.

Comments

- due to geomorphological risks, this technique requires approval by a geomorphological expert (assess possible risks of shoreline erosion, ensure the feasibility of the operation and organise it)
- restrict the volume involved to what is strictly necessary
- repeat the operation depending on results of washing

Underwater agitation

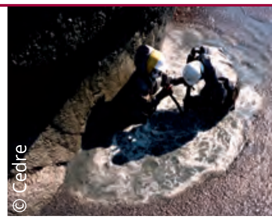
Scope of use

Substrates: sand, pebbles

Pollution: light to very heavy

Pollutant: various

Sea: with (or without) tides



Resources required

Basic equipment:
- fire or PVC Impact hoses
- pumps (30 m^3/h – 4 to 8 bars)

Additional equipment:
- effluent recovery system
- skimming/effluent sorption means
- storage capacities

Description/Principle

Involves remobilising oil trapped in the sediment by vigorous underwater mixing using hoses. The resurfacing oil is recovered within a small boom using either sorbents or a skimmer.
This technique is generally conducted by individual operators on foot, using Impact hoses supplied by a small light pump unit.

Conditions of use

Pollution: (preferably) light oil emulsified to a varying degree – pollution buried up to 40 – 50 cm deep

Substrate: fine to coarse sediments; water depth of 0.5 to 3 m

Site: accessible via a barge/pontoon; relatively calm during operations

Impact on the environment

Physical: temporary disturbance to the first 60 centimetres (loosening, quicksand)
Biological: potential mechanical impact on macrofauna living in the sand; temporary disturbance (less than the initial chemical contamination); recolonisation in the short-term

Performance

Recovery rate: very variable depending on the pollution and the sediment
Minimum workforce required: 10 people (including recovery): 1 to 3 per hose
Waste: pumpable or absorbable emulsified oil (oil content of cleaned sand: < 1g/kg)

Comments

- ensure the safety of operators by providing personal protective equipment: protective suit, waterproofs, boots, gloves, balaclava, goggles, mask. Operators are exposed to a lot of dirt (spray of large particles of pollutant)
- manual technique but its mechanisation has been considered, and still can be, in view of increasing the yield. Either using a battery of hoses mounted on a motor boat (pontoon type) or from the beach using a mobile device (fitted with an articulated arm).
- operation of hoses is arduous; provide hoses with handholds and rotate personnel (hose, water supply, effluent recovery)
- can also be used to remove patches of submerged heavy fuel oil (using extended hoses where necessary, as used during the *Erika* for instance).
- systematically set up a recovery system.

Containment and recovery of effluent on the water surface

Scope of use

Substrates: all types

Pollution: light to very heavy

Pollutant: all types

Sea: with or without tides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Resources required

Basic equipment:
- small floating booms, worksite booms, shore-sealing boom
- skimmers/pumps
- sorbents, scoop nets

Additional equipment:
- onshore and offshore logistical support (equipment deployment, waste disposal...)

Description/Principle

Involves setting up a system to recover effluent floating in front of worksites where washing is being carried out. Containment is conducted using booms attached to the shore, set up in a U-shaped configuration or more or less open. The oil is recovered by absorption or pumping from within the boom from the beach (using weir or oleophilic• skimmers•...) or on the water surface (using a barge/pontoon, a conveyor belt skimmer or weir skimmer, etc., with an integrated or coupled storage capacity). The size of the system will depend on the volume of pollutant and the size of the worksite.

Conditions of use

Pollution: moveable, pumpable oil

Substrate: all types

Site: relatively sheltered (at least during operations), for preference constantly, on the water or narrow foreshore•

Impact on the environment

Physical: low to none
Biological: very low (except if the pollution spreads to the lower foreshore• by migration if the effluents have to travel too far before reaching the water, or in the case of sediment-laden oil sinking in a subtidal• zone).

Performance

Recovery rate: variable according to the volume of oil released, the site and the recovery means
Waste: emulsified oil, polluted water, fine sediment and various types of oiled debris

Comments

- requires major logistic support (mobile recovery/waste disposal area) and a methodical organisation of operations so as not to oil coastal areas that have already been cleaned up, or have not yet been oiled
- the simultaneous use of sorbents (loose or conditioned) on the water surface and the foreshore• can be beneficial especially if the sediments are fine or the water turbid
- should only be considered for narrow beaches.

Containment and recovery of effluent on the foreshore•

Scope of use

Substrates: all types

Pollution: light to very heavy

Pollutant: all types

Sea: with tides

Resources required

Basic equipment:
- shore-sealing boom
- shovels, excavator, planks
- skimmers/pumps, sorbents, scoop nets

Additional equipment:
- storage tanks/bins
- onshore logistical support to deploy equipment/for waste disposal...)

Description/Principle

Consists in recovering effluent from washing and draining operations on the beach. The aim is to channel the effluent to a pumping/skimming point. The effluent is channelled using trenches (lined with tarpaulins) and planks set up in a V-shaped configuration towards the lower foreshore. Retention should be as close to the worksite as possible to reduce the distance over which the effluent will flow. The effluent can be contained using shore-sealing booms, bunds• made of sand and covered with tarpaulins or simple pits protected with geotextiles. Recovery is carried out by absorption or pumping, depending on the volume of pollutant.

Conditions of use

Pollution: remobilised, pumpable oil

Substrate: all types

Site: all types

Impact on the environment

Physical: very limited, temporary disturbance to the areas where channels are dug
Biological: risk of residual pollution if the pollutant is not recovered or becomes buried, due to the collapse of trenches or pits; delayed recolonisation in these areas

Performance

Recovery rate: variable
Waste: emulsified oil, polluted water, fine sediment and various types of oiled debris

Comments

- the retention/recovery phase should be defined and the system put in place before the washing/draining phase;
- anticipate the need for plastic sheeting and geotextiles along the run-off channels and containment pits in order to reduce the infiltration of the pollutant and reinforce the system (prevent collapse)

Temporary removal of sediment

Scope of use

Substrate: all types

Pollution: light to very heavy

Pollutant: all types

Sea: with or without tides

Resources required

Basic equipment:
- earthmoving equipment: front-end loader, excavator
- manual equipment: shovels etc. or low pressure hoses

Additional equipment:
- skips and trucks (waste evacuation)

Description/Principle

Involves:
- removing a layer of clean sediment in order to reach a buried layer of pollutant and treat it;
- or temporarily removing a layer of lightly polluted sediment (but sufficiently contaminated to interfere with the uses of the beach) in order to:
  • clean it immediately at another point on the beach (surfwashing•) or offsite (washing, sand screening)
  • or temporarily store it (in the summer on the upper beach for instance) with a view to treating it at a more suitable later date (deferred autonomous surfwashing• for example)

This operation can be implemented in a number of ways: using earthmoving equipment (large volumes), shovels or low pressure hoses (to reach the polluted base of a rock temporarily covered with sediment for example).

Conditions of use

Pollution: buried heavy pollution or light or residual pollution temporarily interfering with the uses of the beach

Substrate: fine to very coarse sediment

Site: accessible to earthmoving equipment (sufficient bearing capacity)

Impact on the environment

Physical: possibility of limited, temporary instability of the beach profile (in the case of large volumes)
Biological: possibility of limited disturbance (in the case of large volumes)

Performance

Recovery rate and minimum workforce required: variable according to the site, the volume of sediment in question and the equipment used
Waste: layer of pollutant mixed with varying quantity of sediment

Comments

- this process is different from the withdrawal of layers of sediment as it only involves the temporary removal of sediments which remains on or will be rapidly returned to the beach.
- only remove the necessary volumes: carry out a detailed survey (on the surface and in the depths), inform operators, assist drivers.
- mitigate risks: obtain prior advice from experts to assess, organise and plan the operation (especially in the case of surfwashing•)
- ensure safety on the worksite, especially if using heavy equipment

Drainage

Scope of use

Substrates: fine to coarse sediments (marsh, limited)

Pollution: moderate to heavy

Pollutant: fluid

Sea: with tides

Resources required

Basic equipment:
- manual tools (shovels, etc.)
- mechanical machinery (farm ploughshare, excavator)
- possible water supply (pump)

Additional equipment:
- effluent recovery system
- skimming/effluent sorption means
- storage capacities

Description/Principle

Consists of digging drainage trenches on the beach to improve natural drainage. The trenches should be oblique and converge at a lower collection point (shore-sealing boom, bund• with geotextile, planks, pit, etc.). The water entrains the oil trapped in between grains of sand and is recovered at a collection point where it is treated by absorption or pumping. In the case of limited natural drainage, it can be increased by saturating the upper beach (flushing• or flooding•) in order to encourage the washing of the sediment.

Conditions of use

Pollution: moderate to heavy, buried fluid pollutant

Substrate: fine- to coarse-grain sand

Site: more favourable when the groundwater re-emerges on the foreshore•; accessible to small earthmoving machinery

Impact on the environment

Physical: limited, temporary disturbance (possible formation of quicksand in the trenches)
Biological: low disruption

Performance

Recovery rate: very variable according to substrate, degree of pollution, natural drainage
Waste: liquid oil, fine polluted sediment, oiled sorbents

Comments

- low recovery rate; technique generally needs repeated
- use of hoses is not necessary on beaches where there is a lot of surface run-off of ground water

Tilling

Scope of use

Substrates: fine to coarse sediment

Pollution: light to heavy

Pollutant: various

Sea: with (or without) tides

Resources required

Basic equipment:
- farm machinery (harrow, rotovator, plough)

Additional equipment:
- effluent recovery system
- skimming/effluent sorption means
- storage capacities
- beach cleaner•

Description/Principle

This technique fulfils different objectives depending on whether it is carried out in or out of the water:

➞ case 1 (in shallow water at flood tide•) = releases fluid oil trapped in the sediment, by mechanical mixing: as the sand is scoured it releases the oil, which is then recovered at the water surface (= alternative version of underwater agitation carried out with hoses);

➞ case 2 (out of the water) = promotes natural breakdown of oil in situ by increasing aeration and UV exposure: tilling of the upper beach if it is lightly contaminated, or stained, by fluid oil;

➞ case 3 (out of the water) = to assist sand screening operations, using a plough in order to cause patches of viscous pollution buried under a thick layer of clean sand to resurface

Conditions of use

Pollution: (case 1) light to heavy, in the form of localised pockets of buried oil
(case 2) light pollutant which is no longer in the form of mobilisable accumulations but rather of a homogeneous colour of varying intensity
(case 3) buried clusters of heavy fuel oil

Substrate: fine to coarse sediment

Site: accessible to farm machinery; not too exposed to the sea's energy

Impact on the environment

Physical: loosening of the surface layer of the beach; ground temporarily destructured
Biological: can have a significant impact on endogenous macrofauna (e.g. in sand) but recolonisation is rapid

Performance

Recovery rate: variable according to the site; relatively rapid work rate in cases 1 and 2, but slow speed required for case 3 to prevent clusters from being pulverised
Waste: (case 1): liquid waste and polluted sorbents; (case 2): N/A; (case 3) : diverse clusters of heavy fuel oil blended with sand

Comments

- case 1: implement at high tide wherever possible (less risk of vertical transfer of the pollutant into the sediment)
- cases 1 to 3: operation generally needs to be repeated depending on the degree of contamination of the sediment
- case 1: underwater tilling is similar to the principle of underwater agitation; the two can also be combined. Recover the supernatant released oil
- case 2: can be applied to microtidal beaches• polluted due to a surge
- case 2: can be coupled, if deemed necessary, with a bioremediation operation (spreading nutrients).

Hot water pressure washing (with or without detergent)

Scope of use

Substrates: cobbles, boulders, rocks, infrastructures

Pollution: light to very heavy

Pollutant: all types

Sea: with or without tides

Resources required

Basic equipment:
- thermal pressure washer

Additional equipment:
- direct seawater supply; seawater storage
- recovery: small worksite booms, shore-sealing boom, planks, sorbent, skimmer, pump
- cleaning agents (optional)

Description/Principle

This technique should only be carried out once the initial clean-up phase has been completed and the surfaces have been scraped. It involves washing oiled hard surfaces with hot water at high pressure. Washing implies the recovery of effluents; this means a specially designed system must be set up before the washing operations can begin.
Heat and high pressure can be detrimental to certain environments. The temperature and pressure should therefore be adjusted depending on the nature and fragility of the substrate, and also to obey the specific restrictions and recommendations which may exist for certain ecologically sensitive sites.

Conditions of use

Pollution: thin layer; moderately to highly weathered oil

Substrate: mechanically resistant surfaces (cobbles, rocks, quays)

Site: accessible to washing equipment

Impact on the environment

Physical: possibility of impact on very crumbly rock; risk of rockfall/landslide on fragile ground/cliffs (not to be carried out on crumbly cliffs)
Biological: risk of sterilisation of surfaces and possibility of impact on surrounding sedimentary fauna

Performance

Recovery rate: varies depending on the site (a few m²/h per machine)
Minimum workforce required: 10 people for 3 to 4 machines (not including effluent recovery)
Waste: liquid oily effluents, emulsified to varying extent

Comments

- ensure the safety of employees by providing at least the minimum required personal protective equipment: protective suit, waterproofs, boots, gloves, balaclava, goggles, mask. Operators are exposed to a lot of dirt, containing potentially toxic particles (aerosols)
- assess the need for washing operations, taking into account the degree of pollution and the ecological sensitivity of the site, e.g. presence of lichen and vegetation growing in cracks
- do not uproot vegetation or scrape the soil (lithosol in cracks)
- recover loosened oil; protect the surrounding area (using geotextiles)
- use thermal washers which are suitable for seawater and can be easily transported
- rotate users (on the following basis: 1 spraying, 1 monitoring machines and water supply, 1 recovering effluents)
- plan for maintenance/repairs on site (1 mechanic for 10 machines)
- using hot water without high pressure can be a good solution
- the use of a cleaning agent is not always necessary. Tests can however be carried out to assess the potential gain. The decision to use a cleaning agent requires prior approval: only use a product that has been tested by a recognised organisation (for efficiency, toxicity, biodegradability)

Washing in wire mesh tanks

Scope of use

Substrates: pebbles

Pollution: moderate to heavy

Pollutant: all types

Sea: with or without tides

Resources required

Basic equipment:
- wire mesh tanks
- watertight skips
- pressure washers

Additional equipment:
- pebble supply (loader)
- water supply (pump)
- skimming/effluent sorption means
- effluent pumping/storage/settling system

Description/Principle

This technique involves washing pebbles off site in wire mesh tanks positioned over watertight skips. The pebbles collected are laid in thin layers in the tanks to be washed at high pressure with hot water using thermal washers. The effluents are collected in the skip, where the settling then skimming is carried out.

Conditions of use

Pollution: all types, preferably fresh or relatively unweathered oil

Substrate: pebbles, polluted to a varying extent

Site: locally polluted shingle bar; washing off site

Impact on the environment

Physical: none (do not wash pebbles from very crumbly shale rock)
Biological: possible risk connected to the residual presence of pollutant and products or the destruction of vegetation on pebbles at the top of the shingle bar

Performance

Average recovery rate: variable (1 to 3 m^3/h depending on the size of the pebbles, the degree of pollution, the pollutant, the site)

Waste: water + oil + oiled fine sediment (+ possibly solvent)

Comments

- requires a work area (car park, open space) on the backshore, that is relatively quick to set up
- limited recovery rate; concerns small volumes to be cleaned
- management of effluents necessary
- install a spray shield on the edge of the skip
- requires good management (transfer, supply, storage, and removal of sediment)
- extremely heavily polluted pebbles will need to be scraped beforehand
- operate a tight flow: continual removal and return of pebbles to beach as soon they have been washed
- the washed pebbles are subjected to surfwashing• to finish the cleaning
- the use of a washing agent is not always necessary. Tests can however be carried out to assess the potential gain. Only use a product that has been tested by a recognised organisation (for efficiency, toxicity, biodegradability)

Washing in booths

Scope of use

Substrates: pebbles

Pollution: moderate to heavy

Pollutant: all types

Sea: with or without tides

Resources required

Basic equipment:
- booth (wire structure)
- thermal washers (hot water + rinsing)
- geomembranes

Additional equipment:
- stone supply (manual)
- water supply (pump + tanks)
- effluent recovery system
- solvents (optional)

Description/Principle

Consists of washing polluted pebbles using a pressure washer inside a structure which separates the effluents from the pebbles using wire grids and contains the effluents, aerosols and various sprays.
This "booth" is a light metal frame with a strong openwork base (wire or sheet iron), on which the pebbles are washed, and with three lateral sides, covered with geotextile, to contain the spray of effluents and oil. All the washing effluents pass through the base and are collected in a recovery system set up under the booth (drainage ditch protected with geotextile, with filtering and absorption materials, etc.).
In order to wash small pebbles without them being projected out of the booth, they can be placed in plastic mesh bags, such as oyster bags, which are turned over during washing.
The use of a cleaning agent is not always necessary.

Conditions of use

Pollution: all types, preferably fresh or relateively unweathered oil

Substrate: pebbles

Sites: all sites

Impact on the environment

Physical: none (do not wash pebbles from very crumbly shale rock)
Biological: possible risk connected to the residual presence of pollutant and products or the destruction of vegetation on pebbles at the top of the shingle bar

Performance

Average recovery rate: variable
Waste: water + oil + oiled fine sediment (+ possibly solvent)

Comments

- ensure the safety of operators by providing at least the minimum required personal protective equipment: protective suit, waterproofs, boots, gloves, balaclava, goggles, mask. Operators are exposed to a lot of dirt, containing potentially toxic particles (aerosols)
- very little space required, quick to set up
- the polluted pebbles are collected by hand and returned to the lower end or middle of the beach where natural processes will finish cleaning them
- extremely heavily polluted pebbles will need to be scraped beforehand
- recover the oil released
- rotate users (on the following basis: 1 spraying, 1 monitoring machines and water supply, 1 recovering effluents)
- use thermal washers which are suitable for seawater and can be easily transported
- organise the maintenance/repair of washers on site
- using hot water without high pressure can be a good solution for releasing the pollutant without "blasting" it
- the use of a washing agent is not always necessary. Tests can however be carried out to assess the potential gain. Only use a product that has been tested by a recognised organisation (for efficiency, toxicity, biodegradability)

Washing in a concrete mixer

Scope of use

Substrates: pebbles

Pollution: moderate to heavy

Pollutant: all types

Sea: with or without tides

Resources required

Basic equipment:
- concrete mixer
- solvents (possibly)
- thermal washers (hot water + rinsing)
- wire mesh tank (rinsing)

Additional equipment:
- pebble supply (manual)
- water supply (pump)
- skimming/effluent sorption means
- effluent recovery system

Description/Principle

The pebbles are washed in cold water (or possibly lukewarm using thermal washers) for 5 minutes inside the concrete mixer. When using a cleaning agent, pre-mix the sediment with the undiluted solvent (petroleum fraction) for 3 to 5 minutes. At the end of the cycle, fill the concrete mixer with water in order to skim floating oil off via an overflow which is channelled into a designated tank. Alternatively, the entire contents of the mixer can be poured into a wire mesh tank. The washing water is skimmed, filtered, then reused after settling. The pebbles are rinsed in hot water on a grid placed over a tank, then returned to the beach (surfwashing•). Lightly oiled pebbles can simply be mixed with sand (abrasion). With certain viscous pollutants, simply mixing them with water can sometimes be enough to recover the auto-amalgamated pollutant in the form of clusters of pure pollutant.

Conditions of use

Pollution: all types, preferably fresh or little weathered oil

Substrate: polluted to a varying extent

Site: can be at the same beach, or else off site, and always with an effluent recovery system.

Impact on the environment

Physical: none (do not wash pebbles from very crumbly shale rock)
Biological: possible risk connected to the residual presence of pollutant and products or the destruction of vegetation on pebbles at the top of the shingle bar

Performance

Average rate: variable
Waste: water + oil + oiled fine sediment (+ possibly solvent)

Comments

- very little space required: quick to set up
- operate a tight flow
- requires good management (transfer, supply, storage, evacuation of pebbles)
- washing operations may need to be repeated for heavily polluted pebbles
- extremely heavily polluted pebbles will need to be scraped beforehand
- the washed pebbles are subjected to surfwashing• to finish off the cleaning process
- provide ear protectors
- the use of a washing agent is not always necessary. Tests can however be carried out to assess the potential gain. Only use a product that has been tested by a recognised organisation (for efficiency, toxicity, biodegradability)

Washing in a concrete mixing truck

Scope of use

Substrates: pebbles

Pollution: moderate to heavy

Pollutant: all types

Sea: with or without tides

Resources required

Basic equipment:
- 5 or 7 m^3 concrete mixing truck
- cleaning agents (solvents)
- thermal washers (hot water + rinsing)
- settling tanks
- wire mesh tank (rinsing)

Additional equipment:
- pebble supply (loader, hopper tank)
- water supply (water tank + pump)
- skimming equipment
- onshore logistical support: equipment deployment/ sediment management and waste disposal

Description/Principle

The pebbles are mixed for 5 minutes with a pure solvent (a few decilitres/m^3 of a petroleum fraction), then washed in cold water (or lukewarm water using thermal washers) for 10 to 15 minutes inside the drum. At the end of the cycle, the drum is filled with water using a hose in order to skim floating oil off via an overflow which is channelled into a designated tank. The washing water is reused after settling. The pebbles are rinsed in hot water on a grid placed over a tank, then put back on the beach (surfwashing•).

Conditions of use

Pollution: all types of, preferably fresh or relatively unweathered, oil; polluted up to approximately 100 g/kg

Substrate: heavily polluted pebbles

Site: on the backshore, potentially quite a vast open area due to the amount of space the system requires

Impact on the environment

Physical: slight temporary risk (during washing operations) of erosion in the event of a storm: assess this risk
Biological: possible risk connected to the residual presence of pollutant and products (rapid recolonisation if sediment is well rinsed and returned to its original location) or subsequent destruction of vegetation at the top of the shingle bar

Performance

Average rate: pebbles: 4 to 6 t/h

Waste: water + oil + solvent + oiled fine sediment

Comments

- space required: restricted to the concrete mixing truck and settling tanks
- relatively quick to set up
- operate a tight flow to limit the site coverage and more importantly the temporary sediment deficit
- requires good management (turnover, supply, storage, removal of sediment)
- washing operations may need to be repeated for heavily polluted sediments
- extremely heavily polluted sediments should be washed roughly beforehand (wire mesh tank)
- washed sediments should be returned to their original location as quickly as possible
- do not wash pebbles from very crumbly shale rocks
- provide ear protectors
- only use products which have been tested by a recognised organisation (for efficiency, toxicity, biodegradability); carry out a test on site.

Washing at a cleaning station

Scope of use

Substrates: sand, pebbles

Pollution: moderate to very heavy

Pollutant: all types

Sea: with or without tides

Resources required

Basic equipment:
- washing station
- feed hopper and conveyor belt, crane
- boiler (1 t/h, heat exchanger)
- power pack (150 kVA)
- cleaning agents (solvents, flocculants)
- settling tanks

Additional equipment:
- loader; tractor + trailers
- skimming equipment
- land-based logistical support to: deploy equipment/for sediment management and waste disposal

Description/Principle

The sediments are supplied to the plant using a hopper and a conveyor belt. They are washed in hot water inside a sludge separator (after impregnation with solvent and blending inside the trap) for 12 to 18 minutes for sand and 3 minutes for pebbles. When the sediments are removed from the sludge separator, they are then rinsed on a rotary screen, which sorts them: oversized elements (> 5 mm) are removed. The rest is pumped into a hydrocyclone, where centrifugal and gravity separation is carried out (water/oil/solids), to remove sediment particles > 200 μm. The remaining mixture (water/oil/fine solid particles) is discharged into settling tanks where the floating oil is skimmed off.

Conditions of use

Pollution : all types of, preferably fresh or relatively unweathered, oil; polluted up to approximately 100 g/kg

Substrate: sand, pebbles

Site: on the backshore, can imply quite a vast open area due to the amount of space the system requires

Impact on the environment

Physical: (due to removal of sediments) slight temporary risk of erosion (during washing operations) in the event of a storm: assess this risk
Biological: possible risk connected to the residual presence of pollutant and products (rapid recolonisation after operations if sediment is well rinsed and returned to its original location) or the destruction of vegetation on pebbles at the top of the shingle bar

Performance

Average rate: sand 15 m^3/h; pebbles 20 m^3/h with variable pollutant content from 20 to 100 g/kg
Washing efficiency: oil content >1 g/kg
Waste: skimmed oil, oiled fine sediment, washing effluent.

Comments

- dosage of cleaning product: sand 500 l/h; pebbles: 60 to 100 l/h (detergent-to-oil ratio: between 20 and 50 % in weight)
- extremely heavily polluted sediments should be washed beforehand in a wire mesh tank for instance
- operate a tight flow (to reduce the risk of erosion in the event of a storm due to excessive sedimentary deficit)
- washed sediments should be returned to their original location as quickly as possible
- implementation of this technique implies a large volume of polluted pebbles on the one site; otherwise, another solution is preferable.
- do not wash pebbles from very crumbly shale rocks using this method
- provide ear protectors
- requires a relatively large open space.

Sediment removal for off-site treatment

Scope of use

Substrates: sand, pebbles

Pollution: light to very heavy

Pollutant: all types

Sea: with or without tides

Resources required

Basic equipment:
- front loader
- shovels, excavators
- skimmers/pumps, sorbents, scoop nets
- storage tanks/bins

Additional equipment:
- land-based logistical support to deploy equipment/for waste disposal...
- screening (mining screener) or washing installation (concrete mixer, concrete mixing truck, etc.)

Description/Principle

Involves removing oiled sand and pebbles (with a view to treating them by screening or washing at a nearby installation) then returning them to their original location as quickly as possible.

Conditions of use

Pollution: all types (preferably not very weathered)

Substrate: sand, pebbles

Site: site that is accessible to earthmoving machinery and has an open space on the backshore which is close and large enough to accommodate the installation and logistics for washing or screening the sediment

Impact on the environment

Physical and biological: soil degradation due to the traffic of heavy duty machinery and sediment removal; temporary risk of erosion (the impact can be extremely detrimental or even irreversible if this risk is not properly assessed); risk of destruction of the vegetation on pebbles at the top of the shingle bar

Performance

Recovery rate: variable according to the means used and the characteristics of the site and the pollution
Minimum workforce required: 1 person per machine + 1 supervisor
Waste: N/A

Comments

- in the case of large volumes of sediments and long-lasting operations: accurately assess the risks of erosion (for instance in the event of a storm) or the rupture of the shingle bar, or even flooding of the hinterland:
  • seek advice from a geomorphologist beforehand
  • be selective during removal (to restrict the volume which will need to be cleaned)
  • remove sediment progressively
  • compensate for the removal of polluted pebbles by returning identical quantities of cleaned pebbles
- sediments must be returned to the site from which they were removed
- consider the possibility of surfwashing• to complete washing operations

Botanical worksites

Scope of use

Substrates: vegetated areas

Pollution: moderate to heavy

Pollutant: fluid to viscous

Sea: with or without tides

Resources required

Basic equipment:
- manual tools: scrapers, putty knife, brushes, scissors, claws

Additional equipment:
- equipment for waste disposal (bags, quad bikes)

Description/Principle

Involves cleaning up ecologically sensitive areas that cannot tolerate mechanical intervention. This type of worksite is subject to prior scientific recommendations made by experts (botanists, environmentalists) who generally manage or oversee operations. These recommendations vary from one pollution incident to another and one shore to another, and must be clearly explained to response teams.
It is generally a case of removing the bulk of the oil and clusters of oil deposited or buried at the foot of vegetation, without affecting the root system.
Oiled parts of the vegetation above ground may have to be cut back, if possible given the slope.

Conditions of use

Pollution: moderate to heavy: all types of oil

Substrate: vegetated intertidal and supratidal areas (rocks, cliffs, dunes, grassy summit, etc.)

Site: ecologically sensitive and easy access sites

Impact on the environment

Physical: none to very low
Biological: N/A (in principle should be beneficial)

Performance

Recovery rate: variable depending on the biotope, pollution and site
Waste: pollutant mixed with varying quantities of sediment and plant debris

Comments

- be wary of areas which appear to be bare during the winter (do not destroy the root system in place or remove the seeds from the ground)
- a response effort can be postponed to a more favourable season (at least less destructive) if need be.
- organise teams, positions (collection, disposal etc.) and access routes
- proceed methodically: define the sequence of operations and worksite progress (divide into segments)
- always comply with environmental and safety instructions

Cutting vegetation

Scope of use

Substrates: marshes and estuary banks

Pollution: moderate to very heavy

Pollutant: fluid to viscous

Sea: with (or without) tides

Resources required

Basic equipment:
- hand tools: secateurs, sickles, shears
- brushcutter, weed-cutting launch•

Additional equipment:
- nautical support: raft/pontoon
- evacuation: big bags•, stretchers

Description/Principle

This technique involves cutting back heavily oiled vegetation.
In marshes, it can be carried out on foot, for preference from the water, either using manual tools (scythe, sickle, backpack brushcutter) or mechanical machinery (weed-cutting launch•). It must only be carried out once there is no more pollutant (especially fluid oil) on the water (risk of penetration of oil into the plants).
The cuttings should be disposed of as you go along.
Cutting is not always justified (certain plants can tolerate oiling), and is far from systematically recommended. The effect of cutting back plants varies according to the species (from complete incompatibility to high tolerance) and, within the same species, according to the season.
The advice of an expert botanist is therefore indispensable.
This technique can also be used on vegetation on rocks and dunes, requiring the same restrictions.

Conditions of use

Pollution: widespread pollution, heavy oiling of aerial parts of plants, or when there are obvious risks of oiling for birds

Site: estuary banks; intertidal marshes (+ rocks and foot of dunes)

Impact on the environment

Physical: risk of erosion if large areas are made bare by cutting or if there is excessive trampling
Biological: possible destruction of root systems then erosion; possible penetration of bunker fuel into plants via culm

Performance

Recovery rate: depends on the site, the plants and the tools used
Waste: vegetation oiled to varying extent

Comments

- obtain advice from an expert botanist on the advantages, effects and procedures of cutting (season, species...)
- restrict and channel pedestrian traffic on marshes
- wherever possible, work from flat-bottomed boats.
- avoid intensive cutting of vast areas, especially at the edge of a marsh (work on small pockets).
- in the case of the current or expected, even only passing, presence of certain species of birds, it can be advisable to cut back even lightly oiled plants

Scarification

Scope of use

Substrates: fine to coarse heterogeneous sediments, marshland

Pollution: light to moderate

Pollutant: clusters varying in viscosity

Sea: with tides

Resources required

Basic equipment:
- claws, scarifier

Additional equipment:
- equipment for waste disposal (bags, quad bikes)

Description/Principle

Involves scarifying deposits of weathered oil intentionally left on site to avoid disturbing the site. These relatively superficial furrows can, after breakdown of the pollutant, allow for recolonisation of animal and/or plant species. In the case of thick deposits of heavy fuel oil for instance, it must be removed (except where evacuation is not possible—very isolated site).

Conditions of use

Pollution: weathered, hardened deposits of varying thickness

Substrate: unsorted gravel and silt sediments; marsh...

Site: ecologically sensitive; very limited self-cleaning capacity; poor tolerance to intensive clean-up operations

Impact on the environment

Physical: avoids removing sediments and prevents disturbance due to intensive clean-up operations
Biological: recolonisation in the long term

Performance

Recovery rate: N/A
Waste: pollutant remains on site; possible removal of some deposits of hardened oil.

Comments

- can be applied in the case of scattered pollution on very sensitive sites.
- presupposes an initial decision not to respond and a deferred response planned for several months after the spill

Bioremediation

Scope of use

Substrate: all types (sheltered)

Pollution: light to residual

Pollutant: fluid to viscous (biodegradable)

Sea: with (or without) tides

Resources required

Basic equipment:
- bioremediation agents (nutrients)
- spraying equipment

Additional equipment:
- motorised machinery to assist with spraying operations

Description/Principle

Involves increasing the quantity of nutrients (NPK fertilisers) in the polluted area so as to promote/increase natural breakdown by bacteria and other specialist micro-organisms. The addition of nutrients causes the populations of indigenous bacteria to grow and increases their specialised breakdown activity. Seeding with selected exogenous bacteria should not be considered on the shoreline, as its effectiveness in an open environment has never been proven.

Conditions of use

Pollution: residual; degradable pollutant

Substrate: all types

Site: relatively sheltered

Impact on the environment

Physical: none
Biological: possible risk of a temporary eutrophication of adjacent waters in the case of large-scale treatment and overdosage

Performance

Recovery rate: variable according to the pollutant (no results for heavy products), the bioremediation agent, the temperature (season, latitude), the substrate and the chemical and bacteriological quality of local waters.
Waste: N/A

Comments

- all the components of oil are not biodegradable; biodegradation is limited in the case of heavy alkanes, heavy aromatics, resins and asphaltenes
- a prior scientific assessment procedure exists to evaluate the potential contribution of this technique on a case by case basis (Bioremediation in Marine Oil Spills by the International Maritime Organization).
- provide at least the minimum required personal protective equipment: protective suit, waterproofs, boots, gloves, balaclava, goggles, mask. Operators may be exposed to spray of vapours and powders
- should often be considered in association with a sediment aeration operation (e.g. tilling)

Clean-up site management practices

Worksite definition

Aim

The aim of this stage is to precisely define:
- the appropriate techniques depending on the nature of the coastline affected and the type of deposits;
- the limits of the response and the level of clean-up (the use of certain clean-up techniques in certain sensitive areas may be detrimental to the environment);
- the general organisation of the worksite and the location of access points and storage sites on the upper beach.

Assessment team

This work should be carried out by a technical and environmental assessment team working under the authority of the incident command post set up by the authorities:
- a representative of the authority in command of field operations;
- a representative of the municipality affected;
- a specialist in environmental recommendations and worksite organisation;

Depending on the site, other representatives may be involved, for instance:
- site owner or manager;
- regional health department, fishing area or areas frequented by the general public;
- environmental and heritage associations.

Recommendations

The various technical recommendations (especially in terms of clean-up) should be jointly defined by the different participants when they visit the site and should be recorded on a site form which should cover the following points:
- description of the site and the pollution;
- environmental (sensitivity) and logistical constraints (access, storage);
- technical recommendations (strategies, techniques, procedures, necessary resources) and environmental advice;
- response limitations and clean-up endpoints.

During the clean-up provider selection process, these forms can be used as reference documents for companies. Where response is carried out by private companies, these forms can be used as a reference for worksite closure.

Before worksite opening

Take the necessary administrative steps prior to worksite opening:
- obtain the necessary authorisations (access to private land, declaration of works, etc.);
- inform the competent organisations;
- clarify the responsibilities of each party (local authority, companies, ordering party);
- inform the general public.

Operator safety

Risk awareness

All responders must be informed (and team leaders reminded) of the risks that the working conditions present in relation to the pollutant as well as the environment, in particular:
- the movements of heavy duty machinery (for lifting or transportation) within the immediate vicinity;
- the relief and bearing capacity of the ground (cliffs, marshland, etc.);
- the movements of the sea (breaking waves, tides, etc.);
- weather conditions.

Personal Protective Equipment (PPE•)

Personal protective equipment (PPE•) must be worn, and reminders must permanently be given, especially for operations with real risks of:
- oiling of the skin: wear gloves, boots, a cotton suit, a disposable protective suit, etc.;
- oiling or harm to eyes during washing operations using pressure washers for example: wear goggles, a balaclava and a mask to protect the eyes from pollutant spray and fragments of rock, but also from inhalation of vapours;
- harm to respiratory tract: wear a breathing mask suited to the vapours generated by the product
- rockfall, during response below overhang for example, or rock slide: wear a helmet;
- sliding into the water, for instance during operations using a pump strainer in the water from slippery rocks especially on exposed sites: wear a life jacket.

The majority of PPE• is subject to manufacturing standards defined according to the type of risks to which the operator is exposed (oil, falling, drowning, etc.). These standards must be followed wherever the working conditions could lead to these risks.

As well as PPE•, clothing that ensures personal comfort should also be worn: cotton gloves and underwear to reduce the discomfort of perspiration due to poor aeration for instance.

First aid

First aid is highly recommended, or may be mandatory on certain high risk worksites, and can be ensured by:
- the presence of a first aid kit whose content may be altered to suit the specificities of the site (addition of collyrium in the case of a clear risk of pollutant being sprayed into the eyes for instance);
- the recommended presence among the operators of qualified first aiders (2 per team on high risk sites);
- a list of emergency telephone numbers displayed in case of a serious accident;
- accurate signposting of the worksite from the road (especially for remote sites whose name does not appear on existing maps) to allow the emergency services to arrive quickly.

Permanent contact

On high risk sites, all the different team members must be in permanent contact.
To do so:
- never leave an operator to work alone in isolation;
- provide compatible means of transmission, suited to the relief of the ground. Do not simply rely on a mobile phone (which may not work at the foot of a cliff or, as is often the case on remote natural sites, may not have good network coverage).
- position someone at a check point (at the top of a cliff for instance) to ensure permanent contact (visual or voice) and always equipped with a walkie-talkie to rapidly alert the emergency services if need be.

Health and safety

Depending on the particularities of the worksite (size, duration, type of response and dangerousness), certain health and safety measures may be imposed, requiring the existence of specialised installations in various places:
- a decontamination area where heavily oiled PPE• is washed down and removed
- toilet facilities, a sheltered changing room, a sheltered catering area, etc.

Worksite safety

Ensuring the safety of worksite installations

This applies to the whole worksite in the broadest sense (clean-up site, living areas and access routes).
- signpost the different areas of activity (on the beach), living areas (changing room, meals, showers, toilets, etc.), storage areas presenting a risk (fuel, equipment, waste pit etc.)
- define a site for fuel storage away from the changing area:
- provide an extinguisher for each cabin;
- set up a recovery system for fuel leaks;
- provide at least minimum lighting for installations and the surrounding area during the winter.

For public safety:
- set up the necessary signposting (cordoning off, forbidden access signs, etc.) to stop anyone not involved in the worksite from entering;
- remove all equipment, products or parts of installations likely to present any danger to any ill-intentioned or careless person: for instance, at the end of the day, abseiling ropes or jerry cans of fuel, or upon worksite closure stakes and crabs on cliffs and in the surrounding area.

Response in dangerous environments

All response operations in dangerous environments (at a great height, underwater) necessitate the intervention of specialised professional operators, who must be trained, certified and experienced in working in high risk environments. Nonetheless, these operators should be informed of the specific risks on the shoreline response worksite (pollutant, clean-up techniques, other responders, sea- and weather-related factors, etc.)
It is important to ensure that all precautions are taken and permanently respected. In particular:
- responders (rope access technicians and divers) must all be qualified professional with the necessary physical and professional training and aptitudes;
- equipment and installations must comply with the legislation in force;
- the equipment must be in good condition and constantly checked (using a control sheet) by an authorised member of the company;
- the same goes for the specialised installations, whereby an accredited organisation should carry out controls (of all hoisting systems or specialised diving equipment for instance) before the worksite is opened;
- all people present on the worksite must have prior authorisation: minimum training is required for the various coordinators, advisers and controllers working on this very specific type of worksite.

For cliffs:
- ensure that operator safety is the priority over clean-up operations.
- assess the risk of rockfall (in the case of a high risk site, call upon the services of a geologist):
  • systematically have the stability of the rockface assessed by a competent, qualified member of the company of rope access technicians;
  • where necessary, use crack gauges;
  • clear away any overhanging ground or rocks which may be liable to fall.
- ensure site safety: install signposting and safety devices (railing at least 3 m from the edge);
- check that operators working on foot have had the necessary basic training on using the specialised installations set up by the rope access technicians along the cliff to move around the site.
- ensure daily control of PPE• and installations for rope access technicians and pedestrians.

Operator decontamination

Scope of use

Substrates: N/A

Pollution: all types

Pollutant: all types

Sea: with or without tides


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Resources required

Basic equipment:
- flat or slightly sloping open area of sufficient size (approx. 30 m^2)
- plastic tarpaulins, felt or Bidim geotextile
- fluorescent tape and stakes
- boot bath, low-sided tanks with a capacity of around 1 m^2
- brushes, cloths, oakum for rough cleaning
- hot water pressure washer
- cleaning agent (for waterproofs and boots)
- cooking oil and soap for hands

Additional equipment:
- bins, barrels
- storage/settling tanks for effluents
- sorbents
- transfer pump
- possibly, depending on the size of the worksite: work-site cabins (locker rooms, shelter, small equipment)

Description/Principle

The purpose of decontamination is to allow personnel to leave the worksite in satisfactory conditions in terms of hygiene and comfort, but also to stop pollution from spreading from the beach. The principle is to put personnel through a cleaning chain from dirtiest to cleanest, on a watertight platform where washing effluents can be recovered.
Upon entry, hands are roughly cleaned (using cooking oil and cloths or oakum), as are waterproofs and boots (by brushing or buffing, possibly with the addition of non-toxic solvent for overalls). The overalls are then cleaned (by low pressure washing with lukewarm water directed downwards to reduce spray into the person's face, which should be protected by a hood and possibly a face shield). Protective clothing should be removed progressively throughout cleaning. The skin is then washed with hypoallergenic soap.

Conditions of use

Pollution: all types (pollutant and extent)

Substrates: N/A

Site: N/A

Impact on the environment

Physical and biological: only if insufficient regard for the site's sensitivity (sensitive vegetation) and if the area is not completely watertight

Performance

Recovery rate: variable (possible rate of one minute per person, with 3 people simultaneously at work for rough cleaning, washing/rinsing and final wiping down).
Minimum workforce required: variable according to the size of the worksite: 2 to 3 people assigned to the task at least at worksite closing time or mutual assistance.
Waste: pollutant mixed with a varying proportion of sediments, polluted effluents which may be more or less emulsified (cleaning agents), various solids (sorbents, cloths, etc.)

Comments

- work methodically and precisely identify the boundaries of the decontamination area and the pathways: cordon off the area (attach tape to stakes which are also used to hold the plastic film in place on the ground).
- always comply with environmental and safety instructions: recover effluents and dispose of them in a specialised plant. Ensure that the system is watertight (lay linings perpendicular to the slope) and monitor
- check the pressure and temperature of the hose before beginning to wash down responders, protect against spray and vapours, do not use products such as white spirit, petrol, diesel or abrasives on the skin.

Environmentally friendly practices on the worksite

Environmental constraints

Ensure environmentally friendly practices and reduce harm to the environment: throughout the whole duration of the worksite (from its creation to its closure), whatever the sensitivity of the site, but with extra special attention paid to natural sites:
- do not unnecessarily damage the plant cover or destroy rare or legally protected plants: follow environmental experts' advice, especially botanists who will define the exact points where access routes and worksite installations will be set up (huts, decontamination areas, pathways, equipment base, waste storage sites, etc.);
- mitigate the impact of excessive pedestrian and vehicle traffic: organise traffic (circulation plan, cordoning off, no go areas), lay artificial paths (wickerwork fencing, tarpaulins, planks, track linings for vehicles, etc.), use quad bikes;
- prevent the pollution from spreading (from the beach to the backshore): set up decontamination areas or at least boot scraping points according to the case in hand;
- keep the site as clean as possible:
  • group machinery together and raise it above the plant cover (sit it on pallets for example);
  • anticipate leaks from machinery (lay protective geotextile sheeting);
  • provide bins and clean the site once all the installations have been removed.

Prior authorisation

To access worksites, it is sometimes necessary to pass through privately owned land:
- request authorisation from the land owner or manager (enquire with the local authority);
- carry out a joint visit of the site beforehand to explain the planned solutions and actions, and to observe the condition of the site (pre-existing deterioration).

Over and above ecological impact, the creation of access routes can alter the use (and the frequentation) of an area; the creation of all access routes must therefore be studied in collaboration with all the interested parties: most importantly the municipality and the site manager, but also the local authorities, environmental NGOs, etc.

It is sometimes possible to create or reopen access routes without causing serious or irreversible damage:
- look for disused coastal paths;
- find out about the existence of a local practice of regularly or periodically making clearings by cutting back vegetation (creation of a fire break or hunting trails, etc.)
- in some exceptional cases (worksite in a very sensitive natural area far from existing paths), consider the possibility of using a helicopter to bring equipment supplies and to evacuate large volumes of waste (costly operation but can prove to be cost effective if it is well organised simultaneously for several sites. Requires prior authorisation).

Rehabilitation and restoration of damaged sites

Areas of land deteriorated by clean-up operations (access routes, storage sites, etc.) must always be rehabilitated:
- taking into consideration the question: "can we and should we return the site to its former condition?";
- in cooperation with all the concerned parties;
- based on a diagnosis made by environmental specialists (botanists);

The objectives and modalities of this restoration vary according to:
- the type of plant cover (its sensitivity and self-regeneration capacity)
- the usage of the site (initial use and possibly the use anticipated in the long run as part of a development project existing prior to the spill)

All rehabilitation must be subject to botanical monitoring in order to:
- validate/rectify the chosen procedures and techniques,
- provide relevant elements to help to decide when to stop rehabilitation operations.

Warnings to prevent pedestrian access and vehicle traffic will promote the regeneration of the vegetation. They should therefore be installed as soon as possible, as a preventative measure (channelling traffic), but also as a remedial solution by progressive closure of deteriorated areas as the worksite advances, as well as systematically when the worksite is finally closed.

Equipment maintenance

Upkeep and repair

Minor equipment failures can considerably hinder operations, or even bring a worksite to a standstill:
- train operators to use the machines (inform them of misuse, minor failures which can easily be detected and repaired, etc.);
- regularly maintain the machines (pumps, pressure washers, etc.)
- assign a mechanic to each worksite;
- provide an equipped repair and maintenance site (at base camp for example);
- set up a systematic maintenance-cleaning-repair operation at the end of each week.

Protection

It is not necessary to remove equipment from the beach at the end of the day as long as it is out of reach of the sea, but in the event of a bad weather forecast, it should be moved up the beach or even to the backshore:
- do not rely simply on the tidal coefficient on the coasts of the Channel and the Atlantic;
- do not be deceived by an apparent lack of variation in the sea level in the Mediterranean;
- always check weather reports and anticipate storm surges.

Equipment reliability and conformity

When using earthmoving equipment and other heavy duty machinery, ensure that all the legal checks that this type of machinery must go through have been correctly carried out. The same goes for boats.

Theft and vandalism

The possibility of equipment being stolen or vandalised over the weekend must be considered on worksites and even on the base camp, wherever the worksite is located.
- At the worksite: cabins should be fitted with padlocks (although this is often insufficient);
- At the end of each day, and according to the site possibly at lunchtime too, small tools and equipment, and even detachable parts of all equipment remaining outside, should be put away (e.g. stainless steel hopper of small beach cleaners•);
- At the end of each day, storage tanks (especially flexible tanks which are easy to pierce) containing recovered pollutant or even water should be emptied (only leave the amount of water needed to keep the tank in place in strong winds);
- At the weekend, large equipment should be moved to a supervised site. Do not leave anything valuable or essential for the worksite inside the cabins (e.g. tool box, fire extinguisher);
- Security personnel should permanently supervise base camp sites and equipment storage points.

Waste management

Principles

➞ Definition

Primary storage sites should be set up on the upper beach or backshore. The size of these storage facilities will vary with that of the worksite. They can range from a simple daily deposit point for a few dozen to a few hundred kilos (in bulk or packaged in bags, big bags• or skips) to a larger site grouping together these deposit points, to constitute a primary buffer storage point.

➞ Recommendations

Prevent the pollution from spreading, at each link in the storage chain, and reduce resulting damage to sites by:
- protecting the ground from infiltration and the impact of traffic (tarpaulins, geotextiles);
- effectively managing the available space: assessing intermodal transfer operations and the circulation of machinery used for evacuation.

Sort waste at a very early stage:
- where possible, waste should be initially sorted on the beach, however it can be difficult to have enough containers, therefore small quantities of polluted waste which are initially sorted are often evacuated in the one container;
- otherwise, sort waste in an area where there is enough space and a little more time, i.e. at the buffer storage site (sorting and possibly packaging);
- bags or big bags• are very useful (for non-fluid pollutant) but in order to effectively manage them the contents should be identified using a colour code before leaving the worksite (using different coloured spray paints for instance).

Primary buffer storage site

➞ Identification

If it has not been pre-defined in a contingency plan:
- look for a suitable site in terms of sensitivity, proximity and access, with help from local coordinators and *ad hoc* environmental and waste management specialists;
- call upon the services of a botanist very early on;
- accurately define the respective responsibilities of the different parties in the choice, development, use and rehabilitation of the site.

➞ Management

The site will require:
- specific storage areas suited to the different types of waste;
- personnel, in particular:
- at least one person to supervise unloading operations and enforce sorting procedures in the different parts of the storage area;
- regular intervention of a site maintenance team, in particular when it rains;
- site closure outside of unloading hours so that the site does not turn into a dump for all sorts of waste;
- the organised monitoring of waste entering and leaving the site (type of waste and where possible its average oil content, volume, origin, destination etc.)

➞ Rehabilitation

The return of the site to its original condition implies:
- a contamination diagnosis made by a organisation specialised in ground pollution, possibly decontamination operations, and the authority's full discharge;
- in some cases, a botanical evaluation to define a plant cover restoration operation.

Worksite records

Principle

Worksites should be monitored on a daily basis to determine the human resources and equipment used on the different worksites on the shoreline.

In order to do this, forms should be filled up at the end of each day, summarising the operations conducted and listing the means deployed, site by site, during the day.

These daily worksite monitoring forms are a key element in response management:
- during the response, they constitute a valuable management and communication tool, in that they offer an up-to-date summary of human and material resources used on the worksites, meaning that a detailed overview of the worksites (number, equipment used...) is available at all times;
- after the response, they provide a basis for experience feedback, archiving and even compensation procedures.

Filling in the forms

➞ Content

The information required on the worksites in operation mainly concerns the following points: location, date, human resources and equipment (number, origin), operations (type) and results (volumes of waste).
[NB: personal protective equipment (waterproofs, disposable overalls, masks, goggles, gloves, boots, etc.) and manual collection tools (shovels, scrapers, bags, etc.) need not be inventoried daily but rather an overall count should be made by the field command post once a week. Their provision must nonetheless be taken into account (in terms of requirements for the following days).]

➞ Completion

A daily worksite record sheet (see form below) should be filled in at the end of every working day by the different worksite leaders and sent to the incident command post• for the evening meeting.
The field command post will compile all these forms and transfer them to the incident command post• and the Unified Command•.

In France, a computerised information feedback and processing system was developed by Cedre during the *Prestige* spill (2002). With this system, dubbed ARGEPOL•, the situation can be monitored from the moment the pollution is first observed through to the restoration of the shoreline and beyond. It keeps precise daily records of the number of operators mobilised on a site, their organisation, the work carried out (clean-up techniques) and the equipment used (type of equipment, number, origin). Multimedia documents associated with a worksite or a pollution observation can be uploaded. It is able to automatically generate reports and maps based on the data entered. These documents can then be submitted to the authorities as attachments.

DAILY WORKSITE MONITORING FORM

INCIDENT REFERENCE:
WORKSITE RECORD SHEET (one form per day and per site)
To be sent to:

Site: Municipality:	Field command post:	Date:

Personnel		(2) Nature of operations	Equipment used			Waste recovered		Further remarks	Requirements for the following day
Workforce (number)	(1) Origin		Quantity	(1) Origin	(3) Type	Volume (m³)	(4) Type	(Incidents, breakdowns, team handovers, etc.)	Personnel/ equipment

How to fill in the form
(non-exhaustive list to be adapted according to the situation)

(1) Origin		(2) Nature of operations	(3) Type of equipment			(4) Type of waste
Equipment	Personnel		Heavy equipment/ logistics	Specialised equipment	Consumables	
Municipality*	Municipality*	Manual recovery	Earthmoving equipment (e.g. excavator)	Boom	Geotextile	Pure oil
Intermunicipal body *	Intermunicipal body *	Recovery	Farm machinery (e.g. tractors)	Pressure washers	Sorbents	Oiled seaweed
Fire service	Government	Mechanical collection	Water supply equipment	Transfer pump	Cleaning agents	Oiled sediment*
Civil protection	Fire service	Pressure washing	Other *	Impact hose	Tarpaulins	Oiled litter
Private company	Civil protection	Cutting/trimming vegetation		Storage (e.g. skips)	Other *	Oiled consumables
Other *	Private company*	Other *		Beach cleaners		Other *
	Other *			Other *		

* specify

Further information

Glossary and acronyms

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

ARGEPOL: a French crisis management IT system designed to record and process information in the event of a spill and to identify lessons to be learned. It was developed by Cedre during the *Prestige* spill.

Beach cleaner: a machine which lifts a 5 to 20 cm-deep layer of sand and sieves it through a vibrating metal screen. The debris is deposited in a hopper from which the solid waste and tarballs can be recovered.

Big bag: flexible woven bag with a large holding capacity, of approximately 1 m^3, equipped with straps

Bund: construction or dyke made of sediment, for example sand on a beach to contain a spill or sediment in a storage area to limit the spread of waste.

Ebb tide: tidal phase during which the water level is falling.

Emulsion breaker: liquid product capable of breaking water-in-oil emulsions in the form of pastes recovered from the shoreline or at sea.

Field command post: field command structure at which the on-scene worksite management functions are performed.

Flood tide: tidal phase during which the water level is rising.

Flooding: saturation of the beach with water.

Flushing: clean-up technique that remobilises fresh pollution using low-pressure jets to channel the oil to a collection point.

Foreshore: section of the shore between the high and low water levels.

Grain size (or particle size): study of the size of individual grains of sediment and their distribution between different size classes.

Impact hose: hose equipped with a Venturi system to generate a flow of water containing air bubbles to remobilise the oil in the sediment and certain structures and thereby facilitate its recovery.

Incident command post: command structure at which the tactical-level command functions are performed.

Intertidal zone (= foreshore): section of beach from the high tide limit to the low tide limit.

Man-made structure: structures built by humans.

Mesotidal: tidal range between 2 and 4 m; the record for macrotidal environments (tidal range > 4 m) is held by the Bay of Fundy where the tidal range exceeds 17 m.

Microtidal: tidal range < 2 m; characteristic of enclosed seas (30 cm in the west of the Baltic Sea; the Mediterranean has a tidal range of between 20 and 50 cm).

Oleophilic: which has an affinity for fats.

Persistence: propensity of a product to resist degradation and thereby persist in the environment.

PPE: Personal Protective Equipment.

Weed-cutting launch: craft or machine used to cut polluted vegetation, particularly along riverbanks and in marshes.

Scour/scouring: removal of sediment from around the base.

Shingle: loose sediment found on beaches typically consisting of cobbles, pebbles and gravel.

Skimming: selective recovery of oil on the water surface using a skimmer.

Strandline: accumulation of natural or man-made debris deposited by that the sea at the highest point on the foreshore• reached by the high tide.

Subtidal zone: the area located below the variations in water level caused by the tides, and therefore always under water.

Surfwashing: technique which involves moving sand down to the lower foreshore to be cleaned by natural wave action.

Unified Command: joint structure responsible for coordinating the response.

Venturi effect: name given to a phenomenon in fluid dynamics whereby the pressure of a flowing fluid decreases when the flow velocity increases, or when the flow cross-section narrows. The Venturi effect can be used to create negative pressure and thus generate suction, for example to mix liquids or a liquid and a gas (a liquid under negative pressure sucks in the gas or other liquid, thus enabling mixing), for example water and air in impact nozzles or foam and water in fire-fighting foam eductors.

Windrow: row or linear pile of pollutant formed by scraping the polluted substrate to facilitate selective recovery.

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