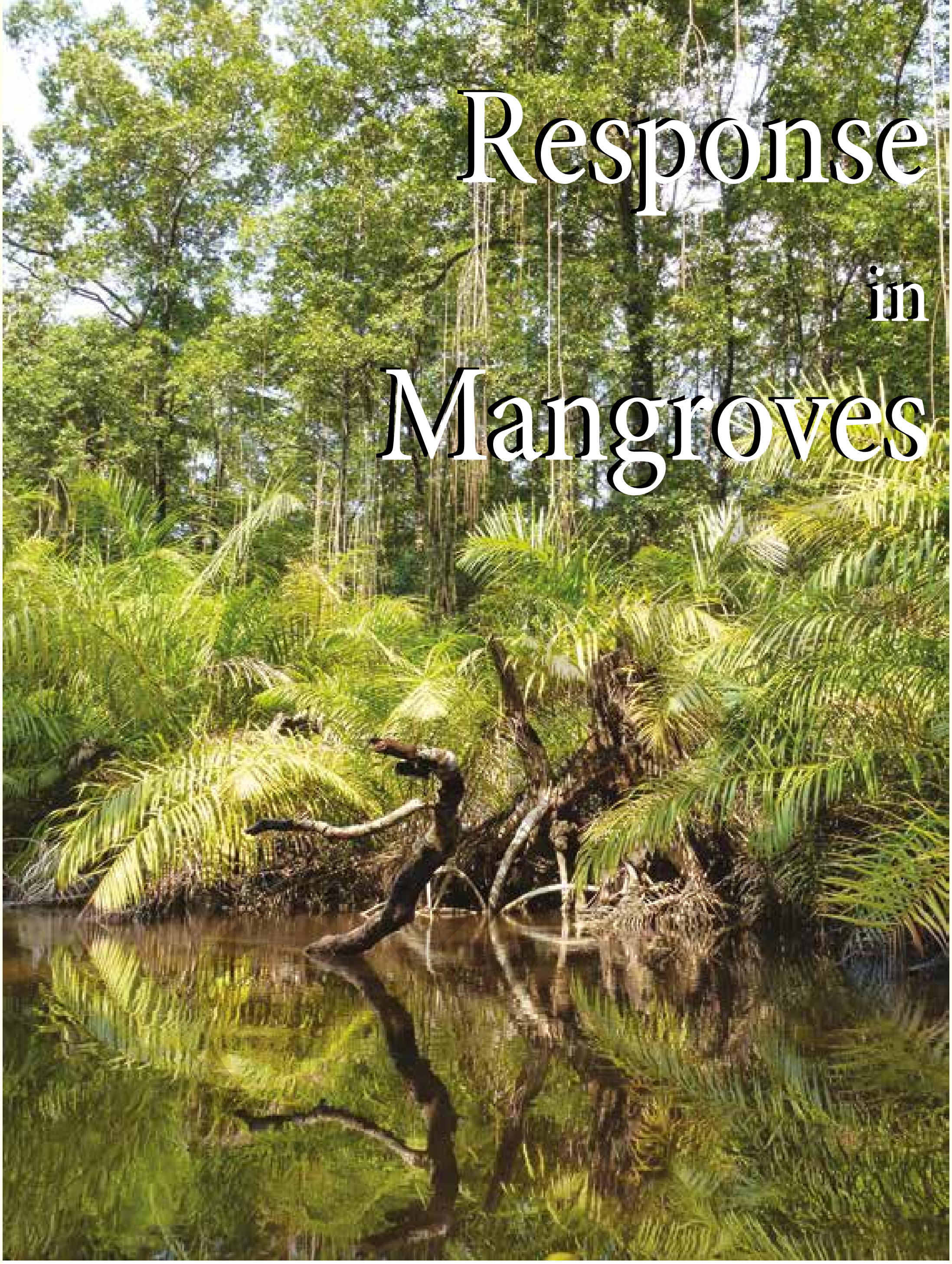

Response in Mangroves

Operational Guide

Cedre

Response in Mangroves

Operational Guide

Information
Decision-making
Response

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Author: Loïc Kerambrun

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Mangrove in Gabon
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Purpose of this guide

An oil spill in a mangrove can have detrimental effects whose intensity and duration will vary according to a number of factors: the type and quantity of oil spilt, the diversity and sensitivity of plant and animal species and communities affected, the fragility of resources and activities, but also the quality of the actions implemented to respond to the spill and mitigate the damage caused.

Response in these highly sensitive and very often hostile environments deserves special attention given that:

- it can cause harmful effects on the environment, sometimes even more so than the spill itself
- responders are required to work in a hostile environment in which the environmental constraints mean difficult, or even arduous, working conditions, and sometimes hazardous situations.

The aim of this guide is two-fold:

- to mitigate the negative impacts of the spill and the response on the mangrove environment
- to facilitate the response and ensure greater responder safety and less arduous working and living conditions.

This guide presents the main aspects to be aware of and considered for response or to decide not to respond. It draws upon a literature review and Cedre's experience in spill response in mangroves. The specificities of mangroves as well as those of the oil spilt in the environment are presented. The broad principles of response in mangroves are outlined and the guide also includes practical datasheets detailing the implementation of specific techniques.

Contents

Response preparedness

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What are mangroves?

Highly characteristic habitats

Cousins of temperate intertidal marshes, mangroves are geomorphological formations characteristic of tropical environments. They are intertidal – generally estuarine – habitats which harbour plant formations composed of varied groups of trees and shrubs. These habitats are among the world's most productive environments and are home to flora and fauna of outstanding ecological diversity and richness.

Threatened and vulnerable species

As very sensitive and vulnerable environments, mangroves are often threatened by overexploitation of their forestry and fishing resources or by other human activities developed either within the mangrove or within the immediate vicinity. In 2005, the Food and Agriculture Organization of the United Nations (FAO) estimated that 3.6 million hectares of mangrove had disappeared during the preceding 25 years, i.e. 20% of the total area initially recorded.

In more recent years, climate change has also started to jeopardise mangrove ecosystems, with for instance increasingly frequent and increasingly violent extreme weather events, a rise in sea level, a rise in temperature, etc.

Principally tropical formations

Mangrove forests are found in 124 countries and mainly lie within the intertropical zone, with a few rare instances in temperate regions. Their maximum extension spreads between latitudes 25°N and 25°S. Situated at the interface between land, sea and freshwater, mangroves can stretch over 100 km inland up river deltas.

World mangrove distribution

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Highly varied formations and evolving environments

The temperature, water, soil, humidity, salt, sediments, nutrients, hydrodynamics and biological interactions condition the balance and development of the mangrove. The panoply of possible combinations of these factors explains the great diversity observed both within a single mangrove and on a global scale.

Influence of topographic and hydrological characteristics

According to the topographic and hydrological characteristics, four types of mangrove forests or ecotypes can be defined:

- fringe forests, which border the sea and are inundated daily by tides
- riverine forests, which flank the estuarine reaches of a river channel and are periodically flooded by fresh or brackish water
- basin forests, which are located inside the mangrove and are occasionally flooded and characterized by stagnant or slow-flowing water
- dwarf forests, which grow in areas where hydrology is restricted.

According to their characteristics, mangrove forests are generally dominated by one of the three most common species of mangrove trees: red mangrove (*Rhizophora*), black mangrove (*Avicennia*) or white mangrove (*Laguncularia*).

Red mangrove (Rhizophora)

Black mangrove (Avicennia)

Influence of longitude and latitude

The extent, size and density of the vegetation tend to decrease towards the tropics. Large delta plains, conducive to mangrove development, are far more common in the equatorial zone than at higher latitudes. In arid areas, the salinity and lack of nutrients hinder plant growth. Species diversity and richness are higher in mangroves bordering the Indian and Pacific Oceans, in particular in Southeast Asia.

Dense mangrove in Bangladesh

Dense mangrove in Gabon

Mangrove on boulders in Cameroon

Dynamic environments

Mangroves develop in intertidal areas, principally with a very high level of sedimentation, with shallow waters characterised by low hydrodynamics. The edge of the mangrove can however be violently hit by the sea, for instance during tropical storms.

By growing on the soft mud, pioneer plants reclaim land from the sea and promote the sedimentation process. This process stabilises the sediment and raises the ground level. The conditions are thus sufficiently modified in the highest areas for pioneer plants, while gaining ground along the edge, to gradually give way to other tree species. It is difficult to determine whether it is the sediment, the vegetation or the hydrodynamics which make the mangrove, given that all the physical, abiotic and biological components are so intrinsically linked. A disturbance which considerably affects one of the components of this trio will jeopardise its balance, which could lead to the destruction of the mangrove.

Heterogeneous vegetation suited to environmental constraints

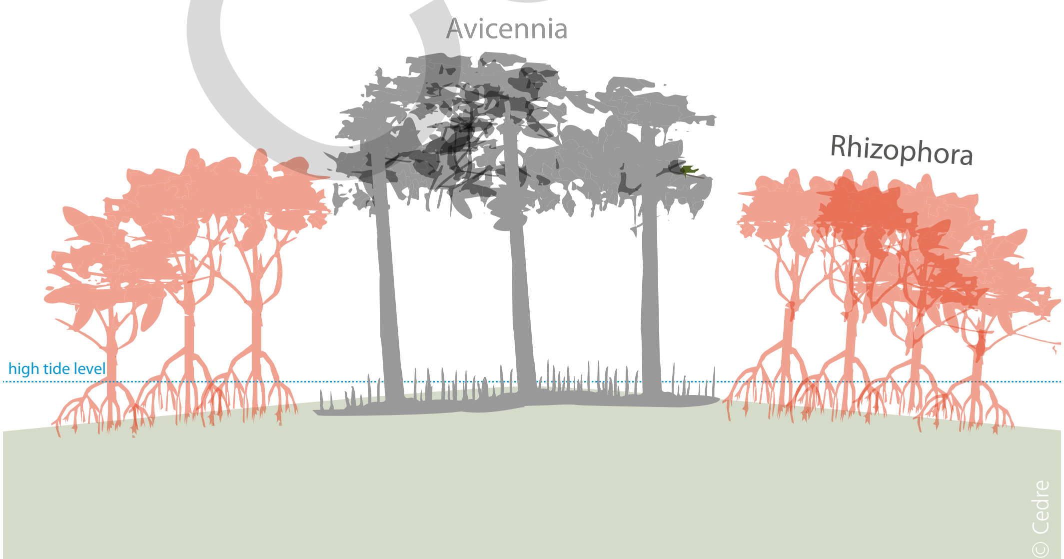
Many environmental stress factors

The various parts of the mangrove are exposed to different environmental stress factors, which are potentially strong and highly fluctuating in the course of the day or indeed of the year, in terms of flooding, temperature, salinity, turbidity and wave exposure. Mangroves are very lively environments which are constantly changing in response to variations in the water which floods them. This creates disturbing conditions which its flora and fauna are able to overcome thanks to their physiological and morphological adaptation.

Vegetation zonation

The vegetation differs according to its location within the mangrove (at the edge, in the middle, or on the river banks), with pioneering species in the softer sediment or more established vegetation on the firmer ground which has gradually formed through sediment accretion. Vegetation zonation occurs based on tidal levels. This is the result of the preferential installation of certain formations in local environmental conditions according to the topographic elevation.

This zonation is not however simply due to a difference in height. In higher areas, less frequent flooding, together with high evaporation of the salt water during dry periods, leads to very high fluctuations in salinity and therefore induces greater stress in these areas than in the lower areas which are flooded on a daily basis and where the salinity gradient is therefore far lower.



Mangrove vegetation zonation

Survival strategies

To overcome these heavy environmental constraints, mangrove plants adopt extraordinary establishment and survival strategies specific to these environments. They are able for instance to:

- put down roots in soft sediment with either prop roots or underground roots with upward appendages
- breathe in anoxic soils using specialised organs such as lenticels or pneumatophores
- cope with high salinity levels by excreting salt through special glands in their leaves or by excluding it at root level
- restrict freshwater loss
- produce offspring by vivipary, developing seedlings known as propagules.

Rhizophora *prop roots*

Avicennia *pneumatophores*

Lenticels on Rhizophora *prop roots*

Rhizophora *propagules*

A wide range of fauna

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From the top of the canopy to the depths of the mud, mangroves are home to a wide range of fauna. Some of the species present are rare, threatened or of major interest and therefore have a special protection status. Many species are still poorly known and others unknown. Among the most characteristic species, reference can be made to the following examples, organised by class:

- terrestrial mammals: raccoons, opossums, otters, deer, tigers, monkeys, etc.
- marine mammals: dolphins, dugongs, etc.
- birds: herons, egrets, kingfishers, pelicans, eagles, etc.
- reptiles: crocodiles, monitor lizards, iguanas, turtles, snakes, etc.
- fishes: mudskippers, catfishes, tarpons, sharks, etc.
- amphibians: frogs, etc.
- arthropods: spiders, horseshoe crabs, etc.
- insects: bees, mosquitos, etc.
- crustaceans: crabs
- bivalves: oysters, clams.

Crocodile

Frog

Heron

Catfishes

Fragile environments with high ecological value

A5

A unique ecosystem

Mangroves are unique ecosystems. Among the hundreds of plant species recorded in the world's mangroves, just over 70 species are only found in these environments. Ranking among the most productive ecosystems worldwide, mangroves play a fundamental ecological and socio-economic role, over a vast area which greatly exceeds the boundaries of the mangrove itself.

Ecological wealth

Mangroves are a latticework of interdependent terrestrial and aquatic habitats. Within this ecosystem, plant and animal species (including humans) are heavily dependent on each other. This interdependence is not limited to the food chain alone, it also takes other forms and performs other functions. For instance, invertebrates (oysters, mussels, barnacles) and epiphytic plants (moss, seaweed, etc.) grow on the prop roots of mangrove trees.

For thousands of years, and until recently, indigenous communities heavily depended on mangroves, maintaining solid symbiotic relationships with these environments. While recent anthropogenic pressure has somewhat altered this traditional balance, certain resources – fished, hunted, harvested or gathered – still hold fundamental socio-economic value for local coastal populations.

Mangroves thus provide an interwoven lattice of ecological and ecosystem products and services including:

- natural process regulating services
- supporting services or ecological functions
- provisioning services
- cultural services.

Traditional subsistence fishing

Traditional subsistence fishing

A fragile balance

Mangroves are environments which have a fragile balance. They are particularly vulnerable to oil pollution. Not only oil can cause severe impact, but the response itself, if it is unnecessary or poorly organised, can also cause harmful effects, which may in fact be greater than those of the spill, and may even be irreversible.

Oil spills can affect flora and fauna in various ways (direct toxicity, oil coating, suffocation, disturbance or destruction of the habitat or certain functional sites) and to a varying degree according to the species, the pollution, the time of year, etc. Response actions can have additional harmful effects on the already impacted flora and fauna, whether contaminated or disturbed. It is therefore important to take the necessary measures to prevent or restrict the impacts of the response. Meanwhile, the risks the mangrove may present for responders must also be assessed and mitigated.

Village situated at the edge of a mangrove

Pond used for shrimp farming

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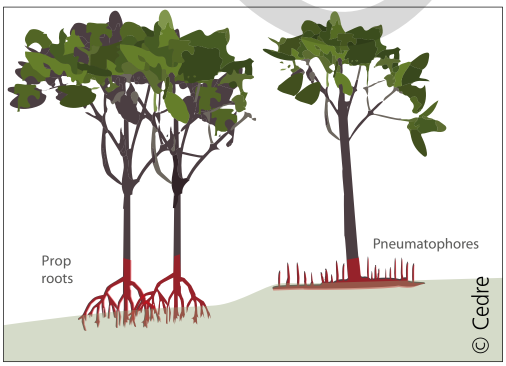
Behaviour of oil spilt in mangroves

Spread of the pollution

The horizontal spread of the oil within the mangrove will depend on the quantity spilt and the type of oil, as well as the flooding conditions at the time of the spill. These factors depend mainly on:

- the geographical configuration of the mangrove and its detailed topography which determine the areas in which the pollutant will accumulate or simply pass through
- the hydrological conditions, of ocean origin (tidal cycle), and weather conditions (dry season/wet season), which determine the water depth, on the day of the spill and the following days.

A spill in a mangrove will not systematically affect the whole area, but only certain submersible parts according to the tidal cycle or the flood level at the time. Statistically, the risk of oiling is higher for *Rhizophora*, which live at lower levels, than for *Avicennia*, positioned slightly higher.



The contamination methods, in red, differ according to the species for a similar theoretical height: Rhizophora *(left) and* Avicennia *(right)*

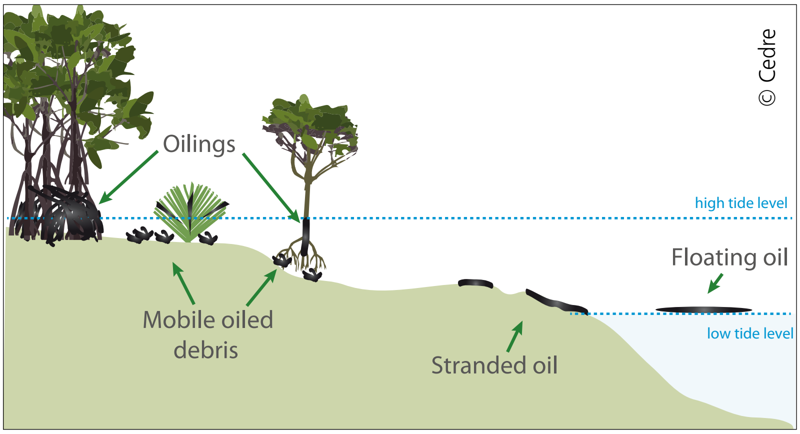
The type of soil, in particular its porosity and water saturation, determine to what extent the oil will either penetrate into the substrate, or be buried due to sedimentation or trampling.

Oil behaviour

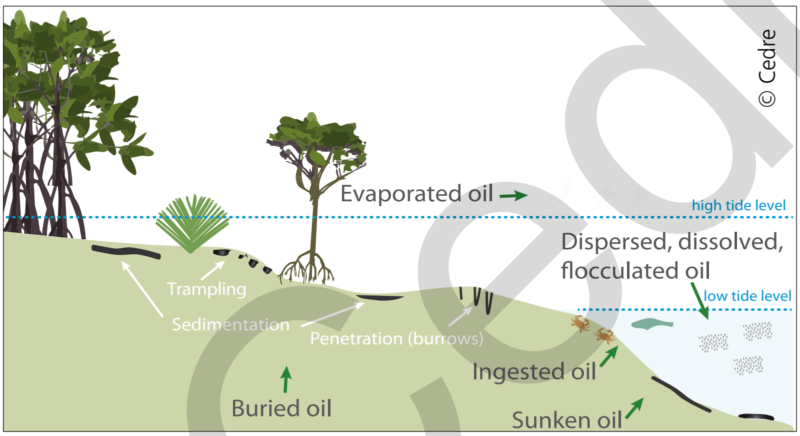
Once it has been spilt, the oil is carried by the water, driven by the prevailing currents and wind. Certain characteristics of the water will affect the oil's behaviour, in particular its salinity, turbidity and agitation. All oils do not however behave in the same way as they do not have the same initial physical and chemical properties, in particular their density and viscosity. Oil can be distributed between all the compartments (air, water, banks, seabed as well as tissues) and can cause contamination which can be divided into two different categories: visible pollution and invisible pollution.

Visible pollution can take three main forms:

- free oil: sheen or accumulations (slicks) which may be floating or stranded and are generally liable to be remobilised
- oilings which, according to their thickness, may stain or coat surfaces (man-made structures, vegetation, animals, etc.)
- oiled debris (vegetation, in particular the litter) which can also be easily remobilised by the water.



Types of visible pollution



Types of invisible pollution

Pollution which is not visible to observers requires the use of specific procedures to be detected. This pollution can take various forms:

- fractions evaporated in the air: mainly present during the first hours following the spill, these volatile compounds are the lightest and most toxic fractions
- deposits buried in the soil: either naturally due to sedimentation or sediment accretion, or due to infiltration (via plant root systems or holes and burrows of burrowing animals), or else artificially due to trampling during response operations for instance
- sunken deposits or slicks: due to reduced buoyancy caused by sediment incorporation, a process occurring either directly in the watercourse or after the oil has washed up on the mud on the banks and at the edge of the mangrove
- dispersed, flocculated, dissolved or ingested oil: light fractions and particles disseminated in the water column, the sediment, flora and fauna.

Fate of spilt oil

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Ineffective natural cleaning

Mangroves are found on coasts where oil is most persistent. Over and above severe weather events, which regularly strike these latitudes and with the exception of the edge which protrudes into the sea, mangroves have low exposure to wave energy. These low hydrodynamics render the environment's natural cleaning capacity relatively ineffective. This means that the oil which enters the mangrove has little chance of being naturally removed.

Differences appear however between the various areas of the mangrove. Greater natural cleaning action can be found in the lower parts of the mangrove than along the edge, banks and channels. The soil is generally water-logged and affected by tides and currents on a daily or near-daily basis. In the internal parts, which are higher and therefore less subject to flooding, natural cleaning is non-existent.

A high degree of sedimentation

Certain areas of the mangrove, in addition to having a low natural cleaning capacity, also experience a high level of sedimentation. Once the oil has been deposited it may be rapidly covered in fine sediment and gradually buried at depths preventing any chemical evolution of the oil, due to the lack of oxygen. Oil trapped in muddy sediment will retain its full toxic potential for very long periods of time. If present in significant quantities, it may compromise the long term survival of nearby plants which appear to have withstood the pollution, and prevent the recolonisation of oiled areas by plants and fauna dwelling in the soil.

Oil which has infiltrated along the trunks and roots of palm trees

Biodegradation potential

Surface sheen and thin surface deposits, as well as fractions disseminated in the water column, may be very rapidly broken down, especially biochemically, in particular due to the intense activity of the bacteria, fungi and other micro-organisms which characterise these environments.

Impact of spilt oil

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Factors influencing the sensitivity of the mangrove

The mangrove's sensitivity to oil will depend on several factors:

- the type of pollutant, and in particular its viscosity, toxicity and persistence. Moderately to very highly viscous oils cause suffocation due to the coating of aerial roots. Low viscosity oils affect the mangrove due to their toxicity.
- the extent of the spill (spread and quantity) as well as the amount of oil remaining after any clean-up operations
- the intrinsic sensitivity of the species of which it is composed
- the season, which will determine the stage in the development cycle of the vegetation and associated fauna and affects the hydrological and chemical conditions (energy, flow, salinity) in the mangrove.

Visible direct effects

Fauna can be affected to varying degrees by a spill due to toxicity, coating effect, habitat destruction... This is notably the case of benthic fauna on the foreshore with low mobility or heavily dependent on this environment (crabs, oysters, worms and other invertebrates), as well as other more mobile animals (insects, batrachians, reptiles, birds, fish, marine and terrestrial mammals, etc.) but which may be taken by surprise or trapped by the pollution, or contaminated when visiting a polluted site.

In the most heavily oiled areas, the layers of oil covering the ground and aerial roots suggest a heavy to very heavy impact, which is generally rapidly confirmed by the discovery of many dead oiled animals.

Large varan

Small varan

Mud crab

At a later stage, additional signs can provide evidence of severe impacts on the vegetation. The first of these signs is the leaves turning yellow, indicating that the plant has lost its ability to absorb and transport nutrients and freshwater to the leaves. Subsequently, the tree may lose its leaves, either partially or completely according to the intensity of the harmful effects. Complete defoliation is generally a precursor of tree death. Defoliation is generally observed relatively quickly (a few weeks after the spill). However it has been known to occur at a much later date (a year or more after the spill). This can be a particularly spectacular phenomenon as it generally occurs in evergreen forests.

Destruction of vegetation

Destroyed forest in the initial stages of recolonisation several years after a spill

Defoliation

Propagule developing within oiled roots (no guarantee of survival)

Oiled roots and obstructed lenticels

Long lasting impacts

In this context, defoliation generally foreshadows tree death. The tree will die a few months, or even years, after it has lost its leaves. Disturbances which initially appear harmless can sometimes have significant delayed repercussions. For instance, tree mortality has been correlated with a high mortality rate and non-return of the large population of burrowing crabs which initially lived around their roots and provided oxygen to the soil by aerating the sediment.

In the case of significant disturbances, the impacts are not always limited to the mangrove itself. Cascade effects can occur. These effects may be temporary or far more devastating. The destruction of the forest can lead to the temporary remobilisation of sediment, which is no longer held in place by the root system. This erosion locally increases the sediment content in water which, if high, can in turn heavily affect any marine ecosystems which closely interact with the mangrove, such as coral reefs and phanerogam seagrass beds. These ecosystems are far less tolerant to turbid waters. The mangrove therefore loses its defence system against erosion and turbidity to the detriment of the associated shoreline and habitats.

Defoliation does not however systematically mean that the pollution is the only cause. It can occur, in non-spill related contexts, in response to a strong chronic environmental stress related to temperature or salinity. An already fragile mangrove will be more vulnerable to the effects of an oil spill.

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Defining priorities before a spill occurs

Defining what needs to be protected and/or saved as a priority and having to decide what will be sacrificed is not always an easy task. Such decisions should not be made during the incident but rather beforehand, during the contingency planning phase.

It is important to have enough time to implement the following actions:

- assess sensitivity by collecting information relating to the habitats, resources and activities taking into account their seasonal variability
- assess the behaviour and impact of the pollutant, especially if it has been previously identified, as is the case if there is an oil facility (well, refinery, storage facility) nearby
- define plausible spill scenarios in terms of the pollutant and incident (type and quantity of oil, type and location of spill)
- provide decision support tools (sensitivity atlas, drift simulation)
- determine the behaviour, fate and drift of pollutants under realistic metocean conditions
- procure and organise response equipment accordingly, including human resources and support boats or even aircraft, to deploy them as and when required
- draw up a review of knowledge on dispersion and its impacts in such environments
- identify the main access points.

Only through planning can an efficient and planned response, based on supported strategic decisions, be implemented when a spill occurs and the distribution of available resources at the most strategic locations and most suitable times be optimised.

Situation assessment

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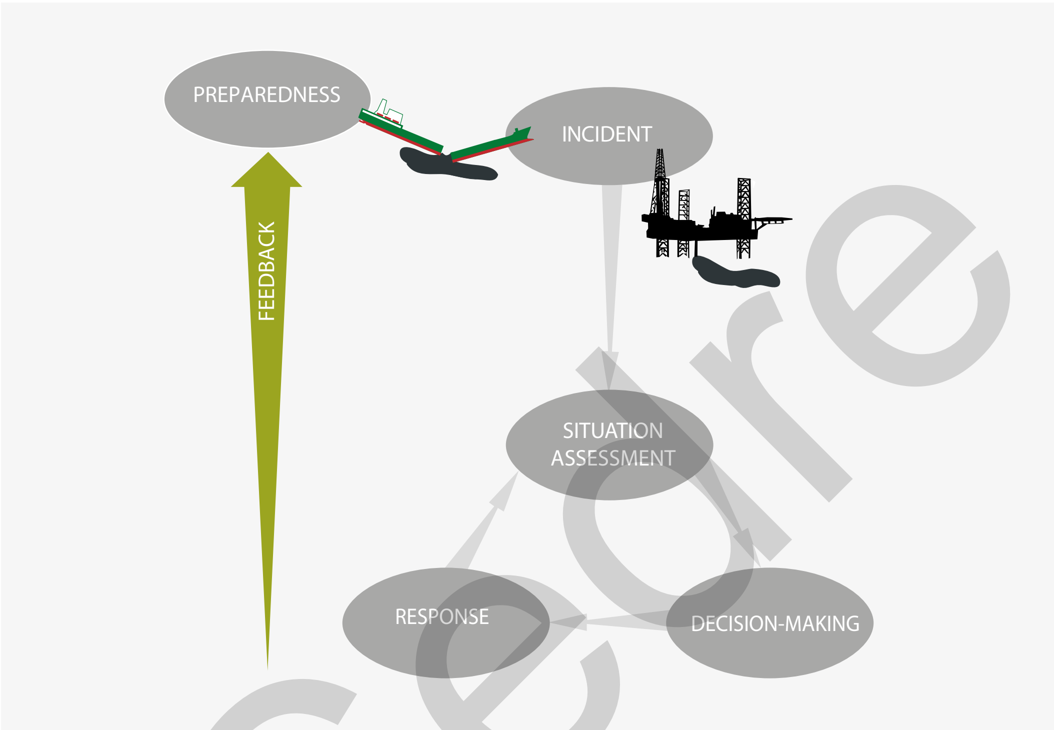
Methodology

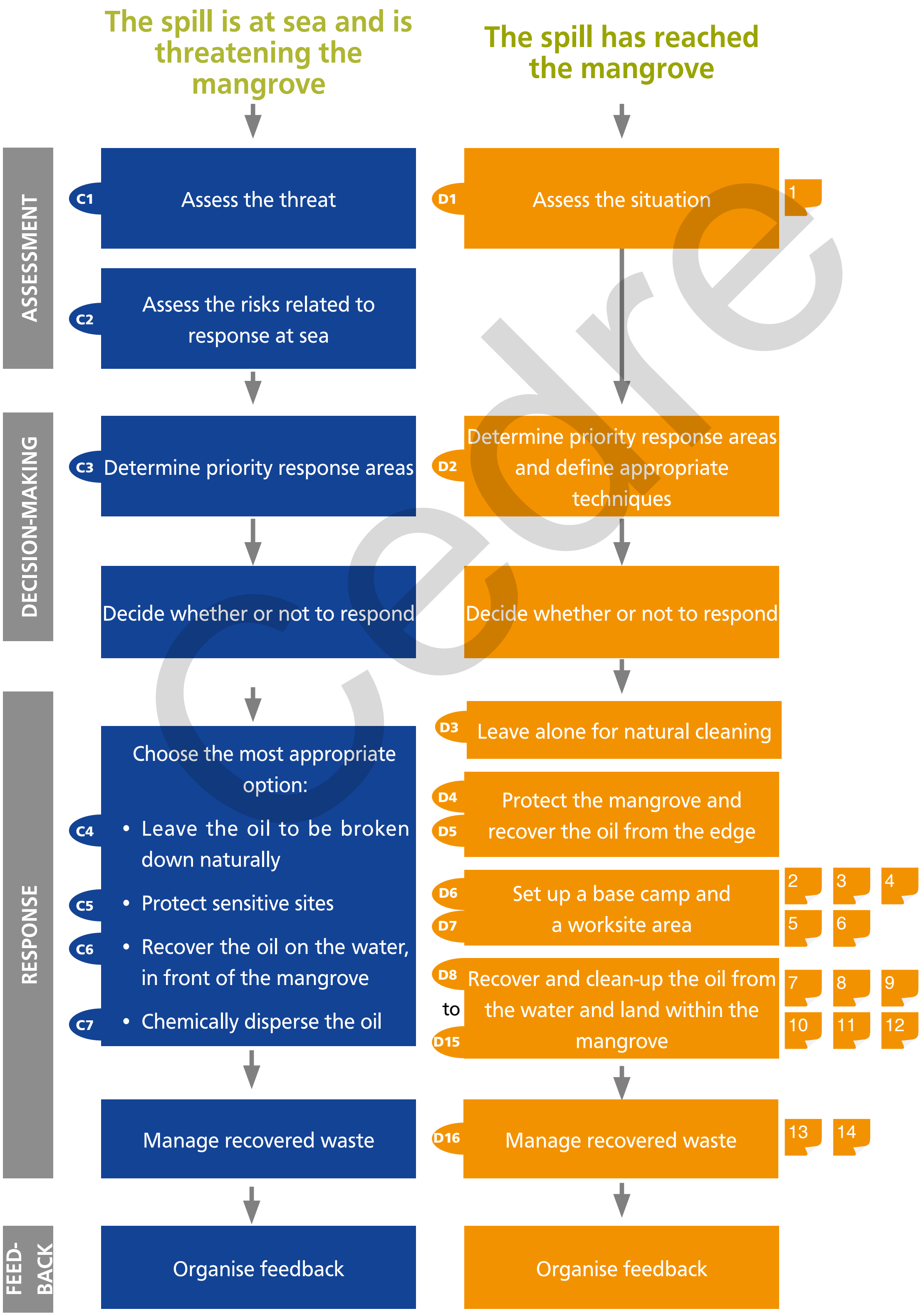


Methodological approach to spill management

Two types of scenarios can be envisaged:

- A spill from a vessel or an (offshore or coastal) oil facility. The spill is drifting in coastal waters and threatening the mangrove. In this case, the response will first be implemented at sea.
- A spill at sea has reached the coast or the spill is emanating from an oil facility within or on the edge of the mangrove. The mangrove is affected. In this case, the response is carried out on land.

Response strategies in mangroves



Response - What to do if the mangrove is at threat

Assessing the threat

Surveys carried out at sea from aircraft or vessels will confirm the alert and help to assess the extent of the incident.

A slick drift forecast for the coming hours can be made using simulation models which can take into account the prevailing and forecast weather conditions and the characteristics of the pollutant.

Knowledge of the physical, ecological and socio-economic environment will help to assess the risks. The existence of shoreline sensitivity maps (in the form of printed atlases or a GIS) proves very useful here. Such maps provide information on the ecological value of the natural areas at threat and on the relative importance of the resources and activities liable to be directly or indirectly affected.

See Cedre operational guide on "Aerial Observation of Oil Pollution at Sea"

Aerial reconnaissance survey

Aerial view of the edge of a mangrove forest

C1

Assessing the risks related to response at sea

At sea, several response options are available: leaving the spill for natural cleaning, chemical dispersion, containment and mechanical recovery and the protection of sensitive sites. Each option has its advantages and disadvantages in terms of efficiency and impact on the environment. Their window of use will depend on the characteristics of the spill, the pollutant and the environment as well as on the performance and limits of the response equipment used. On the day of the spill, first it is important to check whether this window is compatible with the prevailing conditions.

As mangroves are extremely ecologically sensitive, any environmental impacts, in both the short and long term, must be anticipated with regard to the potential response options. To do so, the actual sensitivity of the mangrove and any other sensitive marine habitats present nearby (seagrasses and coral) should be assessed, while bearing in mind the vulnerability of the economic activities and natural resources present in the area at the time of the spill.

This type of methodical approach, known as the Net Benefit Environmental Analysis (NEBA), can be used to identify an efficient option which will generate the least possible impact on the local ecological and socio-economic environment.

Defining what needs protected and/or saved as a priority is not always an easy task. However this question needs to be addressed, especially if a spill is threatening a mangrove. This decision is often the authorities' responsibility, who draw upon advice from technical experts and stakeholders in the local environment and economy. Such a decision should not be made at the time of the crisis – in which case there would be no guarantees as to the soundness of such a decision – but rather during the contingency planning phase.

See the IPIECA report "Choosing Spill Response Options to Minimize Damage (Net Environmental Benefit Analysis)"

Determining priority response areas

In-depth knowledge of the marine environment within and surrounding the mangrove will help to identify priority areas for response actions, in advance, according to possible spill scenarios. To do so, the characteristics of the spill, the influence of the metocean conditions, the viability of the response (access, available resources) and the sensitivity of the habitats and resources at threat must be taken into account, bearing in mind their seasonal variability. When a spill occurs, priority response actions will thus be easier to determine in these areas.

Leave alone

Leaving the oil to be broken down naturally is probably the first option to be considered in the case of a small to moderate spill drifting out to sea. This nonetheless implies a good analysis of the situation and spill monitoring (modelling, surveys) for as long as it remains a potential threat.

Once the decision whether or not to respond has been made, the same must be done for each possible option. The response must then be adapted to the context and scale of the spill.

Protecting sensitive sites

Priority actions

Protection is the option which must always be considered in the case of a spill threatening the mangrove in order to restrict the spread of the spill and protect sites known for their sensitivity (in ecological, socio-economic or even cultural terms). Two main actions should be prioritised:

- trapping the largest accumulations of floating oil and stranded oil at risk of being remobilised
- protecting any sensitive sites as yet unoiled by damning the watercourse or channelling the oil to keep it on the water body where it will be easier to collect.

Possible equipment

The most common technique to protect sites is the use of manufactured floating booms. Such booms are installed using appropriate boats in terms of requirements and navigational possibilities. Booms can be towed over short to moderate distances. In the case of remote sites, it is preferable to use workboats (with front panels for instance) to transport booms to their deployment site. Boom laying generally does not have any environmental impact, except if they require to be anchored in seagrass beds or coral reefs. Nevertheless, containment booms should not be deployed on foreshores where pneumatophores emerge as if many of these roots were ruptured the tree's survival would be endangered.

Boom maintenance is essential, both to continually monitor the containment system's efficiency and to prevent the booms from becoming detached and washing up in fragile areas.

Whatever the protection strategy selected, the contained oil must be recovered.

See the Cedre operational guide entitled "Manufactured Spill Response Booms"

Responding to a slick which is threatening a mangrove is no simple task, given that the timeframe is generally very, if not too, short. The techniques implemented in the event of a spill affecting a mangrove, such as containment by boom deployment and recovery on the water, require prior preparation of response vessels (including small artisanal fishing boats) as well as training of personnel. It is therefore important to regularly test contingency plans through spill response exercises.

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Recovering the oil on the water, in front of the mangrove

This can be done in two ways: dynamically by sweeping slicks drifting at the water surface or statically by intercepting the oil at a fixed point.

See the Cedre operational guide entitled "Skimmers"

Offshore or near mangroves

Dynamic recovery can be implemented using specialised vessels (oil spill recovery vessels or smaller recovery barges) where locally available, or using vessels of opportunity (workboats, fishing boats, etc.). These vessels should in this case be equipped with specialised equipment suitable for containing, recovering or trawling drifting slicks. They should also be able to store the recovered oil onboard, or else have floating storage tanks alongside them. If this is not the case, a possible solution could be the use of a support vessel to which the collected waste could be transferred from the recovery boats.

Inshore or at the river mouth

Local boats, which are smaller and better suited to the environment's specific navigating conditions, can provide good support, when carrying equipment to collect small slicks, clumps of oiled vegetation (using small floating booms, nets or scoop nets) or to "sweep" heavy sheen (using sorbent booms, rolls or mats).

In the immediate vicinity or along the banks of the mangrove

Dynamic recovery at the water surface can be combined with static recovery. The oil can be blocked or deflected by various systems (containment booms, skirted sorbent booms, custom-made barriers) positioned in different configurations. Recovery is carried out continuously, either mechanically (skimming/pumping, netting) or manually (scooping, sorption, direct removal of debris).

Water hyacinth drifting naturally and helping to recover the oil by absorbing it

The involvement of residents, fishermen and other aquaculture professionals in the response provides boats which are perfectly suited to local conditions. It is also the opportunity to benefit from potentially profitable fishing practices and gear as well as from in-depth ancestral knowledge of the water body and the mangrove. In return, this involvement provides a source of revenue for these sea professionals affected by the spill, partially compensating for their loss of income due to the oil which prevents them from carrying out their usual activity.

Chemically dispersing the oil

How dispersants work and their impacts

Chemical dispersion causes the oil to move down into the water column in the form of microdroplets. This dispersed plume temporarily contaminates the top few metres of the water column, and therefore the seabed in shallow waters, which would have been unaffected if the oil had not been dispersed. The organisms living in this layer of water are therefore momentarily exposed to potentially toxic, if not lethal, concentrations. Chemical dispersion can thus have a very severe impact on phanerogam sea grass beds and coral.

Certain experiments suggest that dispersed oil is less harmful for the mangrove than an untreated slick as the dispersed oil adheres less to surfaces. While the results of these experiments cannot be taken as a universal recommendation, they can be taken into consideration when defining the response strategy.

Decision-making and implementation

Even more so than for the other response options, the suitability and feasibility of chemically dispersing a slick in front of a mangrove should be assessed in the contingency plans. This means that the expected benefits should be assessed with regard to any drawbacks, using a Net Environmental Benefit Analysis (NEBA). If the decision is made to chemically disperse the oil, this can be implemented:

- by aircraft, either small locally available aircraft (helicopter or plane) or possibly larger special purpose aircraft called out as back-up
- by vessels equipped with spraying arms.

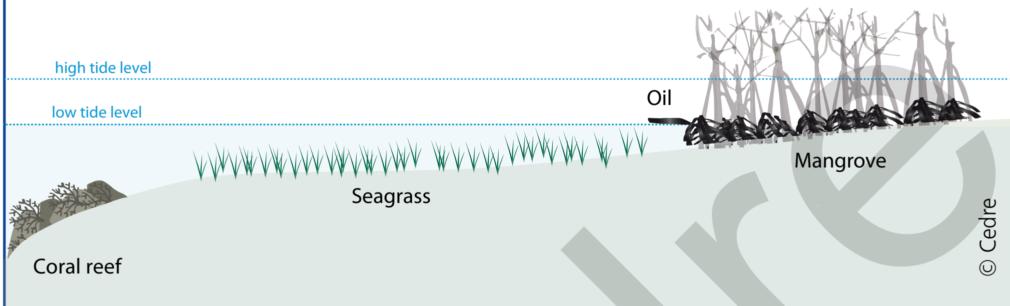
Dispersion is not something that can be improvised on the spur of the moment. It requires not only dispersant and spraying equipment, but also support aircraft and vessels, to be available in sufficient number and quality, at the required time (often within just hours of the spill). Furthermore, dispersants require prior approval by the country's authorities, as does their use near to sensitive sites.

TROPICS is a field study conducted in Panama, on the edge of a mangrove. The aim? To determine whether chemical dispersion in coastal waters is an ecologically acceptable way of mitigating the effects of a spill threatening a mangrove by comparing it to the "leave alone" option. Launched in 1984, TROPICS has been pursued intermittently for thirty years. Through this study, the degradation and recolonisation processes have been observed (without systematically being able to explain them all, as some begin to reverse after 10 years) and trends identified. For some experts, for want of other studies conducted on this scale, TROPICS is a major reference for the application of the NEBA method when deciding whether or not to use chemical dispersion off a tropical coastline.

No chemical dispersion

a. Oil slicks are entering the mangrove, oiling the vegetation, and possibly sinking in the immediate subtidal zone.

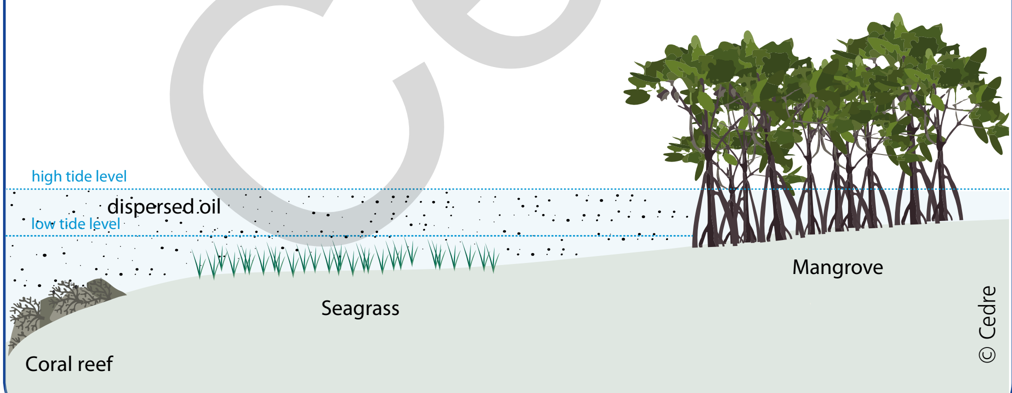
b. Subtidal habitats are spared as the oil remains at the sea surface.



Chemical dispersion

a. The mangrove and its populations are spared.

b. The subtidal habitats bordering the mangrove are temporarily contaminated by a dispersed plume of oil.



See the Cedre operational guide entitled "Using Dispersant to Treat Oil Slicks at Sea"

Response - What to do if the mangrove is affected

Assessing the situation

Why?

Surveying the pollution and the affected area is of the utmost importance. This provides answers to the initial questions which arise. Surveys aim to:

- characterise the spill (location, quantity, form)
- determine whether or not response actions should be implemented or continue to be implemented
- identify the affected environments (substrates, vegetation, habitats, communities, species, etc.) and the socio-economic concerns
- assess the feasibility of accessing these areas, and any related constraints (resources required, access routes, precautions), in order to carry out response actions.

How?

Surveys are more complicated to carry out in mangroves than on other types of coastlines. The canopy often makes it impossible to see the ground from the sky, except in certain open areas such as glades, cleared pipeline corridors and watercourses. At ground level, the luxuriant vegetation greatly restricts the field of view. The survey team must therefore enter the mangrove, to get closer to the spill in order to assess its extent. If necessary, surveys can be carried out simultaneously on land and on the water, travelling upstream along the potentially contaminated rivers and channels.

Like for on-water operations, survey teams must always be accompanied by a local resident (fisherman, hunter, gatherer, forest ranger, etc.) acting as a guide. Such guides offer comprehensive knowledge of the local area as well as of the forest and its dangers. The use of local boats, which are well suited to this environment, should be prioritised whenever shallow, cluttered or narrow watercourses require to be surveyed.

See Cedre Operational Guide "Surveying Sites Polluted by Oil"

Conducting an on-land survey

Conducting an on-water survey

Organising an on-land survey in dense vegetation.. 1

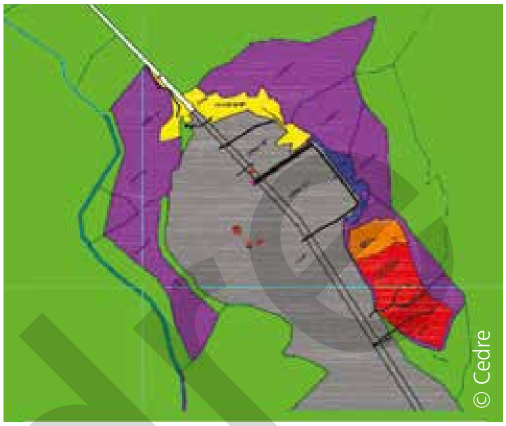
D1

Determining priority response areas and defining appropriate techniques

The purpose of the initial survey is to determine the spread of the spill, to identify the most heavily oiled areas, to record visible impacts and to establish the main environmental constraints. This provides an overview of the situation, enabling response managers to determine where the pollution is significant enough to justify response actions. In this case, an initial action plan can be drawn up: first-line response resources, priority response areas, access, logistics required to implement the response.

Example of a map produced following an initial survey

This initial survey will be followed, as soon as possible, by more detailed surveys, carried out more systematically. These additional surveys will involve more technical resources and skills. Based on the information gathered, detailed mapping of the area will be possible, providing a basis for developing operational documents to be used throughout the response (operational segments, monitoring of the evolution of the situation and of clean-up operations, communication, etc.).



Detailed map produced based on in-depth surveys

D2

Leave alone

On land, the "leave alone" strategy is also a real response option which should be considered, in particular in the case of a small spill, as mangroves can tolerate the presence of small quantities of oil. During a number of incidents and experiments, certain plants (such as *Rhizophora*) have been seen to benefit from such inputs, which appear to boost their growth. The "leave alone" option nevertheless implies at least conducting a survey (to confirm that this is indeed a suitable option), which if necessary, if there is concern over the threat, may be repeated during the following days.

Protecting the mangrove from the edge

Containing, blocking and securing

In the case of moderate to heavy pollution, even if the oil has already reached the mangrove, containment and/or blocking systems should be set up as soon as possible to limit the oil to areas that have already been contaminated. These systems also secure the area by preventing any boats not involved in clean-up operations from entering the area, whether inadvertently or deliberately.

Within the immediate vicinity of the mangrove

Floating booms should be deployed in the area immediately next to the mangrove when possible. In comparison to those used in front of the mangrove, these booms will be smaller and will be required to be left in place for longer. Permanent booms are preferable to inflatable booms as they are easier to maintain over long periods of time. They are also more robust and pirogues can pass over them if their motor is lifted up. Mooring arrangements can be problematic in the case of very soft sediment or a very high tidal range. Along the banks, booms can be attached to tree trunks, possibly using stakes for reinforcement. Booms should not be moored in drying areas strewn with pneumatophores to avoid breaking these roots and hence endangering the trees.

Floating boom in front of a mangrove

Crossing a permanent boom in a pirogue with the motor lifted

In areas of low current

In the narrowest areas with very shallow waters, custom-made systems may be ideally suited to containing/deflecting (planks, tree trunks, bamboo, etc.) or filtering the oil (filter barrier, filtering textile or straight fine-mesh nets).

D4

See the Cedre operational guide entitled "Manufactured Spill Response Booms"

See the Cedre operational guide entitled "Custom-Made Spill Response Barriers"

Straight net at the entrance to a channel

System maintenance

Whatever the type of system used, it must permanently remain operational. Throughout the response, particular attention should be paid to maintaining the system and recovering the contained oil to reduce the risk of the oil escaping from the boom. This two-fold task could be the full-time responsibility of a specific team.

Boom which has reached its maximum containment capacity

Insufficiently taut net

Recovering floating oil at the edge of the mangrove

The aim here is to recover the oil and oiled plant debris floating on the watercourse or trapped in root systems along the bank. Recovery can be carried out either mechanically or manually.

Oil and oiled vegetation trapped in root systems along the banks

Mechanical recovery

Mechanical recovery on the water requires specialised mechanical equipment in the form of skimmers and pumps. To facilitate recovery, the oil must be contained and driven towards the skimmer head using a light boom.

In calmer areas, natural water movements may not be strong enough to drive the oil as efficiently as hoped. The natural water movements, either in terms of the current or the wind, can be artificially amplified. In the first case, a rustic tool (paddle, board) or hoses with small portable pumps can be used. In the second case, a portable blower can prove very effective.
On a relatively open water body, recovery can be carried out using motor boats with sufficient space on board and stability. Traditional fishing gear (e.g. shrimp nets) can also be very useful.

In the narrowest and shallowest areas, local boats such as pirogues, or even more basic craft such as rafts, are often very effective, especially if traditional fishing gear or aquaculture tools prove to be capable of capturing the oil.

Recovery on the water, along the banks and in the channels should be implemented at as early a stage as possible and continue throughout clean-up operations, gradually being downscaled. In this way, small recurrent leaks can be captured as well as any larger, although less frequent, leaks which may occur in the case of exceptionally high tidal ranges, torrential rain, high winds, or following actions related to clean-up (cutting back vegetation, clearing a watercourse, repositioning or retrieving a boom).

See the Cedre operational guide entitled "Skimmers"

Traditional shrimp boat used in a stationary position alongside the bank to recover clumps of oil and oiled aquatic plants

Manual recovery

Manual on-water recovery, from a small boat or from the bank, can be implemented using resources which are easier to handle and may or may not be specific to spill response (e.g. sorbent mats, pads, booms). Tools crafted on site, such as buckets with a perforated base, bailers covered with wire, etc., can prove very efficient at selectively collecting oiled plant debris from the water surface.

To facilitate the cleaning of boats at the end of operations, they should be lined with geotextile and tarpaulins, while mitigating safety hazards for the crew (e.g. entanglement or slipping). During operations, the protective liners should be regularly repositioned and changed as and when required.

Recovery from pirogues in shallow/very shallow waters.. 12

The involvement of local fishermen and other aquaculture professionals in the response has the twofold advantage of offering boats suited to local conditions and individuals with excellent knowledge of the water body and the mangrove. They provide their knowledge of the local area and of sensitive species dwelling there, of water mass movements and navigation. Furthermore, local fishing gear and practices can provide efficient solutions. The experience and know-how of local seafarers can help to predict certain movements of the spill, to refine priorities and to optimise the response by distributing the available resources across the most strategic points and at the most appropriate times.

Organising the overall response

Setting up a base camp

Mangroves are generally located remotely from urban areas. They do not offer accommodation capacities able to cope with a sudden, even minimal, rise in the population for a long period of time, in acceptable health and hygiene conditions. A structure known as a base camp must therefore be set up.

The base camp is geographically located outside of the clean-up site itself. In the best case scenario, an existing industrial infrastructure (such as an oil base) or tourism facility (such as a lodge) can be used, providing its capacity and proximity to the clean-up site make it a suitable choice. If no such structure is available, a base camp will need to be built from scratch, either on land by bringing in huts or other mobile facilities, or on the water onboard a "floatel" anchored near the clean-up site.

To set up, run and manage the base camp, specific skills other than those relating to spill response are required: public works (installation, water connections, power supply), communication (telephone and internet), catering (supplies, cooking, serving), accommodation (cleaning and laundry), security, etc.

Tourist cruise boat

Existing tourist lodge supplemented with site cabins alongside

Organising the worksite area

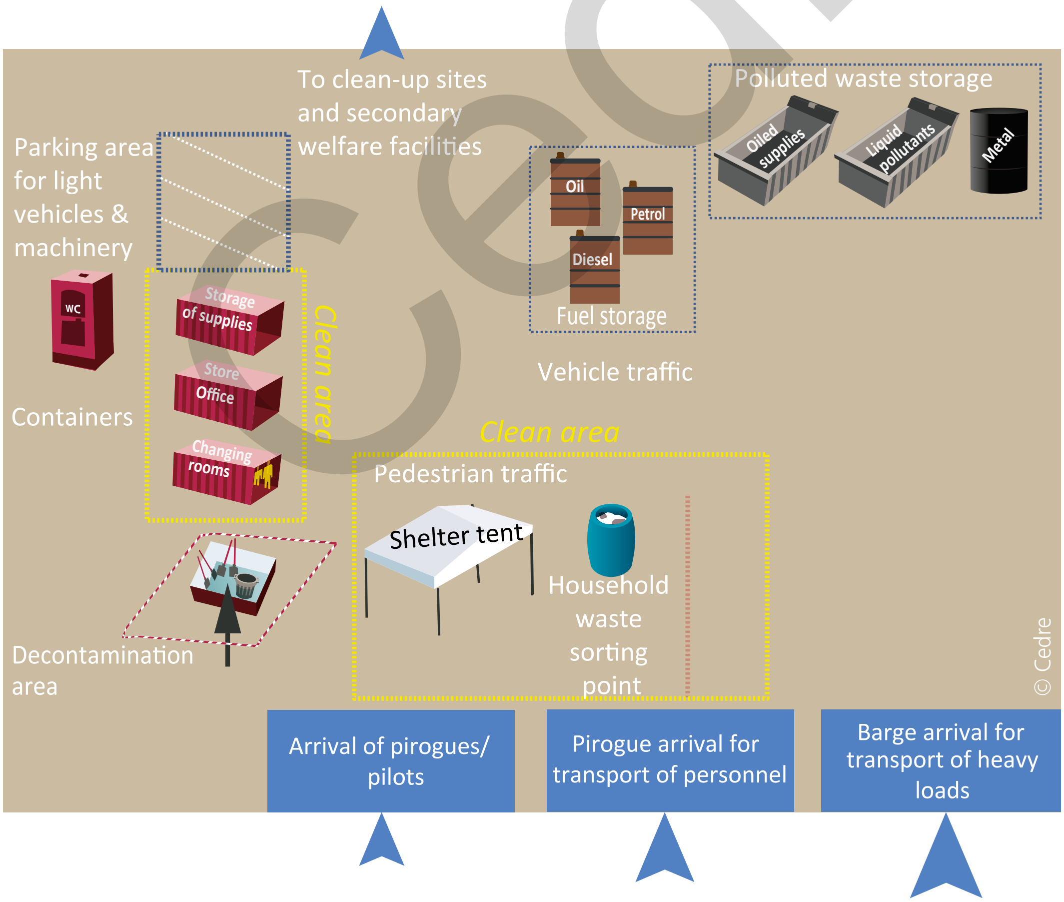
The worksite area comprises the different welfare facilities (entrance site and secondary sites), the sites to be or being cleaned ("clean-up sites"), traffic lanes as well as temporary waste storage and disposal sites. Its overall layout will depend on the location and extent of the pollution, which will dictate the number of clean-up sites and their duration, as well as the logistical possibilities and constraints of the area of land.

The long term success of the response is dependent on the proper organisation of the worksite area. Wherever possible, the efforts required to set up this area should preferably be made before launching clean-up operations. During this crucial stage, the area required for the response should be defined and optimally organised to ensure that clean-up operations are carried out in the most efficient way possible. Responder protection, on-site safety and environmental impact are three aspects which must be kept in mind at all times.

Smooth running of the response requires:

- prior preparation of the different parts of the

worksite area, which should be continually supplied with the necessary resources in sufficient quantity
- maintenance of the area in good functioning order: supply, on time and in sufficient quantity, of the resources required for clean-up operations (from PPE to heavy machinery, fuel supplies to specialised response equipment). It is important not to block access routes or traffic lanes and to refurbish them whenever necessary
- the rehabilitation of the area once clean-up operations are completed, in particular the removal of all waste, facilities and structures related to the response.



Typical plan showing the layout of an entrance site

Ensuring responder safety

In addition to optimising the response and mitigating response-related impacts, worksite management is required to fulfil two other objectives: to reduce the risk of incidents and improve operators' comfort and working conditions. This implies compliance with the precautions and measures taken with a view to ensuring personal health and safety.

Making living and working conditions more tolerable and safer

By definition mangroves are dangerous environments. All or part of a given site should be considered hazardous whenever there is a clear risk for the operator: drowning, getting stuck in mud, falling trees, attack by wild animals, harm by certain plants...

The climatic and environmental constraints make working conditions particularly toilsome. Travelling through the mangrove is no easy task, due to the low load-bearing capacity of the ground, which may even be flooded, the alternative being to move acrobatically across the aerial root systems. Operators are permanently at risk of getting lost in the mangrove whenever they stray out of the recognised and marked out area. The constantly high temperatures combined with the high humidity levels, as well as sometimes torrential rain, make even moderate efforts arduous.

Clean-up operations lead to additional stress which is liable to have a harmful impact on operators' health. Specific measures for operators' comfort, health and hygiene should be taken and constantly enforced to ensure responders are working in satisfactory conditions. In particular, it is essential to:

- establish rules on resting and hydration according to how hard the job is (physical activity, sun exposure, wearing of specific PPE, etc.)
- provide the necessary facilities and equipment
- define a rescue plan suited to the environmental conditions with a timeframe which meets with the urgency of the situation for each risk identified as well as a realistic evacuation procedure.

Decontamination area equipped with a pressure washer connected to a water supply (placed at a height on a container)

Eating area and waste sorting point composed of big bags

Protecting operators.................................. 6

Ensuring site safety

In addition to the hazards inherent to the mangrove environment, other risks are also present:

- risks related to the clean-up sites themselves, i.e. due to the machinery and products used or activities carried out. The operators must therefore be experienced professionals or have the necessary training, qualifications and physical capacities
- risks due to the worksite attracting unauthorised individuals, either simply through curiosity or possibly with a view to malicious activities. Site security must therefore be constantly enforced.

Site safety.. 4

Channelling the oil within the mangrove

Understanding how the oil spreads

It is important to understand, at as early astage as possible, how the oil has spread through the mangrove in order to channel it towards the most suitable and accessible points for recovery. The spread of the oil is generally relatively easy to observe in small watercourses, but is far less so in the depths of the mangrove where inundation occurs due to a laminar flow based on an overflow mechanism. It can however be detected when the water level drops and rises.

Promoting the flow

As the oil spreads, some will very often become trapped within vegetation. These accumulations required to be flushed away. Sometimes this can be achieved simply by increasing the flow rate. If this does not occur naturally, it can be implemented artificially.

In this case, the aim is to locally clear the main stream of obstacles: dead branches and trees, various debris, or even standing vegetation. This increases the current flow rate which may be enough to draw away pockets of oil trapped in the vegetation and carry them to suitable collection points. In addition to this clearing effect, the increased flow rate will temporarily increase the natural rinsing of the mangrove.

Cutting vegetation in a reasoned manner... 7

Scything and cutting vegetation in a reasoned manner

Non-systematic action

Vegetation should not systematically be cut back, as this could cause unnecessarily harmful or even irreversible impacts. Even when there is no oil spill risk, not all plants are very tolerant to cutting. In the case of a spill, cutting a plant exposes it to a greater risk of oil penetration. Cutting can be an acceptable option for certain types of low vegetation, but should be avoided as far as possible or at least kept to a strict minimum. Advice must always be sought from expert botanists before cutting back any vegetation.

Contracting specialists

Certain locals know whether a given type of vegetation is sometimes scythed or cut. This is the case for instance of vegetation management teams who work for oil companies. These workers regularly prune the vegetation immediately surrounding oil facilities located within the mangrove forest (along pipelines, around pumping facilities, etc.). This enables leaks to be rapidly detected during inspection visits or aerial surveillance in the case of clearer areas.

As for trees, partial cutting of aerial roots is liable to weaken the root system, reduce the tree's respiratory potential, increase the intake of pollutant by the tree's tissues and thus induce long-term harmful effects on the forest. In the case of heavy pollution however, the cutting of certain secondary roots can sometimes prove necessary to facilitate access to and recovery of large accumulations of oil. Cutting should of course only be carried out if strictly necessary. Prior advice from specialist botanists is indispensable.

Cutting a dead tree with a chainsaw to improve flow

Preparing a collection point by scything around an oiled pool

The shallow root systems of mangrove trees explain the need to preserve a sufficient number of anchor roots. This should be evaluated according to the diameter and the number of main roots attached to the trunk.

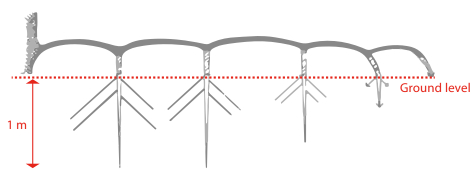


Diagram of the aerial root of a Rhizophora mangrove tree

Facilitating responder movements within the mangrove

Adapting movements according to the bearing capacity of the ground

The method of moving around the mangrove in areas of shallow water (< 1m) will be determined by the accessibility and bearing capacity of the ground:

- using a light, flat-bottomed boat or specially made raft
- on foot, walking on the ground if it has a sufficient load-bearing capacity (sandy sediment)
- on foot, walking on man-made pathways either laid directly on the ground (branches, palm leaves, or even planks), or mounted on piles above the ground.

Operators moving across prop roots

Planks on the ground

Walkway over mud

Building walkways

In the event of a significant spill, piled walkways can be set up, to be left in place for long periods of time, to enable intensive, rapid and safe pedestrian traffic while preventing or at least reducing the harmful effects of trampling on the environment. This mitigates the risks and hazards of advancing tentatively through the mud and water in the mangrove. Piled walkways also facilitate the handling and positioning of equipment (pumps, pipes, skimmers, storage areas) as well as the evacuation of the oil and oiled materials recovered, while providing an excellent platform for attaching custom-made containment and filtration systems.

Setting up a walkway sometimes requires vegetation, or even secondary tree roots, to be cut back. The walkway route will be determined by the need to bypass trees and will be adapted according to whether or not the aerial roots can be cut, notably taking great care not to sever the main roots of mangrove trees.

Walkway above aerial roots

Cutting vegetation in a reasoned manner...... 7

Building walkways...................................... 8

Filtering at the surface within the mangrove

Rough filtering

In areas of even low current, filter systems can be set up to contain the oil while letting the water through. Where no manufactured materials are available (geotextile strips for example), such systems can be built using non-specialised resources available locally or easily sourced nearby: a simple straight fine-mesh net set up across the entrance to a small channel or stream, a series of piles or bamboo stalks driven into the ground side-by-side...

Finer filtering

For finer filtration, a double row of wire mesh can be deployed vertically using piles and filled with sorbents or local materials with a certain adsorption capacity (leaves, various plant fibres). Piled walkways provide an ideal platform for supporting such filtration systems and increase their efficiency by facilitating their long term maintenance. The materials used to filter or absorb the oil should of course be replaced as often as necessary.

To absorb sheen around such filtration systems, used disposable protective suits can be used. This technique can be easily implemented in an emergency when manufactured sorbents are unavailable and enables very selective recovery of the oils.

Filtration system filled with palm tree fibres installed under a walkway

Trapping oil with used disposable polypropylene suits attached under a walkway

Setting up containment systems within the mangrove

Proceeding methodically

To recover oil from shallow waters, it is essential to proceed methodically, section by section, and to implement up a very simple and flexible system. A slick trapped within the vegetation will move around the mangrove, according to tidal movements, increasingly easily as operations to improve the water flow progress. Once the optimum collection point has been defined, the oil should be either naturally or artificially channelled or driven towards this point.

Blocking the oil

The first step consists in blocking the whole slick, by completely surrounding it with a small, very low draught boom. Where no manufactured booms are available or pending their arrival, systems made on-site with locally available resources can be a perfect substitute. This is the case for instance of bottle booms which, in addition to being easy and cheap to make and solid and durable, are a good way of upcycling the many plastic bottles used on the worksite.

Surrounding a spill through prop roots, using a bottle boom

Building a bottle boom............................... 11

Subdividing the area into adjoining segments

The second step consists in subdividing this large containment area into several smaller adjoining sections. This alveolar structure helps to:

- more effectively block the whole of the slick
- clean the area progressively, section by section
- separate cleaned sections from uncleaned sections
- control the slick's movements, by trawling it from one section to another, until reaching the containment point.

Containment using an alveolar structure

Selectively recovering the oil within the mangrove

Recovery from pirogues in shallow/very shallow waters... 12

Mechanical recovery

On sufficiently large spills, mechanical recovery can be carried out providing the necessary equipment can be transported to and implemented at the spill site. Small recovery and pumping systems can be transported manually across short distances. In some cases larger equipment can also be brought on site (for instance using a wheeled vehicle, an amphibious vehicle, a boat, or even a helicopter). The use of such equipment calls for a mechanic to be constantly present on site and also requires appropriate storage and evacuation equipment. To reduce the quantity of oiled waste recovered, selective skimmers should be used wherever possible. Mechanical recovery is generally only possible for a very short timespan and in very limited areas. These operations will rapidly be replaced with manual recovery operations.

Manual recovery

Manual recovery is subject to the same prior requirements as mechanical recovery in terms of the containment and channelling of the oil and oiled debris. It is very often the only viable option. Tools such as forks and rakes can be useful but are generally only used in addition to makeshift tools crafted on site. Hand tools are better suited to the constraints of this environment as they allow operators to work in cramped spaces, to selectively collect small debris and oil floating at the water surface which is generally strewn with aquatic plants or a lattice of aerial roots.

Containing the pollutant using a bottle boom

Perforated bin lid

Recovering the oil using a disc skimmer

Bailer fitted with wire mesh

Cleaning emerged substrates

Areas of bare ground in the mangrove are generally composed of mud or muddy sand. However, mangroves can sometimes be seen to extend along the edge of a beach between rocky boulders. In such areas, clean-up operations should be carried out methodically and progressively, dividing the area into limited sectors. In order to keep environmental disturbance to a minimum, it is better to wait until the pollution is stable before starting clean-up operations, except for heavy accumulations in easily accessible areas.

At the edge of the mangrove

The bearing capacity of the ground at the edge of the forest is too low to implement clean-up operations. At best, in the case of a slick deposited on water-logged mud, it may be possible to flush the slick towards a site where it can be recovered more easily, by creating a surface current to remove the oil without mixing it with the sediment. This operation can be tested with the rising tide using very low pressure hoses, possibly combined with artificial flooding created by a perforated hose placed upstream of the slick and connected to a high flow rate pump.

Low pressure hoses to push the oil towards a collection point

Within the mangrove forest

The ground is relatively firm and the response operations described above are more practicable. Nevertheless, the ground is often underlain with a very dense lattice of root systems from the surrounding plants or even older plants which have since disappeared. This makes these areas vulnerable to trampling and conducive to the infiltration of a fluid pollutant. Oil infiltration occurs via animal burrows and the base of certain plants. Pockets of oil can therefore form at the foot of certain old clumps of vegetation. The empty roots of dead plants act as underground pipes, distributing the oil across distances of several metres. Response in these areas should be carried out using light, temporary walkways (branches, bamboo, palm leaves, planks, geotextile, etc.) which should be moved along as clean-up progresses. Only a small number of authorised responders should be allowed to access such areas.

In the case of surface pollution and layers of oil on bare ground

It is possible to carry out the following operations:

- surface scraping (shovel, scraper, bamboo cut lengthways, upside-down rake)
- selective suction using vacuum units or vacuum trucks
- very low pressure hosing, possibly with flooding by a water flow using a perforated hose placed at the upper end of the slope and connected to a high flow rate pump
- surface drainage from the steepest slope leading to a more suitable collection point lower down. This is achieved by digging small furrows by lightly scraping or simply compact-

ing the soil. Deep furrows should not be dug as this would promote the penetration of the oil into the sediment. At ebb tide, the oil will flow towards the lower collection point composed of a bund or planks designed to contain the oil. It is then recovered by scooping, filtration or sorption.

Surface scraping from a walkway to reduce trampling

Removing pockets of oil by suction using a vacuum truck

If the oil has infiltrated into the sediment

It may be possible to flush the oil from the foot of clumps of vegetation or at points where the oil resurfaces. By creating holes in the soil, the trapped oil is attracted at the same time as the interstitial water. The aim is to remove the floating oil and empty the hole of its water to renew the drainage operation. The floating oil can be removed from the holes by sorption. It is generally however more efficient to implement suction using a mobile vacuum unit or a specialised vehicle such as a vacuum truck (more difficult to achieve but sometimes feasible from the edge of the mangrove if the distance does not exceed the length of hose available).

Cleaning vegetation

To clean or not to clean?

The question of whether or not to clean vegetation often arises. For technical, ecological and/or logistical reasons, roots often cannot be cleaned. Nevertheless, when this operation is viable, the favoured technique is the use of a low pressure hose, or possibly a high pressure washer.

Low pressure washing

The use of a low pressure (< 3 bars) hose (flat then solid jet) should be systematically tested. This is especially the case during the first few hours, or days, following the spill according to the type of oil. This technique is recommended if it is proven to efficiently remove thick layers of oil coating the aerial roots, or to simply rinse off a fine layer of very fluid oil.

Low pressure hosing to remove thick layers of oil from roots

High pressure washing

The use of a pressure washer, even with cold water (or rather lukewarm water given the ambient climate), is far more questionable as the powerful jet is liable to damage the roots (risk of removing the surface layer of the root for instance). Furthermore, after a certain amount of time, even this pressure becomes ineffective.

Managing recovered waste

Waste management – which comprises storage, transfer and treatment – is a crucial part of the response process. This phase can have harmful effects on the environment and human health if it is poorly implemented, especially in the case of a sensitive environment like a mangrove. There are many recommendations applicable to waste management. This guide only addresses those relating to the inherent specificities of mangroves.

See Cedre operational guide on "Oil Spill Waste Management"

Primary storage in a pirogue

On the water

Waste recovered on the water is generally stored onboard collection boats. During this primary storage phase, the waste is placed in small containers which are easily transferable (buckets, bins, watertight crates, etc.). As there is rarely an available site on land within the vicinity of the collection point, an evacuation shuttle system should be set up using one or more small boats.

Primary waste storage in a bin on a pirogue

These shuttle boats will transfer the waste to a single point on the water, if possible in the form of a larger vessel such as a workboat. Whenever this boat is full and at the end of each day, it will travel to the on-land unloading site. It is also on this boat that the first proper waste sorting and separation effort is carried out. It should therefore be equipped with suitable containers:

- for liquid waste: open-topped 200-litre drums and 1 m^3 IBC tanks covered with wire mesh to drain oiled debris
- for drained solid debris: big bags, tanks, tarpaulins, etc.

Pirogue approaching a waste pooling barge

Waste pooling barge complete with suitable containers

On-site settling and vegetation draining...... 13

On land

For waste recovered on land, it is important to set up a primary storage site for oiled waste within a short distance of the manual collection and skimming sites. The waste is then transferred from this primary storage facility, where it is directly deposited, to a pooling site. It is transported either by hand (bins, stretchers) or using wheeled devices (wheelbarrows), or in some cases by pumping and discharge or suction for liquids. Suction is a possibility over distances of up to a few dozen metres if the viscosity of the oil and the slope gradient allow it. The waste is then transferred to a temporary storage site, pending definitive evacuation from the polluted area.

Evacuating waste in a wheelbarrow

All these storage areas must always be:

- set up before starting collection, skimming and cleaning operations
- properly prepared to avoid spreading the oil (oil-tight containers compatible with the type of waste recovered, ground liners)
- organised to optimise waste sorting and transfer.

Temporary waste storage and sorting site

Draining heavily oiled solid waste on wire mesh at a waste pooling point

Draining oiled vegetation in a bamboo storage cage with an oil-tight base liner

The usual recommendations in terms of waste management, and storage site management in particular, naturally apply to mangroves. However, this environment is again more restrictive than other types of shorelines, in terms of logistics and weather conditions. Particular attention should be paid to anticipating the risks of the oil spreading and overflowing due to severe weather events.

On-site settling and vegetation draining...... 13

Waste treatment

The waste resulting from a spill in a mangrove takes the form of liquids (oil with water and sometimes some fine sediment) and pastes or solids (contaminated sediment, vegetation oiled to varying degrees), as well as oiled man-made materials used directly for the response (PPE, sorbents, geotextiles, etc.).

Several options are potentially on offer to treat such waste, but in practice they are often not all available in the countries where mangroves are found.

Recycling and reprocessing options are generally applicable for recovered liquid waste (refinery) and waste with a high oil content (fuel for heavy industry, etc.). They can also be appropriate for disposing of PPE and other man-made equipment which should be treated at specialised incineration facilities. More sophisticated processes (separation/washing, biodegradation, stabilisation, etc.) which enable the reuse of the oiled matter are rarely feasible. We sometimes discover that, due to insufficient infrastructures and know-how, a large proportion of the waste has simply been abandoned at different points along the shoreline as it is unable to be treated.

The selected option(s) must be in compliance with national regulations in force in the given country. This is especially the case of on-site incineration which allows large quantities of plant debris with low to moderate levels of contamination to be gradually disposed of and thus reduces the logistics required for waste transfer. Burning on open fires releases toxic gases and particles into the environment. This technique therefore cannot be systematically recommended. It can sometimes however be an acceptable solution if the oil content of the waste is sufficiently low and if logistical difficulties justify its implementation, for instance to avoid complicated transfers off-site, excessive transfer distances, a lack of temporary storage site or acceptable alternative disposal option or excessive doubt over how the waste will be disposed of after its evacuation.

In such cases, the use of small mobile incinerators is always preferable to in situ burning on open fires. These units are specially designed for this purpose and allow dual smoke combustion, a process which greatly reduces atmospheric emissions of toxic particles and, to a lesser extent, of toxic gases.

Not only do these two techniques require prior authorisation from the authorities, they also call for preventative measures to protect the environment and human health and to prevent the fire from spreading.

On-site incineration.................................... 14

Practical datasheets

Organising an on-land survey in dense vegetation

Aims

- The purpose of the initial survey is to determine the spread of the spill, identify the heaviest oil concentrations, record visible impacts and establish the main environmental constraints.
- The purpose of the subsequent detailed surveys is to fine-tune the initial map and to monitor changes in the situation and the progress of clean-up operations.

Safety and precautions

- Beware of hazards specific to the area while carrying out surveys (plants, animals).
- Always have a possible means of communication (VHF, phone) in case of difficulty.
- Do not forget to remove barricade tape once the clean-up site has been closed down or once impact monitoring is complete.

Resources required

Personnel for initial survey

- ☐ 2 to 3 operators including 1 person familiar with the forest and its dangers.

Personnel for detailed surveys

- ☐ 1 guide familiar with the forest and its dangers
- ☐ 1 geometer or person specialised in taking GPS readings and in mapping
- ☐ 1 person experienced in pollution response and able to distinguish natural phenomena which could be confused with pollution (moss, lichen, natural sheen, etc.)

Equipment

- ☐ Protective clothing and PPE specific to the type of tasks to be implemented (leather gloves for protection when moving through vegetation, boots, hat, mosquito repellent etc.)
- ☐ GPS, camera with integrated GPS, notepad, pen, laptop
- ☐ Satellite image or map of the area
- ☐ Laser rangefinder
- ☐ Barricade tape (if possible in different colours) and a knife
- ☐ Machete
- ☐ Means of communication (mobile phone and/or VHF)
- ☐ Small first aid kit, water, sugar

Operating procedure/protocol

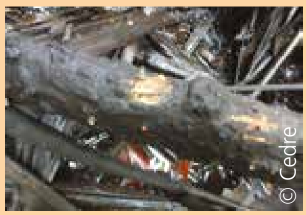
Initial survey

- ☐ Follow the outer boundaries of the pollution as closely as possible
- ☐ Proceed methodically, working segment by segment, starting from one or more easily identified, stationary starting points (source of the spill, paths, watercourses, ponds, etc.)
- ☐ Advance as best possible according to the terrain: by climbing across root systems in flooded forest areas or by clearing a pathway using a machete where it is possible to walk on the ground
- ☐ Continually mark out the pathway with barricade tape
- ☐ Take notes and photos (pollution, types of environments, environmental constraints)
- ☐ Estimate distances (steps or visually, or if possible using a laser rangefinder) and identify (visually and if possible by geographical positioning) the boundaries and points with the heaviest oil concentrations
- ☐ Draw a sketch and, if possible, divide the contaminated area into provisional segments

Detailed surveys

- According to the initial survey, define survey segments and their starting point.
- Ensure that the area initially marked still matches the edge of the pollution. If the pollution has spread further, mark out the new boundaries of the pollution.
- Proceed in the same way as for the initial reconnaissance survey but more systematically to ensure more detailed coverage and produce a more detailed map. To do so, work either along transects, in a ladder configuration or in a spiral pattern according to the terrain.
- Identify sub-segments (including unoiled areas) and identify those which are the most heavily oiled (possibly using different colours of tape). If necessary, signs can subsequently be put up to mark these sub-segments.
- Draw up a detailed map with a key and keep it up-to-date.

Illustrations

Survey points	Notes	Coordinates Projection system		Photos
Point 1	Area of discontinuous pollution (palm trees) Discontinuous deposits = thin black oily film on ground, vegetation, puddles	X XXX E	X XXX S	
Point 2	Moderate pollution: continuous thin black film over aerial roots (50 cm to 1 m) Sheen or thin (a few mm) discontinuous film on the water	X XXX E	X XXX S	
Point 3	Unoiled area: black film on certain roots = moss (vegetation)	X XXX E	X XXX S	

Example of a survey report

Marking out contaminated areas

Conducting an on-land survey

2

Worksite layout and organisation

Aims

- To organise the spatial layout of the worksite as a whole.
- To ensure optimal preparation of the area so that clean-up operations run as smoothly and efficiently as possible.

Resources required

- ☐ Preparation: heavy-duty vehicles
- ☐ Marking: signs, barricade tape
- ☐ Shelter: army tent, plastic sheeting, piles
- ☐ Waste point: big bags, stakes, signs
- ☐ Clean-up site: geotextiles, wire mesh, plastic sheeting, pressure washer
- ☐ Storage site: skips, containers

Main recommendations

Entrance site

The entrance site is the only or main access point by river, sea and/or road. This is where resources enter and leave the site (personnel, equipment, fuel, provisions) and is the point from which they are distributed. It is where teams prepare and the point from which waste is evacuated. It is also the main storage point, first aid station and reception point for official visitors. This site should:

- ☐ be suitable for mooring (equipped with an access ramp or pontoon) or beaching both small and large pirogues (transporting personnel), as well as a barge (transporting loads)
- ☐ be large enough to enable the unloading and loading of large items (earthmoving machinery, skips, etc.) and to facilitate vehicle traffic
- ☐ have a power supply (to run various equipment, recharge batteries, night lighting, etc.)
- ☐ be permanently able to be contacted from the outside – including by the transport means going to and from the site – as well as by secondary sites
- ☐ be as close as possible to a helicopter landing point (in case emergency evacuation is required)
- ☐ be equipped with the following facilities: a communication system (telephone network if possible, VHF), a military marquee (shelter to provide protection against the sun and rain; eating area), portable toilets, personnel and equipment decontamination areas (see datasheet 3), a sorting point for oiled household-type waste and PPE, closed containers (for storing small equipment).

The secondary welfare site(s)

Secondary welfare site(s) are small areas set-up close to the clean-up sites to primarily provide a shaded shelter where operators working on the surrounding sites can rest and eat, as well as where they can get dressed in the morning and be decontaminated at the end of the working day. They will vary in number according to the extent of the pollution. Secondary sites comprise:

- ☐ a shelter composed of a tent equipped with tables and chairs
- ☐ portable toilets
- ☐ a decontamination area (see datasheet 3)
- ☐ a sorting point for oiled waste (PPE, cloths, etc.) and unoiled waste (plastic bottles, compostable waste deposited in shallow pits)
- ☐ a fuel storage area located at a distance, equipped with a ground liner (to collect any leaks) and a fire extinguisher.

Pathways and access points

Pathways run between the various welfare facilities and between these facilities and the clean-up site. These are often specially created pedestrian walkways. In the best case scenario, pre-existing pathways, built for the construction of the pipeline, may be available. They can generally be used by heavy-duty vehicles (excavators, etc.) and 4-wheel drive vehicles.

Clean-up sites

Clean-up sites should be signposted and cordoned off. Traffic, generally only pedestrian, should be organised. Vegetation may be pruned (see datasheets 7 and 8) to mitigate the environmental impact generated by pedestrian traffic, to improve safety (snakes) and to facilitate waste evacuation. Each clean-up site systematically requires a primary storage point for recovered waste (liquid and solid) as well as a shelter (sun, rain, rest), which in the case of short-term clean-up operations may be a makeshift structure.

Temporary waste storage sites and possibly waste disposal sites (burning or off-site incineration where relevant) (see datasheet 14).

Illustrations

Entrance site: shelter/meal tent, decontamination area, waste sorting point, equipment containers, fuel storage area, vehicle parking area

Secondary welfare site: shelter/meal tent and decontamination area, sorting point

Traffic lane alongside a pipeline, clean-up site access and primary storage

Temporary waste storage site

Setting up a decontamination area

3

Aims

- To restrict the spread of pollution outside of the clean-up area.
- To clean oiled equipment and tools so as to use them in the best possible condition.
- To enable personnel to leave the clean-up site in as satisfactory conditions as possible in terms of their hygiene and comfort.

Safety and precautions

- There is a risk of injury when using pressure washers: test the temperature and pressure prior to use, fix settings, ensure the operator continues to wear PPE throughout the operation.

Resources required

- ☐ Flat or slightly sloping open area (> approx. 30 m^2)
- ☐ Geotextile, plastic tarpaulin
- ☐ Barrier tape and stakes
- ☐ Pallets or wire mesh
- ☐ Wooden posts, tarpaulins and nails
- ☐ Footbaths, shallow tanks
- ☐ Brushes, cloths, oakum
- ☐ Autonomous pressure washer (thermal)
- ☐ Washing agent sprayer (for equipment)
- ☐ Cooking oil and soap for hands
- ☐ Bins, drums for waste
- ☐ Sorbents to recover effluent

Operating procedure/protocol

Creating the decontamination area

- ☐ Define a location, preferably located immediately next to the clean-up site exit and define an area around 4 m x 8 m to prepare a slightly sloping pit (dug out or by building bunds).
- ☐ Prepare the pit by creating, if necessary, a slight slope directed towards a lower effluent collection point (option 1) or an effluent containment pit (option 2).
- ☐ Protect this area (pit and surrounding area) with a puncture-resistant material (geotextile, felt).
- ☐ Line the area with a watertight layer, consisting of several layers of polythene sheeting or a plastic tarpaulin.
- ☐ Install a perforated system to allow effluent run-off at the personnel washing station.
- ☐ Provide boot washes and equipment washing tanks (IBC tank cut in half) if available.
- ☐ Build a provisional shelter using wooden posts and attach the roof tarpaulins to them.
- ☐ Position an autonomous pressure washer (combustion engine) so that the spray lance can reach the whole of the platform.
- ☐ Position the water supply accordingly: if necessary at a height to supply the washer by gravity flow.
- ☐ Set up a waste sorting point nearby (disposable PPE).
- ☐ Appoint a pair of operators to be in charge of running and maintaining the area, cleaning equipment and tools as well as preparing the site to decontaminate personnel at the end of each half-day.

Operating procedure for personnel

- ☐ Have the operator to be decontaminated enter the area, still wearing his oiled PPE.
- ☐ Apply the washing agent to waders, boots, gloves and waterproofs using a cloth or a sorbent pad, possibly while standing in a "boot wash".

- Have the operator rub down their PPE, helping them for places that are hard to reach (with cloths or a small brush).
- Rinse down with warm water (40°C), at moderate pressure (40 bar), using a lance kept far from the operator (do not spray above shoulder height).
- Have the operator exit the washing area and go to the changing area to remove their PPE and hang them up to dry.

Operating procedure for equipment

- Place the equipment to be cleaned in the container provided (repeated soaking and brushing are sometimes required) or on the ground on wire mesh.
- Apply washing agent using a sprayer, leave for a few minutes then brush down. Repeat if necessary.
- Rinse down using a pressure washer, being careful not to damage the equipment or the underlying tarpaulin.
- Complete the operation, if necessary, by wiping with a sorbent pad or cloths.

Maintaining the area

- Anticipate the consequences of heavy rainfall (leaching and overflow).
- Recover effluents at the collection point, in the tanks and from the bottom of the pit as often as necessary using sorbents (if a vacuum truck is present do not hesitate to use it at the end of the day).
- Regularly clean the washing area.
- Regularly clear out the solids that have accumulated in the pit.
- Evacuate liquid and solid waste, in particular PPE to be disposed of and oiled sorbents, to suitable tanks in the waste area, ensuring white suits are properly sorted if they are to be reused (see datasheet 10).
- On a daily basis, ensure the area remains fully oil-tight; replace plastic sheeting as often as necessary.
- Monitor the condition and stability of pallets and grating. Replace them if necessary.
- Prepare the decontamination area to ensure the decontamination operation at the end of each half-day runs smoothly: prior to decontamination check pressure washer is working correctly and check water/fuel supply, clear area of vehicles, provide a supply of solvent and cloths, install a sufficient number of stakes nearby to dry waders, boots and gloves.

Illustrations

Full view of a decontamination area

Applying solvent to waders using cloths

Washing using a pressure washer at limited temperature and pressure

Site safety

Aims

- To prevent all hazards inherent to worksites across the whole site (welfare facilities, clean-up sites, access points).
- To prohibit access by unauthorised individuals, attracted either simply by curiosity or with a view to malicious activities.

Resources required

Personnel

- ☐ One or more local resident(s) familiar with the area in question (hunters, fishermen, etc.), or a specialist in such environments for surveys
- ☐ Night watchmen

Equipment

- ☐ Barricade tape and signs
- ☐ Life lines and/or life rings (if necessary)
- ☐ Fire extinguishers and a water pump fitted with pipes and a fire hose
- ☐ Worksite light towers

Main recommendations

- ☐ Assess the risks.
- ☐ Prevent all outsiders from accessing the site by setting up the necessary signage (cordoning off, “no entry” signs).
- ☐ If necessary provide night-time security (1 or 2 trained watchmen).
- ☐ Mark out (barricade tape, signposts) the various welfare, clean-up and storage areas, indicating all prohibited activities.
- ☐ Provide all sensitive areas featuring a particular risk with specific safety equipment (extinguisher, life line, life ring, etc.).
- ☐ Identify the specificities of each area.
- ☐ Define and prepare a clean, remote fuel storage site.
- ☐ Provide a fire extinguisher suitable for fuel fires and a water pump, fitted with pipes and a fire hose.
- ☐ Define and prepare waste storage sites and the oiled vegetation incineration site where required (see datasheet 14).
- ☐ Provide minimum lighting for the main facility (generally the site entrance) and its immediate surroundings, for night security.
- ☐ Remove all equipment, products or parts of facilities liable to attract or cause danger to an ill-intentioned or careless person (e.g. remove keys from motor vehicles; place small equipment that may be hazardous or liable to be stolen or damaged in closed containers).

▶ Illustrations

Signposting and layout plan

Fuel storage area

Overall operation management

Aims

- To organise all activities in order to ensure that the whole of the worksite is correctly run throughout its duration.
- To optimise the response.

Main recommendations

Organisation

- ☐ In the case of unforeseen circumstances (reduced workforce, resource provision difficulties, weather constraints), revise objectives and redefine tasks.

Distributing tasks

- ☐ The worksite manager defines the actions and the team leader has the decision implemented and reports back to the worksite manager.
- ☐ Organise the work according to the number of operators, their skills and abilities, the tasks to be performed and their specific constraints. The majority of general tasks can be conducted by personnel without any specific qualifications. All hazardous tasks should be conducted by specialised operators (drivers, woodcutters, vegetation management team, etc.).
- ☐ Ensure that all personnel (training, certification, etc.) and equipment are in compliance with the regulations in force.
- ☐ Ensure that operators carrying out potentially hazardous tasks (drivers, woodcutters, vegetation management team, etc.) are experienced professionals or have the necessary training, qualifications and physical capacities.
- ☐ Ensure equipment and heavy-duty vehicles are in good working condition and, for those which require it, have the necessary checks carried out by a qualified person from within the company or from the outside.

Activating operations

- ☐ Gather together personnel as soon as they arrive on site to hand out clean PPE (disposable suits + cloths, etc.) and drinking water (bottle) for the beginning of the morning.
- ☐ Conduct a morning brief during which the worksite manager will:
  - review the operations of the previous day: positive and negative points, feedback from operators themselves, reminder of rules
  - explain the programme for the day: operations, possible constraints (weather, supplies, etc.), events (official visit, major transfer operations)
  - define the teams and tasks
  - ask the operators if any of them are feeling any discomfort or in poor physical form
  - hand over to the Health, Safety and Environment (HSE) manager(s) of the company and the contractors present (reminder of instructions and targeted observations if need be)
  - ask operators if they have any questions.
- ☐ Transfer teams to secondary sites where they will put on work clothing (boots, waders, etc.).
- ☐ Launch operations at the different sites:
  - quick inspection of clean-up sites in terms of contamination and safety
  - definition/adaptation of the response strategy according to the pollutant, natural elements, logistics, etc.
  - checking/reinforcement/shifting/set-up of man-made walkways
  - start-up of mechanical equipment and waste storage facilities
  - beginning of operations.

Break times

- ☐ Morning break lasting around 15 minutes under a shelter (tent) with a snack (handed out at base camp in the morning); each operator is given a new bottle of water.
- ☐ Lunch break lasting around 1 to 1½ hours

under a shelter with a hot meal or sandwich brought on site; each operator is given 2 bottles of water (1 for lunch and 1 for the afternoon).

- ☐ Resumption of operations after each break.

Deactivating operations

At the end of the day, 30 to 45 minutes before returning to the base camp:

- ☐ Stop clean-up operations
- ☐ Tidy the area
- ☐ Decontaminate personnel, reusable PPE and tools (see datasheet 3)
- ☐ Sort oiled disposable PPE
- ☐ Sort reusable PPE
- ☐ Transfer teams to the entrance site to board the pirogue wearing clean clothing and a life jacket.

Site maintenance

- ☐ Ensure that the resources required for operations are provided on time and in sufficient quantities (from PPE to heavy-duty vehicles, not forgetting fuel and specialised spill response equipment).
- ☐ Ensure equipment and heavy-duty vehicles are in good working condition and, for those which require it, have the necessary checks carried out (with a check sheet) by a qualified person from within the company or from the outside.
- ☐ Continuously evacuate contaminated waste deposited at the clean-up site exit and waste waiting to be transferred off-site.
- ☐ Ensure access routes and traffic lanes are not blocked.
- ☐ Restore paths.
- ☐ Ensure good communication between responders working at different sites.
- ☐ Enforce rules on cleanliness, tidying and sorting (used PPE and equipment).
- ☐ Anticipate needs or possible shortages.

5

Illustrations

Morning brief next to containers of PPE and small equipment

Waders hung up to drip-dry on stakes

6

Protecting operators

Aims

- To protect operators against the various dangers identified on the clean-up site so as to prevent accidents and injuries.
- To adapt safety measures and vigilance to the specific context of work in mangroves.
- To improve operators' comfort and working conditions.

Resources required

- ☐ Transport means for personnel: pirogues and 4-wheel drive vehicles
- ☐ Shelter for personnel: tents, chairs, tables, lighting, drinking water storage, eating area
- ☐ Transport means for equipment and waste: barge and heavy-duty vehicles
- ☐ Shelter for various equipment: closed containers
- ☐ Decontamination area: agricultural tarpaulins, geotextile, pressure washer, water tank, pumps, soap
- ☐ Storage containers for oiled waste: skips, drums, big bags, wheelbarrows
- ☐ PPE and specific spill response equipment and ancillary equipment
- ☐ First aid supplies, stretcher, VHF, telephone, fire extinguishers

Main recommendations

Safety

- ☐ Ensure that personal safety is the priority over response.
- ☐ Constantly remind responders of the safety instructions and encourage them to take responsibility for each other's well-being.
- ☐ Regularly inform responders of the specificities of each area.
- ☐ Never leave an operator alone.
- ☐ Always indicate where you are going, if not a routine destination.
- ☐ Always stay within earshot or VHF range.
- ☐ Inform the worksite manager of any technical incident or any accident, even minor, which occurs during the day, but also if you are feeling on poor form in the morning.
- ☐ Provide feedback on any incident (at the latest during the brief the following morning).
- ☐ For pruning (machete) and felling (chainsaw) operations, call upon specialised operators, following precautions related to the environment (see datasheet 7).
- ☐ For operations involving a potential risk, always be accompanied by one or more local operator familiar with the forest and its dangers and suitably equipped.
- ☐ In the forest, remain vigilant towards possible dangers (encounters with animals, contact with certain plants, falling trees, getting stuck in marshy ground) and always have a machete within reach (snakes).
- ☐ On the water, ensure you have the following equipment onboard the pirogue: a sufficient number of life jackets (worn permanently), VHF, fuel, bailer, back-up paddles, a machete and possibly a rifle.

Health and safety

- ☐ Anticipate and assess the risks relating to intertropical climates, wildlife, vegetation and clean-up operations.
- ☐ Schedule break times according to the arduousness of the work and in compliance with the labour legislation in force, possibly drawing upon similar experiences in other countries.
- ☐ Provide a sufficient quantity of drinking

water (minimum 5 litres per person per day) in individual rations to prevent contamination.

- ☐ Provide adequate balanced meals, ensuring the cold chain remains unbroken.
- ☐ Provide appropriate PPE and renew it regularly.
- ☐ Provide equipment in good condition and suited to the tasks in hand.
- ☐ Set up decontamination areas at clean-up site exits to clean reusable protective clothing and tools to avoid spreading oil outside of the clean-up area.
- ☐ Install a sufficient number of portable toilets as quickly as possible (near to the shelters).
- ☐ Set up clean areas with toilets, changing rooms and an eating area.
- ☐ Provide at least provisional shelters, in both clean and unclean areas, where operators can shelter regularly from the sun and torrential rain.

Rescue

- ☐ Define a rescue plan suitable for the field conditions.
- ☐ Ensure the rescue teams are compatible with the urgency of the situation for each risk identified (e.g. compatibility between time required for the arrival of a person qualified to give an injection and venom latency period).
- ☐ Ensure a means of evacuation is available, such as a pirogue permanently on-site or in the immediate vicinity and directly contactable.
- ☐ Define the procedure for evacuation by helicopter and identify the closest landing site.
- ☐ Identify persons with first aid training.
- ☐ Provide (in a sheltered, locked place) a first aid kit with suitable contents according to the risks incurred (mild pains, small burns, cuts), as well as a camp bed and a stretcher with straps (for evacuation).
- ☐ Ensure a nurse is regularly or near permanently on-site (especially during the first days or weeks if working conditions are poor in terms of supplies of PPE, toilets, shelter, etc.).
- ☐ Call upon a visit from a medical officer if contagion is observed (pains, dermatitis, diarrhoea, etc.).
- ☐ Order medical evacuation upon recommendation by the medical officer in the event of an accident, illness or need for a medical examination.

▶ Illustrations

Operators boarding a pirogue, wearing life jackets

Provisional shelter at a clean-up site

Portable toilets connected to an underground tank

Cutting vegetation in a reasoned manner

Aims

- To clear a passageway through the inextricable tangle formed by aerial roots to collect the pollutant floating on the water while minimising the impact on trees already stressed by the pollutant.
- To cut the roots in a reasoned and reasonable manner so as to build access walkways (see datasheet 8) and to clear the space required to collect floating pollutant.

Safety and precautions

- Do not cut the main roots or their primary ramifications whose removal is liable to cause the tree to fall, followed by other neighbouring trees (knock-on effect or due to wind flow through the gap formed). The main roots to be preserved can be marked with barricade tape.
- Before deciding on the route of a passageway and clearing it, the roots must be identified starting from the trunk and moving outwards or vice versa, and their importance assessed.
- Restrict cutting to what is strictly necessary, even if the root development shows strong dynamics. Do not forget that the tree is already stressed and threatened due to the oiling of its lenticels and all cutting actions will aggravate this stress and the threat for the tree's survival.
- Raise awareness among responders warning them not to drive their machete into the roots when not in use. This practice may appear harmless but when repeated many times during operations it is liable to further aggravate the tree's stress.

Resources required

- ☐ Machetes with carry cases or systems for attaching them to the waist, or even chain-saws
- ☐ Leather gloves
- ☐ Specialised PPE
- ☐ 60 litre bins

Operating procedure/protocol

Before performing any cutting, build a walkway or a collection area:

- ☐ Identify the trees and their main roots in order to determine the passageway liable to generate the least impact for building a walkway or creating a clearance to form a collection area.
- ☐ For the main roots, start from the trunk and identify the root along its entire length so as to preserve the primary ramifications anchored in the soil.
- ☐ Cut the roots and remove the sections which are no longer connected to the tree.
- ☐ Recover the sections of root using selective makeshift tools (perforated bin lids, etc.).
- ☐ Evacuate the sections of root in bins.

Illustrations

Localised clearance to create an alveolar containment area

Main root cut by mistake

Major roots and their many ramifications which should not be cut as the trapped pollutant could be removed manually or herded with hoses or blowers towards the collection area.

A perforated bin lid made to recover sections of root

Building walkways

Aims

- To allow intense, quick and safe movements of responders within the mangrove forest, towards the most affected areas and priority recovery areas.
- To prevent or restrict repeated trampling of natural areas and vegetation as well as high risk movements through mud or water.
- To facilitate the carrying, handling and positioning of equipment (pumps, hoses, skimmers, storage capacities) as well as the evacuation of pollutants and polluted waste.
- To provide a framework for certain makeshift containment and filtration systems and to facilitate their maintenance or replacement.

Safety and precautions

- Keep the cutting of mangrove tree roots, as well as other plants, to a strict minimum, when positioning walkways (see datasheet 7).
- In the case of walkways used for wheeled devices (e.g. wheelbarrows), lay the planks tightly with no gaps between them.
- Always finish the walkway by covering it with geotextile (non-slip, absorbent) and regularly replace it if necessary.
- Carefully consider water levels and the highest tides to determine the height of the walkway so that it will always be above the water level.
- Provide secondary platforms to allow two-way traffic as well as to temporarily store equipment and waste.

Resources required

Personnel

- ☐ 1 head carpenter
- ☐ 1 to 2 carpenter workers
- ☐ 1 site supervisor for inspection and approval of the walkway

PPE

- ☐ Wear PPE specific to the type of tasks performed

Equipment for 100 m (approximate dimensions)

- ☐ 350 stakes (1.20-1.50 m x 6 cm wide)
- ☐ 200 support planks (50-70 cm x 10-15 cm x 3 cm)
- ☐ 100 walkway planks (floor) (3 m x 20-30 cm x 3 cm)
- ☐ 300 battens to attach the geotextile (15 cm long, 3 cm wide)
- ☐ Wood saws and chainsaws (+ fuel and spare parts)
- ☐ 2,000 wood nails (80-100 mm long + 60 mm long)
- ☐ Hammers, mallets, sledgehammers, pincers

Operating procedure/protocol

- Design the walkway on-site and draft a simple plan: walkway routes, position of crossing and storage platforms, junctions with other walkways, connection to ground and various access points.
- Position and install stakes, driving them at least 40 cm into the ground.
- Reinforce the stakes with support planks.
- Place the floor planks on top and fix them in place. According to how the walkway is intended to be used, the planks may be spaced out, edge-to-edge or overlapping.
- Test the walkway's resistance and reinforce its stability if necessary.
- Lay an absorbent reinforcement material (geo-textile), possibly with a non-slip layer (chicken wire), and fix it in place.
- Reinforce the structure at access points.
- Regularly check the stability of the overall structure as well as of the key components (access points, platform).
- Replace oiled geotextile.
- Dismantle and remove the materials once clean-up operations are finished.

Illustrations

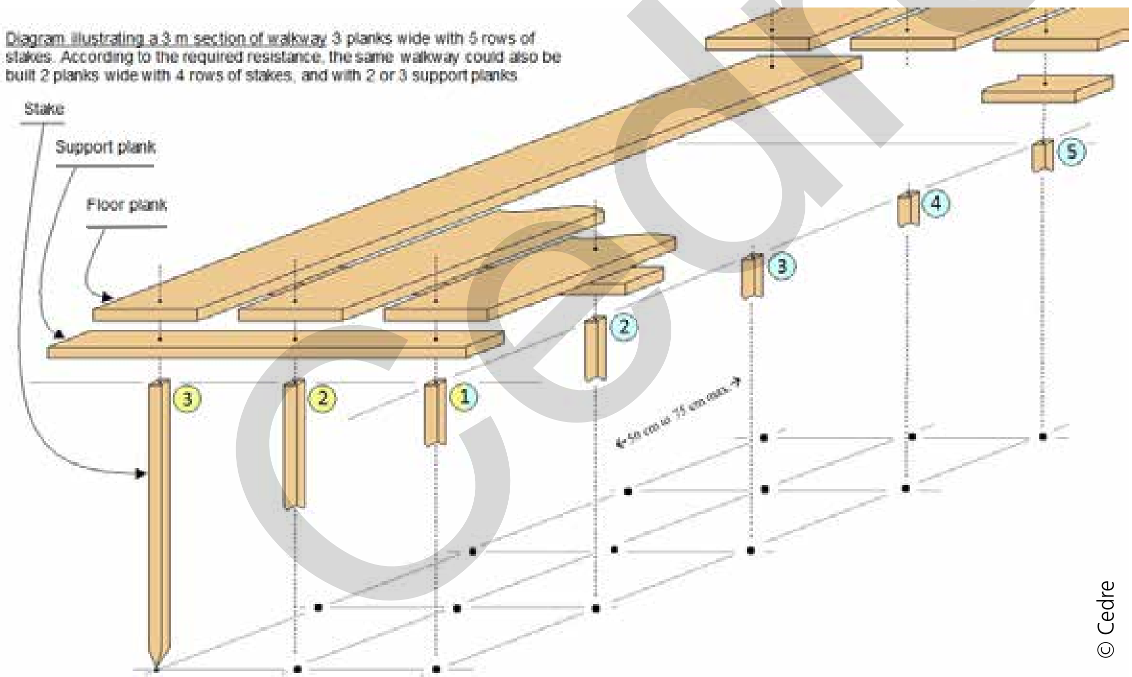


Diagram of a 3 m long section of walkway

Extending an existing walkway

A crossing and storage platform

Installing filtration systems in the water column

Aims

- To filter the water column to trap the pollutant and prevent contamination of downstream sites.
- To recover the bulk of the particulate pollution, without claiming to remove all dissolved oil fractions from the water column.

Safety and precautions

- Maintain the system on a daily basis.
- Combine different types of vegetation within the same barrier to improve filtration.
- Plan for the renewal of vegetation by creating a stockpile in advance near to the barrier.
- Install a net with a larger mesh size upstream in order to collect litter and debris.

Resources required

Personnel

- ☐ 1 supervisor
- ☐ 3 operators

Specialised PPE

- ☐ Disposable suit
- ☐ Close-fitting gloves for building phase and oil-resistant gloves for installation phase
- ☐ Waders and goggles
- ☐ Life jackets when working near the water body (if necessary according to the depth)

Access walkway

- ☐ See datasheet 8

Materials required to build a 3 metre-long, 1 metre-high barrier

- ☐ Casing: chicken wire (at least 1 m wide by 6 m long) or debris netting
- ☐ Filler material: clean, dead plant fibres and leaves (1/2 m^3).
- ☐ Mooring/anchoring: piles (wood, iron) with a minimum length equal to the water depth + 1 m, rope or cord (at least 15 m thick)

Tools

- ☐ Wire cutters, nails
- ☐ Wheelbarrow and fork

Operating procedure/protocol

Set-up

- ☐ Identify the site where the barrier is to be placed (pedestrian routes defined according to tidal currents, narrowness, passage or natural containment of pollutant).
- ☐ Build a walkway for pedestrian traffic and barrier mooring (see datasheet 8).
- ☐ Drive nails into the legs of the walkway at the top to attaching the wire casing.
- ☐ Collect and prepare the filling material by separating the plant fibres and leaves.
- ☐ On the bank, lay out the casing on the ground and fill with the material.
- ☐ Seal the casing with wire at the sides only, so that the fibre can be reached from the top.
- ☐ Ballast the casing to improve its position in the water column.
- ☐ Attach the casing to the walkway.

Maintenance

- ☐ From the walkway, regularly check the system (including its attachment and filler material).
- ☐ Remove the wire casing from the watercourse and bring the system up onto the bank.
- ☐ Open the wire casing on a tarpaulin, remove the oiled filler material and replace it with clean material.
- ☐ Evacuate the oiled materials to suitable treatment facilities (see datasheets 13 and 14).

Illustrations

Collecting and preparing the filler material

Laying out the casing on the ground and filling with fibres

Attaching the wire casing under the walkway

Trapping floating oil with used disposable suits

Aims

- To utilise the sorption capacity of the oleophilic, hydrophobic propylene fabric of disposable suits, in addition to the use of manufactured sorbents, to collect oil dynamically in "mop" mode, statically under walkways or directly in drainage systems.
- To optimise the use of such used suits.

Safety and precautions

- Provide an oil-tight final storage facility to store the oiled suits.
- Never dispose of oiled suits by on-site incineration.

Resources required

Personnel

- ☐ Work at least in pairs
- ☐ Personnel required to cut up the suits into shreds or strips (like a mop) and attach them in the identified areas (walkways, trenches, drainage network, etc.)

Equipment

- ☐ Personal protection suits made of non-woven polypropylene used for one day
- ☐ Thin cord, rope
- ☐ Knife, pair of scissors or utility knife
- ☐ Pole, stick, broom handle
- ☐ Bin, big bag or skip to store suits before and after use to collect oil

Operating procedure/protocol

Set-up

- ☐ To make the "mops":
  - lie the suit out flat on the ground, close the zip, bring both sleeves together and both legs together, and tie a single knot at the waist. This knot can then be used to attach the suit either to a stick or a cord.
  - then cut the 2 sleeves and 2 legs into strips (aim: to increase the surface area in contact with the pollutant and therefore the recovery/trapping capacity).
- ☐ In the case of walkways, thread a long cord through each of the knots made at the waist of the suits, then tighten the knots once they have been spaced out at the required distance.

Maintenance

- ☐ Monitor the suit set-up, check the level of oil saturation and replace with other used suits if necessary.

Closure and monitoring

- ☐ Leave them in place as long as the suits continue to capture residual traces of pollutant.
- ☐ Send the oiled suits off site like all other oiled manufactured waste.

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Illustrations

Use in "mop" mode with a pole

"Suit mops" in series under a walkway

"Suit mops" laid at a drainage network

Building a bottle boom

Aims

- To build booms at a very low cost, which can be used in shallow waters with low current to replace sorbent booms or small manufactured booms (out of stock, pending supplies, etc.).

Resources required

Personnel

- ☐ 3 non-specialised workers can build a 6 m long bottle boom in around 15 minutes. The daily output for 3 operators can be estimated at 160 m of boom.

Materials required for a 6 m section (width of geotextile roll)

- ☐ One strip of geotextile (125 g/m^2) around 50 cm wide
- ☐ 17 empty 1.5 L bottles with their lids
- ☐ 7 m of 3-strand synthetic rope with a diameter of 8 or 10 mm OR barricade tape (3 strips knotted together every 50 cm)
- ☐ 32 pieces of binding wire 15 cm long
- ☐ 1 pair of scissors for cutting felt
- ☐ 1 knife and 1 pair of wire cutters

Operating procedure/protocol

- ☐ Gather all the materials required.
- ☐ Cut a 0.5 m x 6 m strip out of the geotextile roll.
- ☐ Lay the strip out on the ground.
- ☐ Cut the rope, leaving around an extra 80 cm at each end.
- ☐ Position the rope along the top of the geotextile strip.
- ☐ Prepare the sections of binding wire (around 32 sections, each 15 cm long).
- ☐ Line the bottles (closed) up along the rope, placing them all in the same direction.
- ☐ Bind the bottles to the rope by feeding the wire between the strands of the rope and winding it round the narrow part in the middle of each bottle.
- ☐ Roll the geotextile around the bottles.
- ☐ Bind the geotextile to the bottles to hold the cylindrical shape of the boom. Bind each end and around every 50 cm along the boom.
- ☐ Monitoring the overall buoyancy of each element and replace defective or heavily oiled elements.

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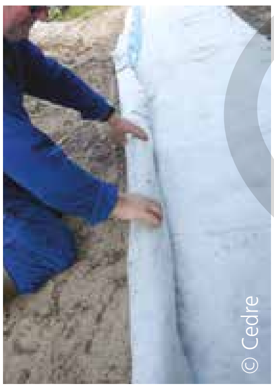
Illustrations

Preparing the necessary materials, laying the strip of geotextile on the ground, laying the rope then the bottles

Threading the wire between the strands of the rope before binding the bottle to the rope



Rolling the geotextile around the bottles

Binding the geotextile around the bottles

Recovery from pirogues in shallow/very shallow waters (< 1 m)

Aims

- To recover oil floating at the surface in shallow, difficult access areas.
- To recover oil deposited on the banks of watercourses, as well as oiled plant debris, deposited on or trapped within root systems, so as to mitigate the risks of the pollutant being remobilised by the tides.

Safety and precautions

- Carry out mechanical recovery on sufficiently large spills and providing the necessary equipment can be transported to and implemented at the spill site.
- Where possible, use small storage capacities (buckets, bins, watertight crates) in order to facilitate transfer operations to intermediate or on-land storage facilities.
- Avoid overfilling buckets and bins on board the pirogues to prevent overflow and risks of capsizing.
- Lift the motor up fully to reduce the risks of failure if the boats are directly entering the slicks.

Resources required

Personnel

- ☐ 1 pilot
- ☐ 2 onboard operators, including 1 with mechanical skills
- ☐ Several other operators on the intermediate waste storage barge or on land to receive the bins containing the collected oil and oiled vegetation.

Equipment

- ☐ VHF sets, walkie-talkies or a mobile phone
- ☐ Life jackets
- ☐ Protective goggles
- ☐ Disposable polypropylene suits
- ☐ Gloves
- ☐ Safety shoes (not boots)
- ☐ Waders for operators working in the water
- ☐ At least 2 pirogues fitted with adaptable beams
- ☐ 1 barge for intermediate waste storage
- ☐ Geotextile liners and sorbent booms to protect the boats
- ☐ Mechanical recovery: light-weight booms, selective skimmers, pump, storage tanks
- ☐ Manual recovery: sorbents, forks, fine mesh nets, mesh screens, scoop nets, makeshift tools such as sieves or screens (perforated bin lid, mesh screen with handle, bailer fitted with wire mesh, buckets with a pierced bottom), bins, buckets, watertight crates
- ☐ Onboard the intermediate storage barge: big bag, IBC tanks with a capacity of at least 1 m^3 fitted with wire mesh to drain oiled debris, skips
- ☐ Fuel feeder tanks

Operating procedure/protocol

- Line the boats with geotextile to protect them and reduce risks of operators slipping.
- If manufactured tools are unavailable, make tools on-site, such as wooden frames fitted with wire mesh to provide rough screening by reducing the amount of water incorporated in the oil/debris mixture collected (see datasheet 13).
- Fit out the pirogue with recovery equipment and the barge with an appropriate storage tank.
- Herd the pollutant towards the suction head using a lightweight boom – either a sorbent boom or a custom-made bottle boom.
- Depending on whether or not animals classified as "dangerous" are present in the area, and on the water depth, an operator can walk through the mangrove to help stabilise the boats during operations and limit the extent to which outboard motors churn up the sediment.
- Using the boat collecting the oil, make shuttle runs to a disposal area on land or on a storage barge.
- At the end of the operation, clean all equipment used onboard as well as the hulls of the boats used in a specially prepared washing area (if possible on land).

Illustrations

Organisation between pirogue pilots

Mesh screen for manual collection

Unloading bins onto the intermediate storage barge

On-site settling and vegetation draining

Aims

- To drain heavily oiled vegetation on site.
- To separate solid waste (plant debris) from liquid waste (water, oil).
- To reduce atmospheric pollution caused by on-site burning operations by reducing the quantity of oil in the debris (see datasheet 14).

Safety and precautions

- Do not overfill tanks to reduce the risk of overflow.
- Remove drained debris regularly.
- Do not overload bins with oiled plant debris to facilitate their deposit on the tank mesh.
- Ensure drainage valves are accessible.

Resources required

Personnel

- ☐ 1 or 2 operators permanently present beside the tanks to lay out the oiled debris on the wire mesh and remove drained debris to burn areas

PPE

- ☐ Protective goggles
- ☐ Disposable polypropylene suits
- ☐ Gloves and safety boots/shoes

Resources required for 1 system comprising 4 draining tanks

- ☐ 4 rigid plastic 1 m^3 IBC tanks, with the top cut off and drainage valves fitted at the bottom
- ☐ 4 wooden pallets (for base)
- ☐ Squares of wire mesh/grating with 1.20 m sides (i.e. wider than the tank). Attach the mesh to the tank if necessary.
- ☐ Approximately 30 m^2 of plastic agricultural tarpaulin, geomembrane or geotextile
- ☐ Build a platform at the foot of each tank to facilitate the handling of oiled debris on the wire mesh
- ☐ Bins, oil-tight big bags, wheelbarrows
- ☐ Sorbent pads and cloths
- ☐ Pumping system (truck) to recover the liquid pollutant collected in the tank.
- ☐ Loader with bucket to evacuate drained debris towards the in situ burning area or debris storage area

Operating procedure/protocol

- ☐ Define an area, located near to the clean-up site access point; mark out an area around 4 x 8 m.
- ☐ Lay a lining made of geomembrane or plastic tarpaulin to protect the ground.
- ☐ After having cut out the top of the tanks, line the tanks up, spacing them out with around 1 m between each of them to allow operators to move around them easily.
- ☐ Dig small trenches at the foot of the tanks (to recover pollutant running down the tanks), or even a pit (retention capacity); protect them with an oil-tight lining.
- ☐ Place metal grating or wire mesh on top of the tanks.
- ☐ Monitor the hold and stability of pallets/tanks and grating and replace them when necessary.
- ☐ Dismantle and remove equipment once the clean-up site has been closed, and rehabilitate the area if necessary.

Illustrations

Unloading vegetation onto the screen using a bin and draining it

Draining vegetation

On-site incineration

Aims

- To dispose of polluted vegetation on site after draining.
- To reduce storage and, more importantly, transport off-site of this vegetation.

Safety and precautions

- Only use this technique if small mobile incinerators cannot be used.
- Obtain prior authorisation from the authorities.
- Define a burn site in an open area, far from any homes, facilities and infrastructures and where safety can easily be ensured.
- Train operators in the safety measures and precautions to be taken.
- Ensure operators are protected against the toxic gases and vapours released by burning operations by systematically wearing respiratory protection and other appropriate PPE.
- Ensure operators are always upwind of the fire.

Resources required

Personnel

- ☐ 2 operators always present simultaneously and taking turns to manage the fire.

PPE

- ☐ Half-mask respirators with gas filters and dust filters + protective goggles, or full-face mask respirators with same filters and face shield
- ☐ Fireproof suit
- ☐ Gloves and safety boots/shoes

Resources required for a 6 m-wide pit

- ☐ Metal plates and flat tank to protect the bottom of the pit
- ☐ 6 sections of metal pipe or beam, 8 to 10 m long
- ☐ 3 to 6 plates of metal grating, 1 m x 6 m
- ☐ Hand tools and long-handled tools: hooks, forks, etc.
- ☐ Blower to keep the fire going
- ☐ Appropriate fire extinguishers

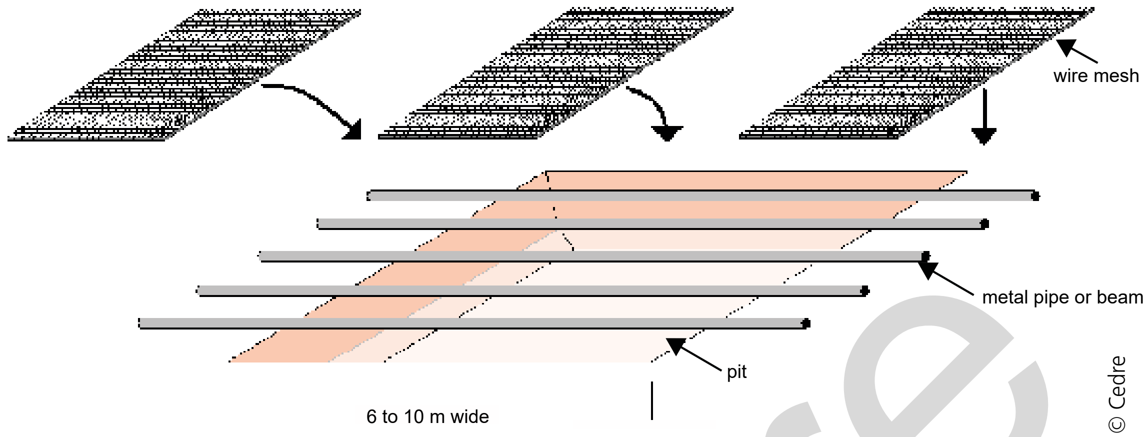
Digging the pit

- ☐ Excavator

Operating procedure/protocol

- ☐ Choose a suitable location.
- ☐ Set up a traffic system for vehicles bringing plant debris for burning to the site.
- ☐ Define an emergency plan for personnel.
- ☐ Consider the weather and especially prevailing winds.
- ☐ Dig a pit around 1 m to 1.5 m deep.
- ☐ Protect the bottom of the pit with a metal plate and a flat tank to collect ash and burn residues.
- ☐ Lay metal pipes or beam across the pit (supporting framework).
- ☐ Place metal grating on the supporting pipes.
- ☐ Monitor the supporting framework and grating and replace them if necessary.
- ☐ Collect the ashes and tarry residue, place them in containers and evacuate as waste.
- ☐ Dismantle and remove equipment from the pit once the clean-up site has been closed, then fill in the pit.

Illustrations



Oiled vegetation burning pit

Lighting the fire and incinerating oiled vegetation

Further information

Glossary and acronyms

Accretion: growth of an area of land due to the addition of material

Anoxic: indicates a depleted level of dioxygen (O_2) in the environment.

Beam: articulated rod attached to each side of a boat.

Defoliation: when a tree loses its leaves.

Epiphyte: plant which grows harmlessly upon another plant.

Gear: equipment onboard a vessel for anchoring, mooring, towing, lifting or fishing purposes.

Geomembrane: synthetic membrane liner with very low permeability.

Geotextile: synthetic textile used as a filter in the public works sector (drainage, etc.).

GIS: Geographic Information System

GPS: Global Positioning System.

Hydrophobic: property of a substance whereby it has no affinity for or does not easily combine with water.

IBC: International Bulk Container. Rigid reusable container designed to transport and store liquids in bulk.

Lenticel: pores present at the surface of the bark of certain trees to allow gas exchange with the atmosphere.

NEBA: Net Environmental Benefit Analysis.

Oakum: rough fibrous material generally obtained from hemp or flax.

Oleophilic: property of substances presenting an affinity for oils, absorbing them selectively.

Phanerogam: plant which reproduces using seeds or flowers.

Pneumatophore: vertical appendages of the roots of certain trees which grow in waterlogged areas to allow gas exchange with the atmosphere.

Polypropylene: polymer used for a wide variety of applications as a thermoplastic and fibre.

PPE: Personal Protective Equipment.

Transect: straight line along which observations are made in the field or representing a boundary.

TROPICS: TRopical Oil Pollution Investigations in Coastal Systems.

Vegetation management team: teams which regularly cut back vegetation within the immediate vicinity of oil facilities within the mangrove

VHF: Very High Frequency.

Waders: waterproof boot extending from the foot to the chest, used by fishermen to stand in ponds or rivers.

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Centre of Documentation, Research and Experimentation on Accidental Water Pollution
715 rue Alain Colas, CS 41836, 29218 BREST CEDEX 2, FRANCE
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