FIGHTING TOGETHER
AGAINST MARINE
POLLUTION

Designing the training programmes for response teams

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Contents

TYPES, SOURCES AND CAUSES OF MARINE OIL POLLUTION

1. INTRODUCTION

The phenomenon of marine oil pollution, although not a new one, started attracting a major public attention since the 1960's. It was due to a generally increased consciousness of environmental problems, but it became a major public concern after the notorious TORRY CANYON accident in 1967 and the subsequent extensive mass media coverage of it. A series of major tanker incidents that followed in the 1970's, resulting in massive oil spills and causing pollution of vast sea and coastal areas in North America and Europe, kept it in the focus of media and general public ever since.

On the other hand, less obvious continuous, chronic, operational pollution, despite being a predominant source of oil and other harmful substances in the sea, never attracted such an interest as did tanker accidents.

This lesson aims at giving an overview of possible sources of marine oil pollution and at providing a basis for better understanding of problems related to preparedness for and response to marine pollution incidents, and to limiting their consequences.

Word "pollution" in this text has a meaning adopted by the United Nations and universally accepted for "pollution of the marine environment":

> "Pollution of the marine environment" means the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities including fishing and other legitimate uses of the sea, impairment of quality for use of sea-water and reduction of amenities".

Although according to this definition oil entering the sea from natural sources should not be considered as "pollution" it is also briefly mentioned, as most of the oil in oceans is nowadays thought to originate from natural sources.

2. NATURAL SOURCES OF OIL

Natural oil seeps (or petroleum seeps) are places where natural liquid or gaseous hydrocarbons escape to the earth's surface or to the atmosphere, from the underground oil accumulations. Such places are found throughout the world, but the best known petroleum seeps are those in the Caribbean region, Gulf of Mexico and in Santa Barbara Channel (California, USA). Accordingly, some of the oldest written reports of "oil spills", dating back to the XVI century, are related to natural oil seepages in the Gulf of Venezuela. It is considered that semi-solid oil originating from natural seeps (asphalt/bitumen, pitch/tar) was used by mankind since the stone age. If the gaseous hydrocarbons seeping into the atmosphere are ignited (by e.g. lightning), various civilizations refer to such places as (natural) "eternal flames".

3. MARINE OIL POLLUTION

Each stage in the "life" of oil i.e. production, transportation, processing and consumption, may result in pollution of the marine environment.

Extensive use of crude oil and various refined products dates back to the second half of the nineteenth century. A significant increase in consumption of crude oil and of refined petroleum products started in the 1930's, and is still steadily growing.

Since the crude oil became the main source of energy there was a discrepancy between the places where it was extracted in major quantities (Middle East, Central America, North Africa) and the main centres of its consumption (Europe, North America, Far East). As a consequence, the use of crude oil has always been directly related to its transportation from the main production areas to the main consumption area, mainly on board ships known as “tankers”. In addition, fuel oil has been the most important fuel for all types of vessels for almost a century.

4. CLASSIFICATION OF SOURCES OF MARINE OIL POLLUTION

Marine pollution is often classified in accordance with the **location** of its source, distinguishing between pollution from land-based sources and pollution caused by maritime (shipping) activities.

Marine (oil) pollution can also be divided according to **circumstances** of the occurrence of pollution. It can be either accidental (i.e. sudden, unexpected, of relatively short duration and caused by an anomalous event) or operational (occurring more or less regularly, due to known and expected causes). Operational pollution is often chronic.

Finally, marine pollution can also be categorized according to the **intention** or otherwise, to release pollutants into the sea: it can be either intentional or unintentional.

While practically all cases of accidental pollution fall into category of unintentional discharges, most operational discharges of oil from either vessels or coastal installations can be considered as intentional (or at least tolerated by the polluter). Since there are few exceptions to this rule, and in order to simplify the matter, accidental pollution could be considered as unintentional and operational as intentional.

Combining the above outlined categories, all possible cases of marine oil pollution caused by human activities can be covered by the four resulting "mixed" categories:

1.	MARITIME / ACCIDENTAL:	collisions, groundings, structural damages, sinking, etc. of ships/vessels;
2.	MARITIME / OPERATIONAL:	operational discharges from ships during e.g. deballasting operations, tank washing, etc.;
3.	LAND-BASED / ACCIDENTAL:	accidents in coastal refineries, tank farms, ruptures of pipelines;
4.	LAND-BASED / OPERATIONAL:	refinery effluents, effluents from coastal municipal sewage systems.

5. OPERATIONAL OIL DISCHARGES

A bigger portion of marine oil pollution originates from operational (and often intentional) discharges of oil, related either to various human activities on coasts or to maritime traffic. The most significant sources of operational discharges are outlined below:

5.1 Coastal refineries and non-refining industry

Coastal industry and especially refineries are considered as a "traditional" source of marine oil pollution, regularly being referred to as one of the worst polluters of the seas. However, during the last five decades most national administrations imposed strict regulations on the quantities of oil that are allowed to be discharged into the sea from facilities on land, while improved separation technologies led to a significant reduction of oil contents in effluents.

5.2 Other land-based sources

Such sources municipal drainage system through which waste lubricating, hydraulic, turbine, spindle, cutting and various other oils reach the sea. A typical example is used car lubricating oil spilled into the drainage system, which is likely to reach a freshwater stream and eventually the sea if the effluent is not properly treated. A significant part of total oil input into the sea originates from coastal river and urban runoff. The introduction and enforcement of legislation regulating the disposal of waste oils is seen as the most important factor in minimizing oil input into the sea from the land-based sources.

5.3 Offshore exploration and production

Technologies used and regulations applied in the field of offshore drilling and production are usually very advanced, thus eliminating a great deal of potential risk. Consequently, normal operations in offshore oil fields generally do not result in significant operational oil releases. The three main sources of operational pollution from offshore installations include discharges of: (a) oil contaminated drilling muds (fluids); (b) production water that accompanies oil extracted from a production well; and (c) displacement water that is similar to tanker ballast water.

On the other hand, accidents on offshore installations are rare, but when they do occur, their consequences may be huge and extremely difficult to control: several recorded accidents on offshore installations resulted in biggest known oil spills (e.g. Ixtoc in 1979, Nowruz in 1983, Deepwater Horizon in 2010).

5.4 Maritime transport

Operational discharges from ships originate from a number of operations on board vessels.

5.4.1 Ballasting operations

In order to retain necessary sea worthiness when not loaded with oil, tankers need to carry ballast on their return voyages to loading ports. Before loading a new cargo, this water needs to be discharged. Non-tanker ships sometimes have to ballast their empty bunker fuel tanks. Ballast waters carried in either cargo or fuel tanks are inevitably contaminated by oil carried before in the same tanks. The vast majority of the world fleet retains oily ballast waters on board, as stipulated by MARPOL Convention, and discharges these into port reception facilities or into the sea under conditions stipulated by the same Convention. The development of oily water separators reduced the oil contents of ballast waters, and the introduction of clean ballast tanks (CBT) and segregated ballast tanks (SBT) on all new ships aims at eliminating the input of oil into the oceans due to ballasting operations.

5.4.2 Tank washing operations

After offloading the cargo, a certain amount of oil remains clung onto the tank walls. When a cargo tank has to be cleaned (e.g. when changing the cargo), relatively large quantities of oil (approximately 0.3% of cargo tanks' volume) are released (e.g. in a vessel of 100.000 tons, about 350 tons of oil may be left in tanks). The introduction since the 1970's of "crude oil washing" (COW) procedure provided for a much better cleaning effect, eliminating at the same time the creation of heavily oil contaminated washings.

Washing of bunker tanks is also necessary before the ship enters a shipyard for repairs, however all repair shipyards are required to provide reception facilities for such tank washings, thus eliminating the need for discharging oil contaminated washings into the sea.

5.4.3 Bunkering operations

Bunker (fuel) tanks are used on some ships for ballasting, and therefore, before loading new bunkers the water has to be discharged from such tanks. As the resulting oily waters are practically the same as those resulting from cargo tanks ballasting, all vessels over 80 GRT, which use fuel tanks for ballast, are required to have oil water separators in order to meet the requirements for the discharge waters quality.

5.4.4 Oil sludge

Fuel oils used in propulsion and auxiliary engines have to be "separated" prior to use. Various oily contaminants (known as “sludge”) separated from the fuel, need to be discharged, and therefore ports are required to provide facilities for disposal of sludge. If sludge is discharged directly into the sea it remains floating on the sea surface for a long time. Moved by winds and currents, sludge is eventually deposited on the shoreline as a weathered oily residue.

5.4.5 Bilge water discharges

Fuel or lubricating oils leaking or spilled in an engine room/machinery space, accumulate in the ship’s bilges, and if discharged directly into the sea significantly contribute to the level of operational marine oil pollution. The quantity of oil accumulated in bilges depends on the vessel’s type and age, maintenance of engines etc. Bilge waters have to be disposed of periodically and ports are required to provide reception facilities for their collection.

5.4.6 Oil ports and terminals

During their normal operation, oil ports and terminals are minor sources of operational pollution, in spite of often being seen as one of the main threats to the marine environment. Operational losses at oil terminals are negligible as compared to the amounts of oil handled, but the risk of accidents in the approaches to oil terminals or inside them remains very high.

6. ACCIDENTAL OIL POLLUTION

The type of marine pollution that attracts the major media and public attention are large accidental oil spills, even though their occurrence is nowadays in fact remarkably rare. Direct or indirect causes of accidental oil spills are numerous. Most spills from tankers originate from routine operations such as loading, discharging and bunkering (because of broken hoses, defective valves, etc.) occurring in oil ports or terminals, and result in release of only several tonnes of oil. On the other hand, shipping accidents such as collisions, groundings, explosions on board ships (very often followed by fires), structural failures, sinking due to adverse weather conditions, etc. are more likely to result in spillages of larger quantities of oil or in major spills, and such accidents can be very often attributed to "human error".

Accidents involving smaller vessels, such as pleasure craft, fishing vessels and tourist boats are usually caused by the same types of incidents. However, they result in smaller spills, ranging in size between several litres and several cubic meters, of usually non-persistent oil (e.g. diesel or petrol) that dissipate naturally and do not necessitate a complex spill response operation.

Most of the factors leading to an accidental spillage are difficult or even impossible to predict, albeit there are others that can be controlled and that significantly reduce the risk of accidents. These include:

- construction of ships in conformity with the required standards;
- proper inspection, maintenance and management of ships;
- adherence to established and required safe practices in ship and cargo handling;
- implementation of recommended safety measures on board ships (tankers and non-tankers) and other vessels;
- use of sophisticated navigational aids; and
- high standard of crews' training.

Unfortunately, even the most rigorous application of all these precautions cannot eliminate the risk of accidental oil spills: it will only minimize it.

A number of massive spills from oil tankers remains in the memory of general public worldwide, the most prominent being the spills from MT Torrey Canyon (1967), MT Amoco Cadiz (1978), MT Atlantic Empress (1979), MT Exxon Valdez (1989), MT Khark 5 (1989), MT Haven (1991), MT Aegean Sea (1992), MT Braer (1993), MT Sea Empress (1996), MT Erika (1999), MT Prestige (2002), MT Hebei Spirit (2007) and MT Sanchi (2018), which all started as shipping incidents.

IMPACT AND EFFECTS OF MARINE OIL POLLUTION

1. INTRODUCTION

Various human activities at sea and on shore such as fisheries, maritime traffic, petroleum exploration and production, industrial activities on shore, energy production, tourism, etc. may result in a release of oil during their normal operation and, in particular, in case of an accident.

Oil spills can threaten and affect, directly and indirectly, **living beings including humans**, their **environment** and their **activities** including the above mentioned human socio-economic activities, as well as cultural and archaeological **resources** and **amenities**.

2. IMPACTS OF SPILLED OIL

In general, **impacts of spilled oil** are mainly caused by **toxicity** and **smothering,** but also by **interference with the activities** of living beings, including human activities.

Impacts from oil (pollution) have been studied over several decades and it is considered that oil spills result in short-term impacts, with only moderate to low long-term ones. It is important to distinguish between impacts on individual organisms and those on population: very often a few individuals may suffer severe adverse effects with no impacts to overall population. Generally, the health of populations is more important than that of individual organisms.

Factors that influence the impact of oil include:

- Type of oil and degree of weathering;
- Biological characteristics of the area;
- Geographic location;
- Degree of oiling;
- Oceanographic and meteorological conditions;
- Season; and
- Choice of response strategy and effectiveness of response

2.1 Impacts on living organisms

Oil can have an impact on various components of a marine environment, including in particular plankton, corals, fish, sea turtles, birds and marine mammals.

Plankton is very sensitive to oil and is particularly affected by naturally or chemically dispersed oil. However, as mortality of plankton is compensated by over-production of young organisms and by recruitment from non-affected area, a significant decline has not been observed following an oil spill.

Corals are highly sensitive organisms and their recovery from exposure to oil is very long and uncertain. Exposed coral reefs can be directly affected (smothered) by floating oil, and those that are submerged can be exposed to dispersed oil, especially near shore with high energy breaking waves. Coral reefs are areas with the highest priority for protection.

Among the fish, juveniles are more susceptible to oil exposure than adults that are more resilient (e.g. free-swimming tends to avoid oil). Fish mortality is related to localized conditions, e.g. whether oil is naturally or chemically dispersed, type of oil, water depth, etc. Fish is subject to depuration processes, and in general oil spills have low impacts on fish population.

All species of sea turtles are endangered and vulnerable to oil, particularly during nesting season and in shallow waters. Sea turtles use sand beaches for nesting and to lay eggs, so clean-up of these areas during nesting season will be high priority. Adult sea turtles can suffer irritation and inflammation of membranes, but it is possible to clean them.

Seabirds, (including wildfowl and waders) are all vulnerable to floating oil and large numbers can die from contact with floating oil at sea or on shorelines. Oiling of plumage (feathers) is the most obvious effect of oil on birds, affecting insulation properties of feathers and resulting in hypothermia. Birds will also ingest oil as they attempt to clean their feathers. Another common effect is the exhaustion caused by smothering, particularly after exposure to viscous oils. Contamination of birds' habitats, especially during nesting season, can cause significant impacts. Oiled birds can be cleaned and rehabilitated but depending on species only a small fraction may survive. Both individuals and population can suffer from short and long-term damages.

Marine mammals, including whales, dolphins, seals, otters, and manatees (sea cows), can be affected by oil spills. Since these are species that must surface to breath, they can be exposed to floating oil that may cause irritation to airways and eyes. Those that use the shoreline (e.g. seals and otters) can suffer from oil exposure if the places where they haul out are contaminated. Fur covered animals can suffer from hypothermia if their fur is oiled. Generally, impacts of oil spills on mammals are mild: skin irritations and disruption are the most reported ones. Their mortality is usually rare following an oil spill, but it may occur.

2.2 Impacts on different types of marine environment

Most cases oil pollution incidents lead to pollution of the adjacent shoreline(s). As the impact of oil on different types of shoreline varies in relation to their types, these can be categorized in relation to their sensitivity to oil pollution, taking into consideration how easy the cleaning of a certain type of shoreline would be, and how long would oil persist on it.

Sensitivity to oil pollution of shoreline types common in the Adriatic and the Mediterranean regions increases in the following order:

- Exposed rocky headlands (the least sensitive);
- Wave-cut platforms;
- Fine-grained sandy beaches;
- Coarse-grained sandy beaches;
- Mixed sand and gravel beaches;
- Pebble/cobble beaches;
- Sheltered rocky coasts;
- Sheltered tidal flats (mud flats) and estuaries; and
- Marshy areas with vegetation (the most sensitive).

In general, **rocky shorelines**, and in particular steep, exposed rocky cliffs and banks, are the least susceptible to damage by oil, as it cannot penetrate into the rock and will be washed off quickly by the waves and tides. Rocky shorelines are usually colonized by algae or small invertebrates, and after an oil spill the recolonization can be rapid. The short-term impacts are typical for rocky shorelines.

Sandy shores are also less biologically active and therefore less sensitive to oil pollution, and short-term impacts are typical for these type of shorelines too. However, due to sand movement oil can be buried on sandy beaches, thus hindering their cleaning and recovery, while interaction between oil and sand in the inter-tidal zone leads to sinking of oil.

Sheltered **tidal flats (mud flats)** are used as habitat by many vertebrate and invertebrate species. These are low energy shorelines, and long-term effects are generally caused by oil penetration into sediments because of trampling, or by oil penetration through worm burrows.

Salt marshes are highly biologically important as these are the most productive aquatic environments. If not removed oil can persist in them for a number of years. Despite a relative resistance of plants to oiling (depending on growth cycle) long-term effects are expected due to the penetration of oil in the substrate, affecting the root system. Penetration is generally caused by trampling and use of mechanical equipment in clean-up operations, so a proper clean-up method for such areas has to be considered on a case-by-case basis.

Various post spill studies can be undertaken, including e.g. chemical analyses, population inventories, etc., in order to evaluate actual environmental damages caused by an oil spill. Such studies should have clear objectives, achievable goals and focus on likely impacts from the spill. Restoration measures can be identified based on these studies, and in some cases implemented, if necessary.

2.3 Impacts on social and economic activities

An oil spill is likely to interfere with numerous activities at sea and on coasts and can cause their disturbance or interruption, which can in turn result in significant inconveniences and financial losses in various sectors.

Impacts on **coastal communities**:

- Large populations live in towns and villages located on or near the coast;
- Exposure to oil vapours can cause breathing difficulties, headaches and nausea;
- Vapours are usually present at the beginning of a spill and the impact is likely to be short-lived;
- Daily activities can be impacted by the presence of oil and by response operations.

Impacts on **tourism**:

- Income from tourism is important for many coastal communities;
- Direct oil impacts on beaches and coastal facilities can necessitate their closure;
- A spill may result in loss of clients for restaurants, hotels, water parks, etc.;
- Archaeological sites and associated artefacts found in coastal areas can be contaminated by direct contact with oil – these are very sensitive, and clean-up methods must be adapted to preserve these sites;
- Impacts are generally short-lived and activities resume following clean-up, however potential damage of image may be significant and may persist.

Impacts on **water intakes**:

- Many industries (including refineries, power plants, desalination plants, aquariums, pools, etc.) need sea water for proper functioning;
- Oil in a water intake can lead to contamination of water supply, malfunctions, etc.;
- Can have serious implications for power generation and desalination activities;
- It is important to protect the areas near water intakes to avoid contamination.

Impacts on **ports and marinas**:

- Ports are the key entrance or exit points for many essential goods and trade;
- Ports and marinas can be affected by:
  - Navigation channels being closed or restricted;
  - Contamination of structures such as wharves, jetties, etc.;
  - Contamination of vessels;
  - Closure or limited access due to response operations (booms deployment);
- Cleaning of vessels, in particular yachts, is often required;
- Contaminated structures can be difficult to clean.

Impacts on **fisheries** and **mariculture**:

- Fisheries and mariculture are important economic and subsistence activities;
- Fisheries can be affected by oil because of:
  - Smothering (of organisms by oil);
  - Toxicity (of oil components);
  - Tainting (oil taste in flesh of fish and shellfish);
  - Business disruption;
- Mariculture is particularly vulnerable:
  - Animals cannot escape;
  - Oiling of equipment;
  - Some species will eliminate oil over time (depuration);
- Free-swimming fish are rarely affected unless they are exposed to dispersed oil.
- There are many concerns when fisheries are affected:
  - Public health concerns
    - Toxic compounds (PAHs) in flesh;
    - Many international guidelines;
  - Market confidence;
    - Sales might be affected even if fish are not contaminated by oil;
  - Fisheries closure (fishing bans);
    - Fishing bans are often imposed during an oil spill, but these should be based on well-defined technical/scientific criteria.

- Management strategies should consider:
  - Organoleptic testing
    - Detection of taste and odours of oil in flesh;
  - Sampling and chemical analyses
    - Detection of toxic compounds in flesh;
    - Comparing results with public health guidelines;
  - Marketing campaigns aimed at restoring confidence

3. EFFECTS OF SPILLED OIL

The effects of spilled oil can be either **acute** or **chronic**.

Acute effects of light oils are mostly related to its toxicity causing intoxication through inhaling and ingestion, which in extreme cases may cause mortality of certain organisms, while acute effects of heavy and medium crude oil and heavy refined products are smothering (physical contamination) of living organism and asphyxia.

Tainting (acquiring odour or flavour of oil) of fish, crustaceans and shellfish is considered to be an acute effect as it occurs in minutes or hours. It is reversible but the depuration process, whereas the contaminants are metabolised and eliminated from the organism, is much slower (weeks).

Consumption of marine organisms that have been in contact with oil can be risky for organisms that are higher in the food chain, e.g. the consumption of contaminated fish, crustaceans and shellfish can create health risk for humans and marine mammals through cumulative effects.

Chronic effects in marine organisms cause physiological problems (such as decrease in productivity, slower growth and decrease in olfaction capacity), behavioural disruption (such as slower reaction time, feeding problems and reproductive problems) and bioaccumulation.

OIL AND ITS BEHAVIOUR, FATE, MOVEMENT AND APPEARANCE WHEN SPILT ON THE SEA SURFACE

1. OIL

In the terminology used in the field of marine pollution response the word "oil" is used for both crude oils and any refined products obtained by its distillation.

"Oil" thus encompasses various mixtures of chemical compounds consisting mainly of carbon and hydrogen, which chemists call "hydrocarbons", although some other organic and inorganic compounds that are not hydrocarbons also form part of crude oils and petroleum derivatives. Percentages (in weight) of carbon and hydrogen respectively in different crude oils produced throughout the world, varies between 83 to 87% for carbon and between 11 and 14% for hydrogen. The amounts of other elements are minor, except for sulphur which can reach up to 8% (in some Iraqi crude oils). The total number of chemical substances in a crude oil ranges between 10^5 et 10^6, and most of them are in heavy fractions. As a result, a detailed and precise knowledge of each component of a certain crude oil or refined product cannot be expected. However, the three series of hydrocarbons are known to constitute at least 95% of all crude oils:

Alkanes (**paraffins**) – a series of stable, saturated organic compounds consisting only of carbon and hydrogen. They contain chains of carbon atoms, linked with only single carbon-carbon bonds, with attached hydrogen atoms. Alkanes that have small number of carbon atoms are gases (e.g. methane, ethane, propane and butane), while those with larger number of carbon atoms are either liquids or solids at the temperature of 15 °C. With an increase of the number of carbon atoms in a molecule, the boiling point is increased and volatility is decreased.

Cycloalkanes (**naphtenes**) – a series of saturated hydrocarbons, similar to alkanes but with ends joined to form a ring structure. Carbon-carbon bonds are single

Aromatic hydrocarbons – a series organic compounds characterized by benzene ring(s) of 6 carbon atoms. Low boiling aromatic hydrocarbons are responsible for toxicity of most oils. Higher boiling aromatics, especially multi-ring compounds are suspected as long term poisons and some of them are known carcinogens.

Other components of oil include **organic compounds** containing **nitrogen**, **oxygen** or **sulphur**, as well as traces of **metals** such as **iron**, **nickel**, **copper** and **vanadium**.

Asphaltenes – a series of compounds with very high molecular weights (100 000 and more) and of imprecise definition, although they are sometimes defined as very high boiling solid tars. Their structure is very often unknown. They contain sulphur, nitrogen and oxygen, as well as metals such as nickel and vanadium.

Resins – a group of heterocyclic molecules, containing one or more atoms of oxygen, nitrogen or sulphur. The presence of this heteroatom in their structure causes their slightly surface-active properties which are responsible for initial formation of inverse emulsions with sea water.

The contents of the above-mentioned groups of organic compounds vary considerably from one crude oil to another: saturated hydrocarbons (alkanes and cycloalkanes) 30-70% (weight), aromatic hydrocarbons 20-40%, asphaltenes 0-10% and resins 5-25%.

Finally, a class of hydrocarbons that are not found in crude oils but are common in refined products are **alkenes** (**olefins**) – a series of unsaturated, non-cyclic hydrocarbons that contain at least one double bond between carbon atoms, and whose chains may be straight and branched. Due to their higher reactivity, alkenes are considered to be more toxic than alkanes.

1.1 Characteristics of crude oils

Crude oils are liquids ranging in colour from light amber to opaque black (asphalthenic crudes). They can have green (paraffinic) or blue (naphtenic) fluorescence, and their smell is unpleasant due to the presence of sulphurous compounds.

- Viscosity of crude oils varies as a function of the contents of light fractions.
- Crude oils are highly inflammable (flash points less than 30 °C).
- Specific gravity of crude oils varies between 0.750 (paraffinic crudes) and 1.06.
- Before transportation, crude oils are dehydrated and stabilized in order to remove gases that are not condensable and are nauseous, as well as water and impurities

2. BEHAVIOUR OF OIL FOLLOWING THE SPILLAGE

Following their spillage on sea, oils are subject to various physical and chemical changes, depending on their nature, as well as on the oceanographic conditions. After being spilt at sea the oil continues to spread, move (drift) and change its original characteristics, which influences a great deal the selection of oil spill response techniques to be used:

- The **spreading** of oil affects its thickness on the sea surface.
- The **movement** (drift) results in change of its position in relation to the original spill site.
- The **weathering**[1] causes various changes of oil characteristics, as well as of its volume and the remaining quantity, that occur after the release of oil onto the sea surface.

It is emphasized that spreading, movement and weathering of spilt oil occur simultaneously.

2.1 Spreading of oil

The most obvious characteristic of oil spilled on the sea surface is its tendency to spread horizontally under the combined forces of gravity, viscosity and surface tension. As a rule, gravity dominates initially, influenced by the viscosity of the oil. After a few hours, the oil thickness will be much reduced and surface tension succeeds gravity as the main spreading force. Typically, oil spilled on water will form a thin lens with the inner portion thicker than the edges. In the absence of other influences, spreading continues until an almost monomolecular layer of oil has been formed, not more than 0.5 µm (micrometres) thick, which appears on the sea surface only as a faint silvery sheen. Once the spreading has progressed to the formation of rainbow-coloured or silvery sheens, it is followed by a rapid natural dispersion, providing there is a minimum of agitation.

- Low viscosity, very fluid oils spread faster than high viscosity oils;
- Small spills of low viscosity oils spread uniformly;
- Spreading of more viscous oils is not uniform, and the thickness of oil within a slick may vary between less than 1 µm and several mm (millimetres) or more;

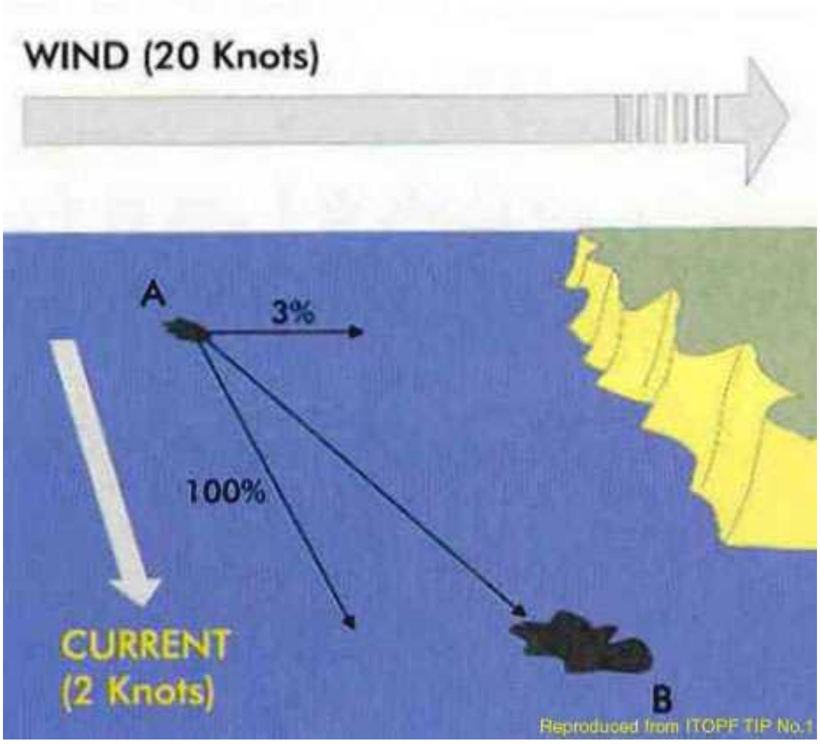
[1] In its original meaning **weathering** denotes various mechanical and chemical processes (e.g. contact with water, atmospheric gases, and biological organisms) that cause rock (but also soil and minerals, and sometimes wood and artificial materials) to decompose (break down). The use of term 'weathering' in the field of marine oil pollution response refers to similar changes that oil spilt on the sea (water) surface undergoes.

- Wind, waves, currents and tidal streams influence the way and rate of spreading and fragmentation of an oil slick;
- An initially homogeneous oil slick is may often be fragmented into patches;
- In the open sea wind creates narrow rows of oil, parallel to the wind direction, known as “windrows”;

2.2 Movement of oil

It has been found empirically that oil floating on the sea surface moves in the same direction in which the wind blows, at a rate of about 3% of the wind speed. On the other hand, in the absence of wind, floating oil will move in the same direction as the surface sea (water) current, at a speed equal to the speed (100%) of such surface current. When both, wind and current are present, the movement of oil proportional to the current velocity and direction will be superimposed on any movement caused by wind. In areas with strong tidal currents close to the shore, their strength and direction should also be taken into consideration when predicting oil movement, while further out at (open) sea the influence of tidal currents is less significant because of the cyclic nature of tidal movement.

Therefore, if the original position of an oil slick is known, as well as the velocities and directions of wind and current in the area, the expected position of the floating oil after a certain period of time can be predicted using a simple vector addition, as shown in the picture below:



Reproduced from "Technical Information Paper No. 1 – Aerial Observation of Marine Oil Spills", ITOPF, London, UK, 2012

2.3 Weathering of oil

2.3.1 Evaporation

- Occurs within a few hours of a spill;
- Volatile fractions are lost to the atmosphere;
- Rate is determined by oil type, wind speed, and ambient temperature;
- Rough seas increase the rate of evaporation;
- Residue has higher density and higher viscosity than the original oil;
- Most crude oils lose up to 40% of the original volume;
- Heavy fuel oils show little evaporation loss;
- Light refined products (petrol/gasoline, kerosene, diesel) evaporate almost completely in a matter of hours, creating a fire hazard in confined area such as ports.

2.3.2 Dissolution

- Factors determining the rate and extent of dissolution of oil include its composition, spreading, the sea/water temperature, wind strength and degree of dispersion;
- Losses are relatively low as most petroleum hydrocarbons have a low solubility in sea water;
- Heavy oils are practically insoluble;
- As the most soluble components of oil are also the most volatile, the loss through evaporation offsets dissolution: it may be 10 to 1000 times slower than evaporation;
- The process is rather long;
- Dissolution of certain oil components is responsible for toxic effects of spilled oil.

2.3.3 Dispersion

- Waves and turbulence break oil slick into droplets, which are then mixed into the upper layers of water column;
- Dispersion rate depends on oil type and the sea state;
- Smaller droplets (diameter less than 70μm) remain in suspension;
- Increased surface area of dispersed oil promotes biodegradation, dissolution and sedimentation;
- Larger droplets resurface;
- Natural dispersion rate can be increased by applying chemical dispersants to liquid, floating oil.

2.3.4 Emulsification

- The emulsification is caused by mixing oil with sea water, due to wave action;
- The term usually refers to the formation of water-in-oil (inverse) emulsions;
- Crude oils are most likely to create water-in-oil emulsions, which are commonly known as “CHOCOLATE MOUSSE”;
- The water contents in the emulsion may be up to 80%;
- Emulsification increases the total volume of the oily material to needs to be dealt with;
- Emulsification drastically increases the viscosity of the original oil.

2.3.5 Sedimentation

- Sedimentation starts when dispersed oil droplets interact with sediment particles and suspended solids, thus increasing the density of oil and causing its sinking;
- Sinking is favoured by incorporation of suspended solids into weathered oil;
- On sandy beaches oil can accumulate large amounts of sand;
- Most crude oils will not sink in sea water;
- Some heavy refined products may sink in sea waters of low salinity or in fresh water that have lower specific gravity;
- Temperature may affect buoyancy of oil.

2.3.6 Biodegradation

- Numerous bacteria, moulds, fungi, yeasts, unicellular algae and protozoa, that are present in the marine environment can biodegrade hydrocarbons;
- Biodegradation occurs regularly;
- The rate depends on the characteristics of oil, the presence of oxygen and nutrients (nitrogen, phosphorus), and the temperature;
- Results of biodegradation are carbon dioxide and water;
- Lighter components are biodegraded faster;
- Micro-organisms are active only at oil/water interface;
- Oil dispersion into droplets increases the rate of biodegradation.

2.3.7 Photo-oxidation

- Hydrocarbons in oil can react with oxygen, producing either soluble products or tar;
- Photo-oxidation occurs under the influence of the ultra-violet radiation from sunlight;
- Occurs at the oil surface, very slowly but more rapidly when oil is spread in a thin film;
- Oxidised light oils are generally more soluble, prone to disperse and biodegradable;
- Very viscous oils oxidise to persistent residues (tar).

2.4 Appearance of oil on the sea surface

When spilled on the sea surface, oil forms a **slick** that drifts with the wind and current, and subsequently breaks up into smaller **slicks (patches)**, usually interspersed with the areas of relatively thin **sheen**, and scatters over areas which, with time, become considerably large. With the changing in wind direction, the refloating of oil already deposited on shores might occur. After being at sea for a certain period oil can be mixed with algae and debris.

Different types oil floating on the sea surface have different appearance:

- **Light refined products** (petrol/gasoline, kerosene, diesel) spread uniformly on big surfaces and undergo strong evaporation and rapid natural dispersion processes, often resulting in their total disappearance in a couple of days. They form thin **sheens**.
- **Heavy refined products** (fuel No.6 and most types of fuel oils used by merchant ships), which are very viscous spread less rapidly and do not disappear naturally. These form **dark** thicker patches, separated by areas of intermediate and thin **sheens**.
- **Crude oils**, whose characteristics and behaviour vary greatly according to their type and origin, usually rapidly break into areas of **dark**, thicker oil interspersed with areas of intermediate and thin **sheens**.

Generally, the thick parts of an oil slick have **dull (dark)** colours, patches of intermediate thickness are **blue** or **iridescent (rainbow)**, and the thinnest parts appear as areas of **grey** or **silvery sheen**.

Sheen (silver, grey or iridescent) consists of only small quantities of oil but is the most visible proof of pollution. Frequently, thick patches can be found in the midst and windward of an area covered by sheen.

Thick patches represent big quantities of oil and are generally, **black or dark brown** at the early stages of pollution. Most of the crude oils and heavy refined products form water-in-oil emulsions (chocolate mousse) (see para. 2.3.4) which appear as **brown, red, orange or yellow** patches.

The table below gives an indication of relations between the oil type, its appearance (colour), the approximate thickness and the approximate volume of oil that slick contains:

OIL TYPE	APPEARENCE	APPROXIMATE THICKNESS [mm]	APPROXIMATE. VOLUME [m^3/km^2]
Oil sheen	Silver	>0.0001	0.1
Oil sheen	Iridescent (rainbow)	>0.0003	0.3
Crude and fuel oil	Brown to black	>0.1	100
Water-in-oil emulsions	Brown / orange	>1	1000

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USE OF SPILL FORECASTING MODELS

1. INTRODUCTION

The lesson aims at providing basic information on what oil spill forecasting models are, and how they can be used to assist those responsible for preparedness for and response to accidental marine pollution.

Oil spill modelling is a process that **simulates the fate of spilled oil**. It has been used since 1960s, and nowadays there are numerous oil spill models that can simulate weathering processes and forecast the fate of spilt oil. Their complexity, the scope of geographical applicability, and simplicity of use vary significantly. Some can be run on a laptop computer, while others only on large mainframe computers. There are models that can be downloaded **free of charge** (e.g. ADIOS 2 and GNOME, developed by NOAA, USA; MEDSLIK II developed by Cyprus and Italy), those that can be accessed **via internet** (e.g. SeaTrackWeb-STW, developed by a group of countries around the Baltic Sea), those that can be **bought from commercial companies** (e.g. OILMAP, available from RPS, UK), and those that have been **developed by national organizations** and scientific **institutions** and are generally not available to external users (e.g. MOTHY, developed and operated by the French national meteorological service).

Oil **spill models** are **computer based decision support tools** designed to (a) show how the physical and chemical properties of different types of oil change over time in the marine environment, (b) forecast the trajectory of a spill, and (c) estimate the time that oil needs to reach specific areas of interest. Most models are able to make predictions ranging from several hours to several days. Environmental parameters can be, and should be, regularly updated to match actual conditions of the incident.

In general, two categories of oil spill models can be distinguished:

- The models belonging to the first category, usually referred to as **oil weathering models**, estimate how different types of oil weather (undergo physical and chemical changes) in the marine environment, but do not predict potential movement of the oil slick.
- The models in the second category, known as **oil spill trajectory models**, in addition to predicting changes that a certain oil undergoes after being spilt on the sea surface, also estimate the evolution of a slick over time, i.e. how the oil slick moves across the water surface, and the distribution of oil in three dimensions.

Information on the **oil type**, complemented with **environmental input data** including wind velocity and direction, sea current speed and direction, tides, air and sea temperatures and bathymetry are the **main data inputs** to the software that generates the prediction, as well as **electronic charts** of areas of interest. In addition to the information from **built-in databases** of the physical and chemical properties of oils, and those from the **hydrodynamic model** (using environmental input data), some models can also use **live data feeds** from e.g. satellite observation and live wind, wave and weather data provided by the meteorological services.

The accuracy and availability of **input data** and the quality of the **hydrodynamic model** are the key factors of the accuracy of the predictions generated by a model. The procedures for specifying spill scenarios and entering required environmental data usually include a “graphical user interface”, that is kept straightforward and can be learned easily.

Outputs of the oil spill models may include graphical and tabular listings of the results of calculations of mass balance, and GIS displays of areas affected by the spill.

2. THE USE OF OIL SPILL MODELS

Oil spill models are valuable support tools for authorities responsible for preparedness and response marine pollution incidents, but also for pollution response teams and professional companies involved in this field.

Models can be used in:

- **risk assessment** (for risk analysis aimed at estimating potential loss of life, damage to environment, damage to coastal economic resources, property and marine facilities);
- **contingency planning** (to define appropriate oil spill response strategies for different parts of the sea and coastal area, to assess the intervention time, to establish the requirements in human resources and response equipment, etc.)
- **training and exercises** (to train designated personnel in making decisions on different aspects of oil and HNS spill response, to prepare realistic scenarios for spill response exercises - in hind-cast mode by tracing the source of a spill, or in forecast mode by predicting the oil trajectory);
- **spill response** (to facilitate making decisions in case of a marine pollution emergency, to forecast the movement of the oil slick, to predict the fate, behaviour and effects of weathering on the released oil, to predict dispersion of spilled oil, to assess the effectiveness of envisaged spill response operations and the impact of specific spill response scenarios, to assimilate information obtained by (aerial) spill surveillance, to establish what mitigation measures are necessary and to develop appropriate clean-up tactics, to estimate how long spilled oil may remain in a certain environment, etc.);
- **environmental and human impact assessment** (to estimate the effects of clean-up techniques that were used or planned to be used, e.g. use of dispersants, containment and recovery of oil, etc., to prepare Environmental Impact Assessment (EIA) studies).

However, when models are used in real spill response situations it is important to bear in mind that **oil spill models** have their limitations and **cannot replace actual observations**, either from air (aerial surveillance) or from land (shoreline survey).

Ideally, the oil spill models should:

- facilitate timely response;
- provide accurate predictions of key parameters for decision making;
- allow the assimilation of data from field observations and adjusting predictions;
- be based on a user-friendly software; and
- be fully operational on portable equipment and in remote areas.

If an oil spill model is available in the country or a region, the information on its characteristics, the required input data, and procedure to access the model in case of emergency should be attached in an annex to the relevant marine pollution contingency plan.

PREPAREDNESS FOR RESPONSE AND CONTINGENCY PLANNING WITH A REFERENCE TO CONTINGENCY ARRANGEMENTS IN PILOT ZONES OF THE PEPSEA PROJECT

1. INTRODUCTION

Regardless of it size, each marine pollution incident is likely to affect the **environment** and **economic activities** in the area where it has occurred. A spill may cause damages to the environment, in particular in the intertidal zone, i.e. on or near the shore. On the other hand, a marine pollution incident will also affect various human activities at sea and in the coastal area, some of which may have serious consequences on the welfare of community living in the affected area, and of a country as a whole. Economic activities that may suffer from consequences of an oil or HNS spill include fisheries, tourism, maritime activities, energy generation (power plants) and industrial activities.

To mitigate such negative consequences, each spill requires a certain level of response, which is commensurate to the size of the spill and the prevailing circumstances. In order to be successful, the response has to be **prompt** (starting as soon as possible after the notification of the incident has been received), **accurate** (adapted to the circumstances of the spill) and **efficient** (using knowledge and skills in the best possible manner, without wasting time, effort and resources).

For response to achieve its goals, the response **organization**, **trained personnel**, **equipment** and **response strategy** have to be in place prior to beginning the actual activities.

Setting up a marine pollution **preparedness and response systems** (at local, regional, national and international levels), that includes a contingency plan and all above mentioned elements, is a proven way of providing a proper reaction to a marine pollution incident.

In an emergency situation it is easy to forget or overlook many important issues, and therefore the best way of ensuring that response to an oil spill will function properly is to prepare a marine pollution contingency plan in advance, when there are no emergencies. The plan, regardless of its scope, must define **who** will do **what**, **where** and **how**, or in other words the plan has to define **responsibilities**, response **policy/strategy**, **coverage/scope**, and to a certain extent, oil spill **response methods**. As regards the latter issue, it should be borne in mind that a contingency **plan is not an oil pollution response manual**.

Making sure that response to an (oil or HNS) spill will function properly when the need arises is the objective of a number of preparedness activities, and in particular of contingency planning. This lesson aims at explaining the basic principles of contingency planning as a **key element of preparedness for** response to a marine pollution incident.

2. CONTINGENCY PLANNING

The existence of a reliable **system for preparedness and response** (be it international, national, regional or local), including response organization, trained personnel, basic equipment and a **contingency plan** for responding to marine pollution incidents, is the single most important factor which determines the effectiveness and the success of response to a spill, by the competent public authorities.

Marine pollution contingency plan, can be described as a document that outlines the **organization** and **strategy (policy)** of response to marine pollution incidents, describes **emergency procedures** and provides **information** necessary for conducting spill response operations. Overall objective of a contingency plan is to ensure an efficient, adequate and timely response to pollution or a threat of pollution by oil (or by other hazardous and noxious substances), with a view to reducing damage to the environment and to minimizing economic and social impact of the spill.

A contingency plan should be a **concise** document containing brief **definitions, descriptions and instructions**, outlining (local, area or national) **policy** for dealing with marine pollution incidents, and clearly reflecting provisions of legal documents on which it is based. A good contingency plan should be written in a simple yet precise language, not loaded with complicated scientific or technical terminology.

More information on specific contingency plans are included in the lesson concerning arrangements for dealing with marine oil pollution incidents (**Lesson L 2.2**).

3. CONTENTS OF A CONTINGENCY PLAN

It has been proven that it is **not possible** to develop a **universal "model"** contingency plan, however, certain elements common to most plans can be identified, and these are listed below. The same applies to the **format** of the plan, although the experience shows that most marine pollution contingency plans are divided into **two**, or rather **three**, distinguished parts:

The first part should address the **policy and organizational issues**, and define:

- the purpose of the plan and its objectives;
- the authority, jurisdiction, definitions and geographical scope;
- the summary of risk assessment;
- response system and policies (relations with other plans);
- organization of response including in particular roles and responsibilities of various authorities and other stakeholders;
- response strategies;
- financing of response;
- health and safety policy;
- training and exercises (type, frequency);
- revision/update requirements and procedures.

This part has to be general enough to provide a **flexible framework** for the second part.

The second part should address **operational procedures relating to spill response**, including:

- initial notification procedure;
- command post;
- data collection (initial report, spill surveillance, spill modelling);
- verification/completion of information;
- situation analysis;
- environmental impact assessment;
- activation of the plan;
- administration (record keeping, reporting, funding, cost documentation);
- logistics (permits, personnel, equipment, support);
- communications (communications plan, means, resources);
- envisaged response activities;
- monitoring the development of the situation and progress of response operations;
- termination of response activities and demobilization of resources;
- waste management (including transport, temporary storage and disposal of collected oil/oily waste);
- site health and safety plan;
- public information and media relations;

This part should be regularly updated and modified in accordance with the changing of e.g. legal and administrative framework (local, regional or national) and development of technology.

Finally, the plan should be complemented with a **set of data** necessary for organizing and conducting spill response that are usually presented in annexes to the plan, or in a separate third part of the plan, known as **"data directory"**. Information contained in annexes or data directory should comprise:

- environmental data (meteorological, oceanographic, climatic, biological, etc.);
- contact details of relevant authorities, organizations, services and institutions;
- pollution reporting format;
- SCAT - Oiled Shoreline Assessment Form;
- inventories of different categories of available resources (specialized response equipment and products, non-specific equipment that can be used in shoreline clean-up activities, land vehicles, vessels, aircraft, OZO, etc.);
- directories of sources (owners or managers) of resources listed in the inventories;
- directory of authorized laboratories;
- sensitive areas (identification, locations, priorities)
- locations for potential temporary waste storage
- distribution list of the plan
- The above information has to be regularly updated, revised and amended as necessary.

3. CONTINGENCY ARRANGEMENTS IN THE PEPSEA PROJECT'S PILOT ZONES

The marine pollution contingency arrangements that have been prepared under PEPSEA projects for the selected Pilot zones generally **follow the guidelines** outlined in the previous section. Draft marine pollution contingency plans and the recommendations that have been prepared clearly set out the **legal framework** for local action **based on the existing** national and regional **regulations** for response to marine pollution incidents, and **define roles and responsibilities** of those involved in the response management at local level.

Potential **participants** in response to a marine pollution incident at local level **have been defined**, as well as the **key operational procedures** to be followed (i.e. the activation of the plan, situation assessment, communication arrangements, transfer of authority, spill response strategy, control/supervision of response activities, termination of response operations, records keeping, training and exercises, public information, and updating the data directory).

Various **data sets** that have been collated and processed under the PEPSEA project should be considered as part of **data directory** of each plan, all the more so because these data are stored in a **GIS specifically prepared** for the Pilot zones.

4. USE OF GIS TO INCREASE PREPAREDNESS FOR RESPONSE TO MARINE POLLUTION INCIDENTS

GIS (Geographic Information System) applications are computer-based tools that allow the user to create queries (searches), to store and edit spatial and non-spatial (e.g. tabular) data, analyse spatial information output, and visually share the results of these operations by presenting them as maps. Thanks to its versatility, GIS has found numerous uses in preparedness activities, but also in actual spill response operations.

In preparedness related activities the GIS is used during **contingency planning** process, in particular in environmental sensitivity mapping, studying vessel traffic patterns and shipping safety issues, assessing risks, developing strategies for mitigating the impacts of potential oil spills, identifying areas in which dispersants can be used (considering water depths and specific sensitive resources), identifying places of refuge for ships in distress, considering the sensitivity to hazardous and noxious substances (HNS), etc. GIS products can also be used to prepare exercises and for training purposes.

The use of a GIS in **developing sensitivity maps** is of particular importance as it allows maps to be easily created and updated. GIS also facilitates sharing and communicating the information contained on the maps, storing and managing the information (e.g. images, statistics, etc.), and producing maps at various scales, with the relevant layers of information, and in various formats (e.g. paper, PDF, interactive internet maps). Geographic layers and parameters can be overlaid and interrogated to illustrate a range of information (e.g. sensitive areas, habitats, plans for boom deployment, transport routes, waste storage and disposal sites, response times, etc.).

During the implementation of the **PEPSEA project**, the geographic information system (GIS), consisting of a GIS database, a GIS data server (Geoserver) and a web page with a GIS module for visualizing spatial data, was used the development of risk models and for the preparation of marine pollution contingency plans for different localities. GIS was also used in several other project components e.g. to develop the model for the Adriatic Sea level rise, the model of floods risk, the fire outbreak index (the risk of fire), the model of susceptibility to soil erosion, the digital relief model, the vegetation cover model, and for the analysis of the vegetation cover data, for the classification of sediments, and for the mapping of *Posidonia oceanica* meadows.

OIL SPILL RESPONSE OPTIONS

1. INTRODUCTION

Regardless of the scale of the problem, response to a marine pollution emergency can be expected to be successful only if response **organization** exists, if (trained) **personnel** and necessary **equipment** are available, and if the **strategy** of response has been agreed upon. Combined with careful **planning** of response activities for each specific incident, the presence of these key elements significantly increases the chances that response efforts will succeed.

At the local level, efficient organization of spill response can be achieved through setting up an adequate **local system for preparedness** for **and response** to accidental marine pollution, fully compatible with the regional and national systems.

Responsibility for pollution preparedness and response should be vested in an appropriate part (department, service, office) of **local self-government**, which will be supported by an appropriate mechanism for coordination with regional authorities. However, close co-operation with the local industry, if it exists in the area, and other stakeholders (e.g. operators of marinas, tourist sector organizations, fishermen, non-governmental organizations, etc.) is necessary for increasing the efficiency of a local system for preparedness and response.

All relevant information concerning administrative, legal, operational, logistic, technical, environmental, financial, etc. aspects of response to marine emergencies should be collected and presented in a local **contingency plan** (compatible with regional and national plans), which will significantly reduce the time spent on collecting indispensable information (regarding e.g. communications, manpower, equipment, environmental data, etc.).

Finally, the successful outcome of each particular spill response operation will largely depend on the selection of the most appropriate **spill response option**.

2. RESPONSE OPTIONS

The number of available **spill response options**, or rather methods and techniques that can be applied, is in fact very limited and includes:

1. Surveillance, tracking and forecasting the spill development;
2. Elimination of the source of oil (or other pollutant);
3. Spill containment and protection of sensitive resources;
4. Removal of spilled oil from the sea surface, by:
    - 4.1. Mechanical collection/recovery of spilled oil;
    - 4.2. The use of dispersants;
    - 4.3. The use of other treatment products (including sorbents);
    - 4.4. In situ burning of spilled oil;
5. Removal of oil deposited on shore (shoreline clean-up); and
6. Restoration of the spill site.

Two operations that, strictly speaking, do not belong to spill response options, but should be considered as integral and vital part of any option that involves collection of oil/oiled material are:

7. Transport, storage and treatment of collected oil/oiled material; i
8. Final disposal of collected oil/oiled material.

Finally, another operation that should be considered as part of any response to a marine oil pollution incident is:

9. Oiled wildlife response.

These nine options are briefly outlined hereunder, while detailed information on each of them can be found in specific documents also included in the PEPSEA training programme.

2.1 Surveillance, tracking and forecasting a spill development

This option is an acceptable and legitimate option for dealing with an oil spill when the spilled product (such as petrol/gasoline, kerosene, diesel, and other light, non-persistent products) does not necessitate a full scale response operation, or when the intervention on such products may endanger the response personnel (e.g. as their fast evaporation may cause formation of an explosive atmosphere). On the other hand, launching a response operation for dealing with such products may be unnecessary, bearing in mind that they rapidly degrade naturally due to the evaporation, dissolution and/or natural dispersion.

It is also an adequate solution for dealing with oil in particularly sensitive areas where any intervention could cause more damage to the environment than the oil itself.

Finally, this option may be the only reasonable one when adverse weather conditions do not permit the implementation of any other spill response measures because of risks for health and safety of the personnel, or safe operation of equipment, vessels and aircraft.

2.2 Elimination of the source of oil (or other pollutant)

Response at the source of pollution includes highly specialized salvage activities such as stabilizing the (damaged) vessel, stopping and reducing the outflow of oil, transferring oil into another tank on board the (damaged) vessel and lightering the vessel (transferring oil into another vessel/barge). All these operations require specific knowledge, highly trained personnel, sophisticate equipment and specialized vessels, and can be carried out only by specialized salvage companies.

2.3 Containment of oil and protection of sensitive areas

Limiting the spreading and movement of oil and achieving a certain control upon it has been one of the prime goals of oil spill control technology. Purposely designed floating barriers (usually called

booms) can provide a reasonably high degree of control of spilled oil movement and spreading, and booms are therefore defined as devices (floating barriers) specially designed for the control of oil movement on the sea (water) surface.

Booms can be used to contain and to direct spilled oil and main objectives of their use are:

- to concentrate spilled oil in order to facilitate its recovery;
- to protect certain parts of a coastline from contamination with spilled oil.

It is important to note that booms should always be used together with some kind of recovery device since none of their aforementioned functions can be achieved if oil is not successively removed from the area in which it has been confined.

2.4 Removal of spilled oil from the sea surface

Removing the floating oil from the sea surface, which is the final goal of any spill response operation, can be achieved using mechanical devices, dispersing it using chemical dispersants that enhance their dispersion into the sea water column, using specially designed products including adsorbents (or absorbents), and by burning the spilled oil on the sea surface.

2.4.1 Mechanical collection/recovery of spilled, floating oil

Mechanical collection/recovery of floating oil at sea (usually assisted by oil containment) is often considered as the preferable response option, provided that specialized equipment required for containment, collection and storage of spilled oil (booms, skimmers, specialized pollution response vessels, floating tanks/barges) exists.

The best results are achieved by using purposely built **oil recovery units** known as "**skimmers**", which are defined as mechanical devices specifically designed for the removal of oil (or oil/water mixture) from the sea (water) surface without considerably altering its physical and/or chemical characteristics. This definition comprises numerous designs and working principles utilized in skimmers' construction.

Most skimmers are not self-propelled and have to be deployed either from a vessel (boat or ship) or from shore, however there are also specialized pollution response vessels that have a skimmer (recovery device) built-in, as their integral part.

2.4.2 Use of dispersants

Dispersants (or chemical dispersants) are mixtures of solvents, wetting agents and surface active agents that reduce the interfacial tension between oil and water. When applied to oil floating on the sea surface, dispersants stimulate its dispersion and assist an oil slick to break into fine droplets that are rapidly distributed throughout the water column. The surface to volume ratio of the oil is thus increased, accelerating the process of natural biodegradation.

Because of possible negative effects of dispersed oil on certain marine organisms, the use of dispersants is limited to those circumstances in which potential damage to biological and physical resources could clearly be greater if they were not used.

The use of dispersants should be considered in open sea where booms and skimmers are less effective or even ineffective, and in cases when the movement of an oil slick threatens areas of major biological or economic importance. As a general rule, their use in shallow, coastal waters is not recommended.

2.4.3 Use of other treatment products (including adsorbents/absorbents)

Variety of chemical and physical agents have been proposed for treatment of spilled oil, including e.g. sorbents (adsorbents and absorbents), gelling agents, surface tension modifiers (chemical barriers), sinking agents and biological agents. However most of these do not have significant practical importance, in particular for dealing with major spills.

Only sorbents, which are defined as products that fix liquid oil either by absorption or by adsorption, have found a wider use in oil spill response. They are available in various forms (pillows, mats, sheets, pom-poms, powder, granules, etc.). The use of sorbents is limited to small or medium size spills in sheltered areas near the shore. They are often used in shore clean-up operations when more common recovery methods either give poor results or are inapplicable.

2.4.4 In situ burning

The controlled burning of spilled oil, at or near the spill source, can potentially remove relatively large amounts of floating oil. Its implementation requires the use of fire-resistant containment booms, ignition devices (igniters), and substances known as “primers” (ignition promoters), “wicking agents” (combustion promoters) and “chemical herders”.

Despite the inflammability of many hydrocarbons that are found in oil and extensive research in this field, the method still has a number of limitations that impede its wider use, such as e.g. the loss of lighter (more volatile) oil fractions through evaporation and difficulties in keeping the oil contained/accumulated in order to maintain it sufficiently thick to sustain burning.

On the other hand, burning which is never complete, results in severe air pollution that rises health concerns, besides leaving considerable amounts of heavy, partly burnt residues that are prone to sinking and potentially affecting marine life on sea bed.

The use of in situ burning of spilled oil in nearshore areas is usually not allowed, while burning of oil and oil-contaminated material (e.g. vegetation) on land is a sometimes used as part of shoreline clean-up measures.

2.5 Shoreline clean-up

If an oil spill occurs relatively near a shore, a smaller or a bigger part of spilled oil will reach the shoreline, resulting in its coating by oil. The decision on whether to clean the affected shoreline or not, and on how to do it, will depend on a number of factors including *inter alia* the environmental, economic, logistic, meteorological, oceanographic, (geo)morphological and technical ones, as well as on the availability of personnel and equipment in the affected area.

Methods of shoreline clean-up generally fall into four main categories, namely **removal** (manual or mechanical) of oil and oily material, **flushing** of oil (usually with water), controlled **burning** of oil and oily material on land, and **leaving** oil to degrade naturally (sometimes assisted by **bioremediation**). Booms, skimmers and sorbents are often used in shoreline clean-up, for removing the oil floating near the shore.

2.6 Restoration of the spill site

Restoration (which is also referred to as reinstatement or remediation) of the environment affected by an oil spill is a set of (reasonable) measures that are taken with a view to accelerating natural recovery of environmental damage.

Such measures may include e.g. replanting of saltmarsh plants, restricting access and human activities in damaged areas, imposing control on fishing in order to reduce competition for limited food sources, closing access to the beaches on which turtles nest, etc. The complexity of marine environment is likely to limit the extent to which ecological damage can be repaired artificially and very often natural recovery is sufficiently rapid.

2.7 Transport, storage and treatment of collected oil/oiled material

Transport of oil and oiled material from the site of recovery/collection to temporary storage or final disposal sites presents a major logistic problem. Means of transportation may include sea going vessels and land vehicles, and in certain cases even aircraft (helicopters). All used means of transportation must be equipped with some kind of leak-proof container(s) in order to prevent contamination of non-polluted areas.

Very often the rate of oil/oiled material recovery (offshore and onshore) is higher than the rate of its final disposal, even when the methods, sites and facilities for it have been studied and defined in advance, thus necessitating provision of **temporary storage capacities**, preferably as close as possible to the site where oil is being recovered. Such capacities may include improvised pits, open top oil drums, heavy duty plastic bags, flexible/collapsible tanks and fixed storage capacities.

Oil collected during spill response operations has to be **separated** from of sea water and/or solid materials collected with it, in order to reduce the volume of material which has to be handled, transported and stored, and to facilitate the final disposal or possible re-use of oil. The purest oil is that collected by skimmers from the sea surface (up to 90% of oil), while beach material collected during the shore clean-up may contain only 1-2% of oil. Oil contents of various emulsions and different types of oiled material varies between these two figures. The methods of **treatment** of collected oil and oiled material include gravity separation of oil and water, removal of debris, collection of leaking oil, washing oily material, extraction of oil and sieving.

2.8 Final disposal of collected oil/oiled material

The disposal of waste from an oil spill is often the longest and the costliest part of the response. Available disposal methods can be grouped in accordance with the "fate" of oil/oily material as follows:

- **Recovery** of (part) of the oil for re-use.
- **Stabilization** of collected oiled material by landfilling or by use in civil works.
- **Destruction** of oil/oiled material by heat/incineration (with the possibility of heat recovery) or biodegradation.

The most appropriate method should be chosen taking into consideration the nature of the collected oil/oiled material and the availability of the necessary equipment or facilities for its processing. A close cooperation between the authorities in charge of oil spill response and the industry is necessary in order to dispose of the collected oily waste, observing in this process all national and local legal requirements concerning waste management.

2.9 Oiled wildlife response

Oiled wildlife response does not relate only to the rehabilitation of oiled animals, but also to a series of activities that aim at minimizing the impacts of an oil spill on wildlife (including birds, mammals and reptiles) by both preventing oiling when possible, and mitigating the effects on individual animals when oiling has occurred.

It includes the assessment of risks for wildlife, real-time monitoring of the location of wildlife in relation to the oil spill, protection of nesting sites, scaring animals away from oil, pre-emptive capture and collection of un-oiled animals and eggs, collection and analysis of corpses, euthanasia, rehabilitation of live oiled animals, their release to the wild, and monitoring of post-release survival.

NATIONAL, REGIONAL AND LOCAL ARRANGEMENTS FOR RESPONDING TO MARINE OIL POLLUTION INCIDENTS (WITH REFERENCE TO CONTINGENCY ARRANGEMENTS IN THE PILOT ZONES OF THE PEPSEA PROJECT)

1. INTRODUCTION

Lesson L 1.4 outlined what are considered as the main components of a “marine pollution **preparedness and response systems**” and summarised the process of contingency planning and the plan itself.

However, having a contingency plan in place does not guarantee that response to a marine pollution incident will be efficient or successful. The **organization of spill response** will be usually established during the contingency planning process and the plan will describe it, including the **roles and responsibilities** of persons included in both the response management and field operations. The plan will also define the **strategy of spill response**, and list the **sources of human and material resources** required to respond to a spill. However, in order to successfully react to a spill, additional arrangements may need to be made for the implementation of provisions of the plan (regardless of whether it is local, regional or national plan).

2. TIERED RESPONSE

The response a marine pollution incident requires must be proportional to the **size of spill and its proximity to sensitive resources** (that are usually on the coast). In order to avoid over- or underreacting, response is usually divided into three categories. A widely accepted international practice is to set up marine pollution preparedness and response systems on the basis of the **tiered response concept**.

It provides for **three (3) response tiers**, in accordance with the seriousness of the pollution incident, in which response at a local level is the basis of any response. Usually, contingency plans **do not define limits** of each tier **in relation to the exact volume** of spilled pollutant.

In general, **Tier 1** covers preparedness and response to **small spills** that can be carried out with the **resources available at the local** (municipality) **level**.

Tier 2 covers preparedness and response to major spills that go beyond the response capabilities and resources available at the local level, but can be confronted with those available at the regional level.

Tier 3 covers major spills that cannot be effectively dealt with by Tier 2 response arrangement and resources, thus calling for the mobilization of all available national resources. It also implies the possible mobilization of external (international) resources and expertise.

The appropriate level of response for a specific pollution incident can be determined only following the assessment of the actual situation in each specific case, and therefore contingency plans usually **do not define limits** of each tier **in relation to the exact volume** of the spilled pollutant.

3. LOCAL ARRANGEMENTS

Marine pollution contingency plans (**local**, or **Tier 1**) prepared under the PEPSEA project contain certain data (or indicate their source), however all necessary information (meteorological, oceanographic, biological, etc.) concerning the areas covered by these plans must be readily available to the response personnel in case of need, which necessitates making arrangements for obtaining the required information (for each locality identified as important in each area) following the adoption of the plans.

In order to ensure their active participation in possible response operations (e.g. as volunteers) the local community should be involved in all processes for increasing the level of preparedness much as possible. Arrangements for the participation of local personnel in future spill response operations should be me made at the local level, as soon as possible after the official promulgation of the plans. These may include presentations of the plans to the local community through organizing short seminars aimed at familiarizing the general public with the relevant provisions of the plans.

Each local (**Tier 1**) plan necessarily has to consider the **limits of responsibility** of local public authorities, as assigned to them by the relevant legal acts. Necessary arrangements for **transferring responsibility** to higher authorities, as well as the arrangements for **reporting pollution** incidents to the higher authorities, as envisaged in local plans developed under the PEPSEA project, must be made before marine pollution occurs.

4. REGIONAL AND NATIONAL ARRANGEMENTS

Tier 2 (**regional**) **plans** are prepared in accordance with the territorial division of a country into administrative units (regions, provinces, counties) and provide a basis for responding to any medium or large size pollution that exceeds the capabilities of local (Tier 1) spill response arrangements. They should be based on pooling locally available resources (human and material) and on complementing these with resources available at regional or state levels. In particular, Tier 2 plans are expected to define the responsibilities for co-ordination of response efforts in case of any larger spills.

Taking into consideration the geographical coverage of the **PEPSEA project**, **Tier 2** plans that could be activated include **several regional** (Italy) **and county** (Croatia) **contingency plans** that are already in force. Making arrangements for familiarizing the local personnel, expected to be involved in spill response in the future, with the contents and provisions of the existing regional and county contingency plans, should be one of the priorities of competent local authorities.

National contingency plan, that represents a **Tier 3 plan**, defines the overall national policy of response to marine pollution incidents, in particular in case of a **major spill** that exceed any particular local or regional response capability and may even necessitate international assistance. National plan should coordinate various lower level contingency plans and provide support to regional authorities when the size of spill exceeds regional response capacities.

As regards areas in which PEPSEA project is being implemented, **Tier 3** plans that could be activated in case of massive spill incidents are:

Croatia "National Contingency Plan for Accidental Marine Pollution" (*Plan intervencija kod iznenadnih onečišćenja mora*), 2008, prepared by the Ministry of the Sea, Transport and Infrastructure),

Italy "National Contingency Plan for the protection from pollution by oils and other noxious substances caused by maritime incidents" (*Piano di pronto intervento nazionale per la difesa da inquinamenti da idrocarburi e di altre sostanze nocive causati da incidenti marini*), 2010, prepared by the Civil Protection Department. If a major oil pollution incident occurs at sea under the Italian jurisdiction (including the coastal/internal waters, territorial sea, ecological protection zone EPZ and the high sea), the "Operational Contingency Plan for protection of the sea and coastal areas against accidental pollution by oil and other noxious substances" (*Piano operativo di pronto intervento per la difesa del mare e delle zone costiere dagli inquinamenti accidentali da idrocarburi e da altre sostanze nocive*), 2013, prepared by the Italian Ministry in charge of the environment, may also be activated.

If these were not addressed during the development of the relevant contingency plan, the following issues may need to be addressed by the authorities in charge of accidental spill response (at all levels, including the **local level** of response) after the drafting of the plan, by making arrangements for:

- complementing the available spill response resources through the acquisition of additional ones (e.g. through the available international sources of financing);
- supporting response efforts of the competent local authorities, as necessary, by professional, private clean-up contractors;
- assessing financial consequences of response measures envisaged for different spill scenarios, and ensuring the availability of the necessary emergency funds on time (e.g. from the budget of the local self-government);
- implementing the agreed policy on human resources development (regarding e.g. training and exercises);
- co-operation with the oil and shipping industry;
- exchange of information with the relevant neighbouring local, regional or national authorities responsible for marine pollution response.

In case of the highest level of response (national, tier 3) it may be necessary to make arrangements for benefitting from international mechanisms for mutual assistance and co-operation, in particular through **REMPEC** (Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea), under the **Prevention and Emergency Protocol** to the Barcelona Convention, or using the provisions of the existing international contingency plan for the Adriatic region ("Sub-regional Contingency Plan for the prevention of, preparedness for and response to major marine pollution incidents in the Adriatic").

HEALTH AND SAFETY ISSUES RELATED TO OIL POLLUTION RESPONSE ACTIVITIES[2]

1. INTRODUCTION

The highest priority during response to marine oil pollution incidents is to be assigned to ensuring that the risk to human life, health and safety of response personnel is minimized as much as reasonably possible. Ensuring good health and safety standards shall have priority over all other actions.

The national authority having an overall responsibility for responding to marine pollution incidents has to ensure that health and safety issues are adequately addressed in the national marine pollution contingency plan, as well as in all other subordinate contingency plans. In general, national, regional and local authorities in charge of response to oil spills have duty to provide the response personnel with appropriate training and briefings in order to ensure that they are aware of the risks associated with oil spill response operations and of how to avoid them.

The objective of the lesson is to underline the most important aspects of health and safety concerns during oil spill response, however detailed measures for the protection of health and ensuring the safe conduct of spill response operations should be sought in the applicable national regulations on safety at work and occupational health.

[2] Excerpts from the joint publication of IPIECA (The global oil and gas industry association for environmental and social issues) and IGOP (International Association of Oil & Gas Producers) "**Oil spill responder health and safety**" (2012, rev. 2016) has been used in the preparation of this lesson.

2. HAZARDOUS PROPERTIES OF OILS

Properties of oils, both crude oils and refined products, that may render spill response operations unsafe for response personnel include:

- flammability;
- explosive vapours;
- toxicity;
- displacement of oxygen; and
- slippery nature of oils.

NOTE: incidents that besides oil involve also other hazardous and noxious substances (HNS) may pose **significant additional risk** to human health, and therefore oil spill response may be hindered or even not be possible in the presence of HNS.

2.1 Flammability

Spilled refined products, crude oils and condensates may be **ignited** in the presence of a source of ignition. Usually, oil remains easily inflammable for a **short time**, due to quick evaporation of the more volatile components. Whilst oil is still fresh, any potential sources of ignition must be excluded from the area of incident or response, with a view to minimizing the risk of fire. Only intrinsically safe response equipment should be used, and any potential source of ignition should be kept out of the spill area (e.g. smoking, sparking tools, vehicles). Access to the response area must be strictly controlled until the risk of ignition exists. Light products, such as gasoline or kerosene, represent a particular hazard and approaching spills of these products requires special precautions. (See also the next paragraph.)

2.2 Explosive vapours

Spilled refined products (as well as volatile crude oils) release hydrocarbon vapours, in particular during the initial stages of the incident. Vapour cloud that is formed can drift under the influence of wind towards populated areas or locations where there is a risk of ignition of such vapours.

In order to minimize the risk of explosion, **safety exclusion zone** and **air monitoring stations** may need to be established to determine the vapour levels and whether or not these are within **explosive limits**. Internal combustion engines should not be operated in areas where a risk of explosion exists. As a precaution, engines should be protected by fitting air inlet shut-off devices and spark arresters.

2.3 Toxicity

During response operations **at sea and on shore**, i.e. **in the open air**, the toxicity of most spilled oils pose little or no threat to human health. The risk of potentially harmful exposure may be present during the initial stages of a spill, in particular in case of spillage of volatile products (e.g. light refined products, certain crude oils and condensates). Despite the fact that oils contain some potentially harmful components, exposure risk can be minimized by wearing **appropriate personal protection equipment (PPE)**.

On the other hand, in case of intervention in **enclosed spaces** (e.g. on board tankers carrying crude oil, during cargo transfer operations) the risks increase due to higher concentrations of hydrocarbons and the presence of benzene and hydrogen sulphide H_2S (in crude oils).

Albeit it is very unlikely that non-professional spill responders will be involved in response in enclosed spaces, the following notes on exposure to H_2S are still included as basic guidelines:

Exposure to hydrogen sulphide (H_2S)

Hydrogen sulphide (H_2S) is a colourless gas, smelling of rotten eggs, that is found in most types of crude oil (more than 3% of H_2S in some Middle East crudes). **Lack of the characteristic smell must never be considered as the absence of H_2S**, as in high concentrations it paralyses the sense of smell. Inhaling H_2S vapours emitted by sulphurous crudes is dangerous: depending on the concentration and duration of exposure, the effects range from the irritation of eyes, nose, throat and bronchi, to coma and death. If the casualty resists to inhaling H_2S, recovery is generally complete with no after effects.

First aid measures include: removing the casualty to fresh air, applying (if necessary) artificial respiration, treating for unconsciousness, and administering amyl nitrite by inhalation.

2.3.1 Consequences for human health

Human organism can be directly affected by **inhaling hydrocarbon vapours**, by **skin contact with liquid oil** and by **accidental ingestion** of oil.

- Inhalation: The smell of hydrocarbon vapours can vary significantly. In certain cases, hydrocarbon vapours can disturb the sense of smell and therefore, the **absence of smell should never be considered as the absence of vapours**. If the person is treated in time, the effects are reversible and, in principle, there are no long term effects caused by hydrocarbons themselves, **except benzene**. Depending on the concentration of vapours and the duration of exposure, the symptoms of exposure may range from the irritation of eyes, throat and nose, to weariness, to the symptoms of inebriation, and coma. Wearing **appropriate PPE is mandatory** to avoid any potentially harmful effects of exposure to hydrocarbon vapours.

- Skin contact with liquid oils: In general, hydrocarbons dry the skin and can provoke dermatosis and eczema (**short term effects**), and certain hydrocarbons, particularly aromatic ones, can provoke skin cancer as a result of prolonged contact with the skin (**long term effects**).

- Oil and some of the chemical compounds used in clean-up operations can have a degreasing effect on skin, leading to irritation and dermatitis, and can also be absorbed through damaged skin causing toxic effects internally.

- Accidental ingestion: Although very unlikely, accidental ingestion of oil requires medical intervention. As a general rule, the casualty must not be induced to vomit, with a view to avoiding the risk of increased penetration of hydrocarbons into the lungs and bronchi.

Besides direct intoxication, the **consumption of marine animals** (fish, crustaceans, shellfish) that have been in contact with oil can also be dangerous for human health.

2.4 Displacement of oxygen

Displacement of oxygen occurs generally only in **enclosed spaces** where hydrocarbon gases can displace the oxygen (O_2), particularly when these accumulate in confined spaces or trenches that are not adequately ventilated, leading to a risk of asphyxiation for those entering. Operations in confined spaces should be left exclusively to professional response personnel (firefighters, employees of specialized salvage companies) and not to the personnel engaged in spill response at sea and on shore. In general, entry should be permitted if oxygen contents readings are above 19.5% O_2, or otherwise an independent oxygen source should be used.

2.5 Slippery nature of oil

Most oil products are naturally slippery, and it is not surprising that slips, trips and falls on oiled surfaces are some of the main causes of injury and generally the most common form of accidents during spill response operations. In order to minimize the risk of personal injury response personnel must be repeatedly reminded of risks related to the slippery nature of oil. The same oil characteristic renders difficult equipment handling with oily gloves, thus slowing down and even preventing response personnel from properly executing some of their tasks without decontaminating the equipment first.

3. MANAGEMENT OF HEALT AND SAFETY ISSUES

In case of a smaller oil spill incident a person proficient in matters related to health and safety (possibly from a local health centre) should be included in spill response organization as a “health and safety officer” (HSO), and entrusted with ensuring that the stipulated health and safety standards are duly observed during response. Duties of the HSO should include:

- conducting an initial risk assessment of the envisaged response operations and their site (hazard identification, selection of responders, availability of PPE, identification of decontamination areas, assessment of training requirements concerning health and safety standards);
- developing and implementing a Site Safety and Health Plan (SSHP), jointly with the competent health and safety professionals;
- establishing first-aid stations in accordance with the SSHP;
- supervising spill site safety during response operations;
- monitoring safety and health implications of the planned response activities or those already in progress;
- participating in planning meetings in order to identify health and safety concerns;
- correcting any observed unsafe practices, and stopping them as necessary;
- investigating any accidents or exposures that may occur during response operations;
- organizing regular briefings of response personnel prior to and during oil pollution response operations.

Briefings of response personnel are one of the basic methods of managing health and safety. Such briefings shall ensure that all those concerned (response personnel) understand:

- characteristics of the worksite;
- information on hazards posed by the spilled product;
- control measures (e.g. PPE);
- evacuation routes;
- assembly point;
- first-aid post location;
- location of staging areas;
- command post location; and
- how to respond to other emergencies that may arise.

4. PERSONAL PROTECTIVE EQUIPMENT (PPE)

Because of hazardous properties of oils and general risks associated with working in a potentially unsafe environment (e.g. at sea or on shorelines exposed to bad weather), protection of response personnel should be one of the main priorities of the response management.

Providing all personnel directly involved in clean-up operations with appropriate PPE (to minimize contact with oil and chemical products used in response), and with lifejackets if working on boats/vessels, is the **responsibility of the response management**. On the other hand, it is the responsibility of response personnel to watch out for each other as well as for themselves, and to wear and/or use the PPE appropriate for the job being carried out.

The key items of PPE for protection of specific parts of a body during oil spill response include:

Eyes

Hazard: chemical or metal splash, dust, projectiles, gas and vapour, radiation

PPE: safety spectacles, goggles, face shields, visors (all specific to the hazard involved).

Head

Hazard: impact from falling or flying objects, risk of head bumping, hair entanglement.

PPE: helmets and bump caps.

Body

Hazard: temperature extremes, adverse weather, chemical or metal splash, spray from pressure leaks or spray guns, impact or penetration, contaminated dust, excessive wear or entanglement of own clothing, drowning.

PPE: conventional or disposable overalls, boiler suits, high-visibility clothing and specialist protective clothing (e.g. for chemical exposure), life jackets/vests.

Hands and arms	Hazard: abrasion, temperature extremes, cuts and punctures, impact, chemicals, skin infection or contamination. **PPE:** gloves (refer to manufacturers' specifications), gauntlets. *No glove material will protect against all substances and no gloves will protect against a specific substance forever.*
Feet and legs	Hazard: wet, slipping, cuts and punctures, falling objects, chemical splash, abrasion. **PPE:** safety boots and shoes with protective toe caps and penetration-resistant mid-sole, gaiters, leggings, spats. (*Some chemicals penetrate leather easily - material to be selected according to manufacturers' information*)
Hearing	Hazard: noise at levels of 85 dBA or more. **PPE:** ear defenders (hearing protection devices) in the form of plugs or muffs, with an element of personal selection.

Respiratory protective equipment (RPE), designed to protect the wearer against inhalation of hazardous substances in the air, may also be necessary. Two main types include **respirators** (filtering devices) that use filters to remove contaminants in the workplace air (never to be used for protection in situations with reduced oxygen levels), and **breathing apparatus** (**BA**) that requires a supply of breathing quality air from an air cylinder or compressor and is used for protection in situations with reduced oxygen levels. Different facepieces (e.g. filtering facepieces/masks, half and full face masks), hoods and helmets are available for both types of RPE.

FLOATING BOOMS AND THEIR USE IN RESPONSE TO MARINE POLLUTION INCIDENTS

1. INTRODUCTION

Oil spilled on the sea (water) surface spreads under the influence of gravity and moves under the influence of sea currents and winds. Both actions adversely affect attempts to remove spilled oil from the sea surface that is the final aim of all spill response activity.

Any obstruction in the course of oil influences its motion, until it reaches the coastline. In most cases the uncontrolled arrival of oil on a coastline is the least desirable result of a spill, and therefore achieving a certain control upon the movement and spreading of the oil slick has been one of the prime goals of oil spill response.

Some results in terms of oil spill motion control can be achieved using improvised barriers (e.g. logs, beams, poles, air inflated fire hoses, earth or sand dams, etc.). However, only purposely-designed and built floating barriers (in the domain of marine pollution response called "**booms**") can provide a reasonable degree of control over the movement of spilled oil.

ISO 16446:2013 standard defines **boom** as "floating barrier used to control the movement of substances that float".

The main objectives of using booms are:

- to contain oil and restrict its spreading on the sea surface
- to concentrate spilled oil in order to facilitate its collection/recovery;
- to protect certain parts of a coastline from contamination with floating oil.

It is important to understand that there is no such boom that can retain oil indefinitely and that oil concentrated by a boom has to be removed, rapidly and continuously, from contact with the boom before it starts escaping over or under it.

2. DESIGN

2.1 Construction elements

Booms are available in various shapes and sizes, however, regardless of their design, five basic elements can be distinguished in each of them:

Flotation element (float) ensures the buoyancy of the boom and functions as a freeboard that prevents oil from spilling and splashing over the boom. It is filled either with air or a solid material (usually synthetic e.g. expanded polyethylene, polyurethane, polystyrene).

Skirt acts as a barrier that prevents passing of oil underneath the boom. Skirt's depth affects the efficiency of the boom, but also greatly affects the total load exerted on the whole system. Skirts of most booms are made of synthetic rubber or plastic-coated fabrics.

Ballast is attached to the bottom of the skirt to keep the boom in a position perpendicular to the water surface. In most cases it is either a chain (special or galvanized steel) or specially designed metal weights (lead, galvanized steel). In some designs water-filled tube act as skirt and ballast at the same time.

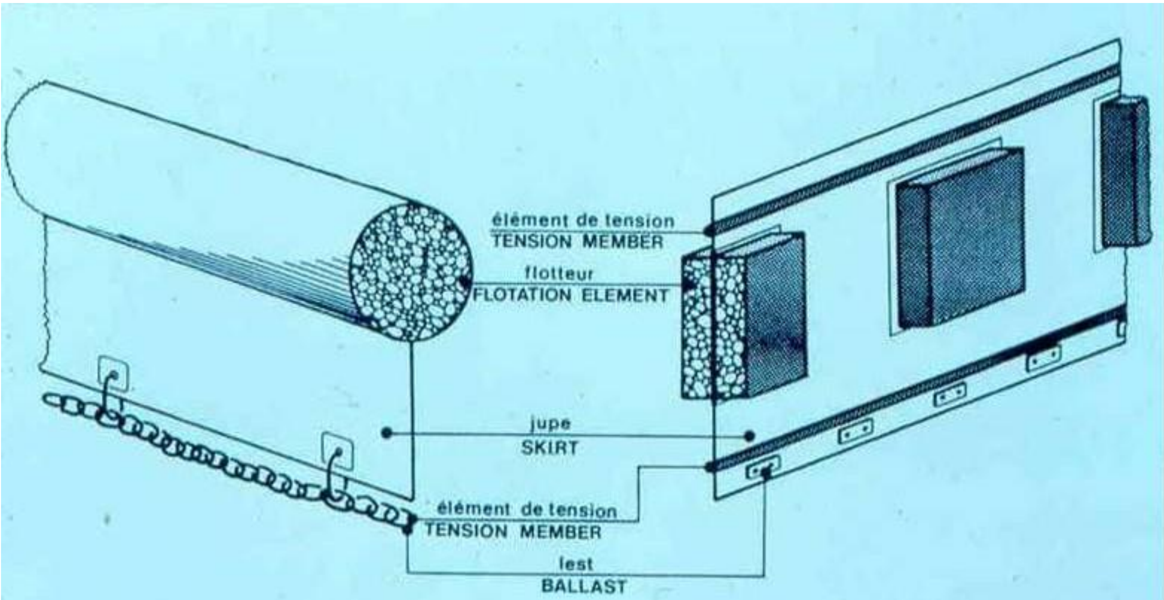
Longitudinal tension member provides tensile strength of the boom, bearing most of the load created by winds, waves and currents. It may be incorporated into the boom (nylon rope, webbing, wire cable) or attached to it as a separate tension member (stainless steel cable, rope).

Often the ballast chain doubles as a tension member. If the material used in boom manufacturing is strong enough i.e. has high tensile strength, additional tension members are not added.

Connectors are “devices attached to boom used for joining boom sections to one another or to other accessory devices”. As most booms are produced in sections of standard lengths, several of these may need to be connected to obtain the adequate length of boom for a specific purpose. This is done by connectors (couplings) fastened on both ends of each section. There is a design known as "standard connector", but different manufacturers often use different designs. The previously quoted ISO standard specifies a universal method for the joining of booms with dissimilar connectors through the use of a standard adaptor.

Properly designed booms also have **anchor points** built in or attached to the boom structure.

Figure 1: Basic boom construction elements



2.2 Types of booms

Most booms can be categorized as either “fence” booms or “curtain” booms.

Fence Booms have a vertical screen that extends above and below the water line and acts at the same time as both the freeboard and the skirt. A flotation element is either fastened to the "fence" or integrated into it to provide for the buoyancy of the boom. Ballast attached to the bottom of the screen keeps the boom in a position perpendicular to the water surface. Cross section of a fence boom is usually more flat than that of curtain type booms.

Curtain booms have a longitudinal flotation element, acting as a freeboard, and a curtain (skirt) suspended from it under the water line. Ballast is attached to the base of the skirt to keep it in a more or less vertical position. Tension member can either be integrated (built in) into the boom or attached to its bottom. The ballast chain may also act as a tension member.

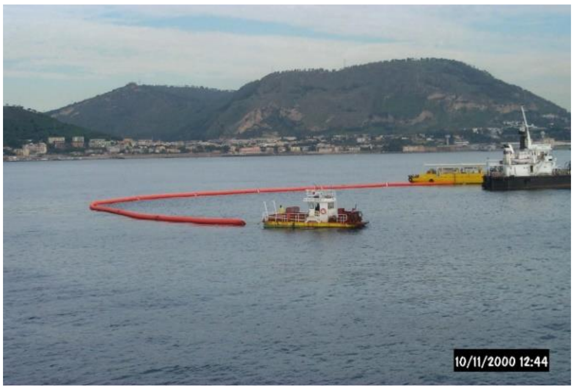
Characteristic designs of fence and curtain booms respectively are illustrated in **Figures 2 - 5**.

Figure 2: Fence boom being deployed from shore

Figure 3: A fence boom at sea

Figure 4: Moored air flotation curtain boom

Figure 5: Curtain boom being towed



2.3 Boom material behaviour

Booms can be flexible, semi-flexible and rigid.

- **Flexible booms** do not resist (or resist only slightly) to changing their shape in keeping with the sea (water) surface motion.
- **Semi-flexible booms** follow the shape of water surface with some resistance.
- **Rigid booms** keep their original shape regardless of the waves and water agitation.

Most commercial booms are semi-flexible, representing a reasonable compromise between the necessary elasticity of the boom assembly and its required strength.

2.4 Dimensions

The height of most commercially available booms ranges between 0.25 m and almost 3 m, but the height of commonly used booms is usually between 0.5 m and 1.5 m. In most designs the draught accounts for approximately 60% of the overall height and the freeboard for the other 40%.

Booms are usually manufactured in sections, whose length may vary between 5 and 500 m.

Booms are sometimes divided into categories according to the environment in which these are expected to be used. The table below shows the boom height corresponding to the maximum wave heights in three main categories of operating environment.

Table 1: Boom categories

OPERATING ENVIRONMENT	**SEA STATE** [Beaufort]	**SIGNIFICANT WAVE HEIGHT** [metre]	**BOOM HEIGHT** (**draft + freeboard**) [metre]
Calm water	1	< 0.3	0.25 – 0.55
Protected water	2	< 1	0.55 – 1.10
Open water	3 – 4	< 2	> 1.10

3. USE OF BOOMS

When used, booms can be either stationary (moored, anchored) or mobile (towed by one or more vessels): in containment and protective modes booms are stationary, while in collection (trawling) mode they are mobile.

3.1 Use of booms in containment mode

- Boom is positioned near the source of spillage in order to contain oil and prevent its spreading over the water surface.
- Boom is placed along the polluted shoreline with a view to preventing the contamination of the rest of the shore with e.g. oil either trapped on beaches, in small bays and coves, tidal pools, etc. or by oil washed off during shoreline clean-up operations.

Fig. 6: Boom positioned around a ship in port

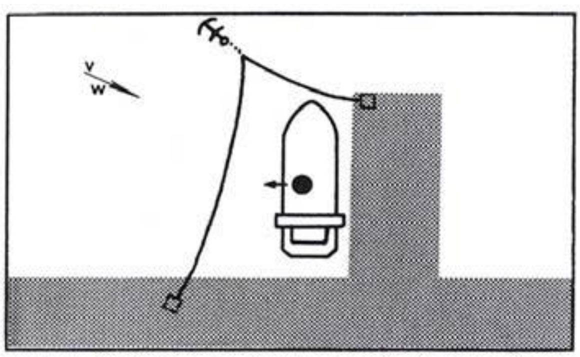
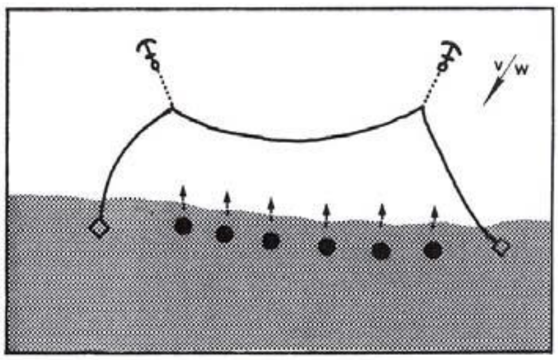


Figure 7: Boom placed around a section of oil contaminated beach



3.2 Use of booms in protective mode

Booms are used in protective mode when a sensitive (environmentally or economically) area needs to be protected from oil contamination. Sensitive areas or resources can also be protected by attempting to deflect oil from e.g. power plant, yacht marina, popular beach, etc. or from an area not convenient for oil collection, to a place which is less sensitive or/and more suitable for collecting it due to e.g. better access. The latter is sometimes called the deflective or diversionary mode of using booms.

Figure 8: Protection of a bird sanctuary area

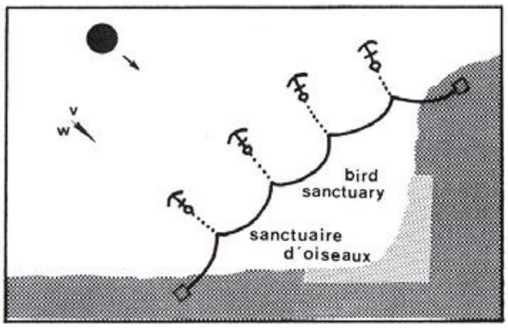


Figure 9: Protection of a touristic amenity

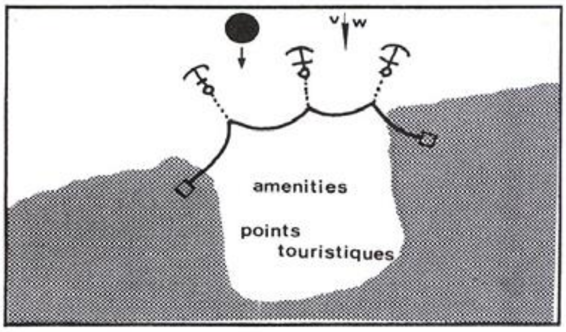


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Figure 10: Protection of a water intake

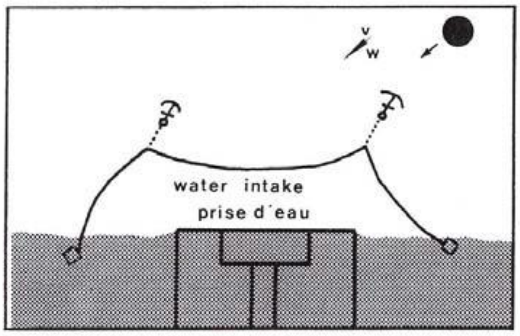


Figure 11: Protection of a marina

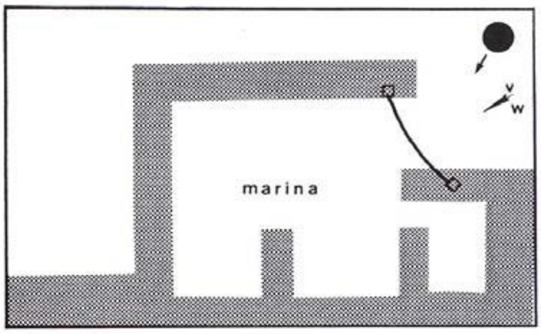
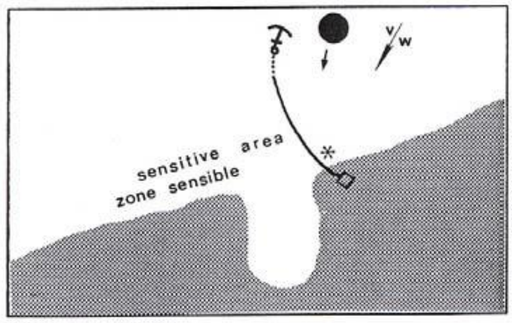
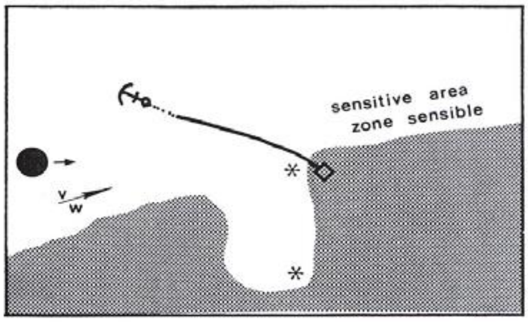


Figure 12: Deflection from a sensitive area towards a collection point

Figure 13:Deflection to a less sensitive area





3.3 Use of booms in collection mode (trawling)

Booms are used in collection mode to concentrate floating oil with a view to facilitating its removal from the sea surface. Oil is collected at sea using a combination of one, two or three vessels and a boom. Vessels must be able to maintain necessary navigational properties at very low speeds required for effective "trawling", and their crews must be well trained and drilled. Communication problems associated with the coordination of multi-vessel systems further complicate the use of this spill response method. Finally, collection of oil by trawling a boom is useless and ineffective if the rate of removal of collected oil does not correspond to the rate of its collection.

Figure 14: U - configuration (boom towed by two vessels and recovery unit deployed from a third one)

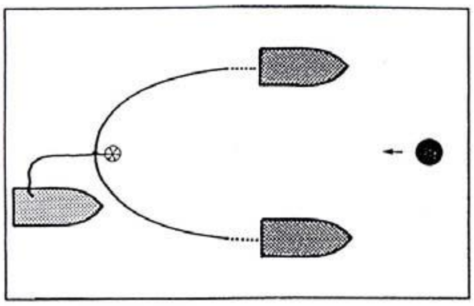


Figure 15: V - configuration (boom and recovery unit towed by two vessels - oil transferred to the third one

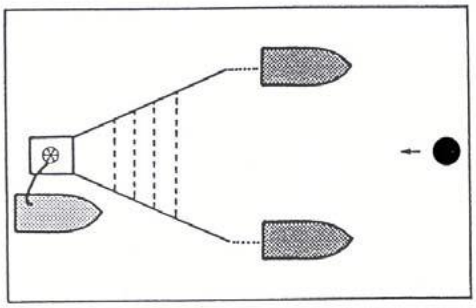


Figure 16: J - configuration (boom towed by two vessels, recovery unit deployed from one of these that also has oil storage capacity)

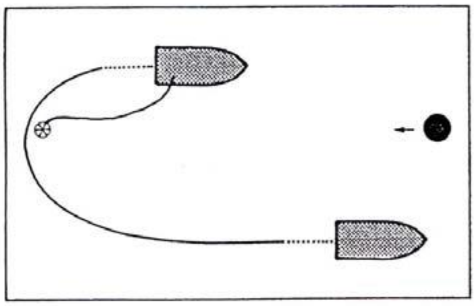
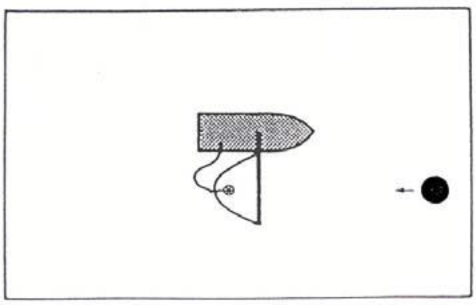


Figure 17: Single vessel system (boom and recovery device deployed from one vessel, generally with the help of a jib)



Decision on how a boom will be used and, if there is a choice, which type of boom will be used has to be taken considering a number of factors including:

- location and size of oil spill;
- meteorological conditions;
- oceanographic conditions;
- movement of the slick;
- shape of the shoreline and characteristics of the adjacent sea; and
- sensitivity of the area and priorities for protection.

4. GUIDELINES FOR THE USE OF BOOMS

The use of booms is limited by a number of factors, mainly of purely physical nature, and these limitations must be acknowledged in order to benefit from the use of booms and to protect them from damage or destruction. Most below guidelines are based on experiments and experience gained through (often incorrect) use of booms. Besides, it should be kept in mind that boom deployment is in most cases a hard and labour intensive job that may result in a failure. All such failures should be analysed, the mistakes identified, and avoided or corrected in the future.

Finally, it is important to remember that the effective use of booms depends on careful **planning** of their deployment, use and retrieval, and that personnel designated to handle booms in case of emergency has to be regularly trained through **training courses and practical exercises**.

4.1 Oil Retention Capability

Performance of a boom is affected by winds, waves and currents. Under their influence oil contained by a boom will tend to continue moving: it will try to escape either over the boom's freeboard ("splash-over") or underneath its skirt ("entrainment"). Wind and waves generally cause splash-over, while currents are responsible for entrainment and for "drainage" of oil.

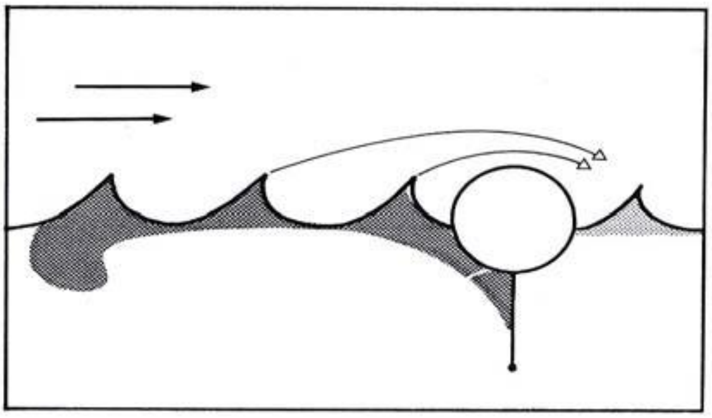
“Drainage” is a rare failure, similar to entrainment, and occurs when a small boom has collected too much oil so it flows down the boom’s face and escapes. “Submergence” occurs when a boom is exposed to a fast current, but is not common because entrainment occurs before the speed needed for submergence has been reached. Finally, “planing” is a common failure that occurs when strong currents and winds move in opposite directions and cause the flattening of boom on the water surface, and the loss of contained oil. All these phenomena can affect both moored and towed booms.

4.1.1 Splash-over

Short period waves (length to height ratio ≤ 4 and smaller), which are normally generated in restricted areas and are very common in the Adriatic region, may cause splash-over, while long waves (length to height ratio ≥ 8) should not influence the boom's performance if the boom is flexible enough.

- The only way to overcome the problem of splash-over is to increase the size of a boom (freeboard), that is, to use a larger boom if choppy conditions are expected in a certain area. Incidentally, deployment of a larger boom requires more time, personnel and additional equipment.
- The figures suggested by manufacturers concerning performance in waves and winds of their booms, besides sometimes being very “optimistic”, correspond rather to the limits of a boom's resistance and integrity than to its capacity to retain oil.

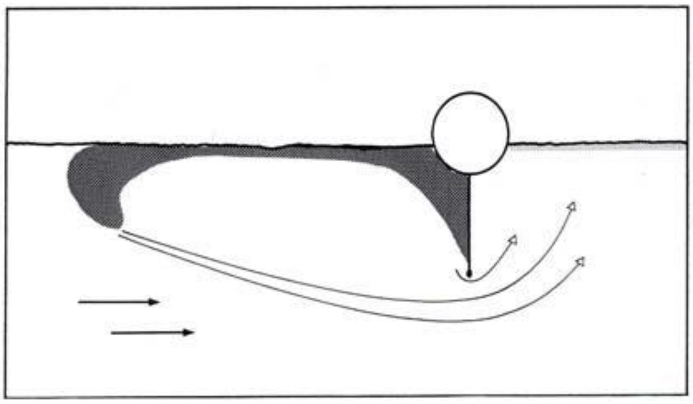
Figure 18: Splash-over



4.1.2 Entrainment

When current velocity at right angles to a boom exceeds 0.58-0.70 knots or 0.30-0.36 m/s ("critical velocity") oil starts to escape underneath the boom. This phenomenon is known as "entrainment" and cannot be avoided by increasing the depth of the skirt.

Figure 19: Entrainment



The performance of a boom in currents exceeding the "critical velocity" can be improved by positioning the boom at an acute angle to the flow. Relative velocity of the current is thus reduced and oil is retained by the boom and diverted alongside it. In order to avoid "entrainment" the angle between the boom and the current direction should satisfy the inequality sin $\alpha \le V_{cr} / V_{cu}$. ($V_{cr}$ = critical velocity; V_{cu} = current velocity; α = acute angle between the boom and current direction; V_{cr} and V_{cu} should be expressed in the same unit, usually knots or m/s).

Figure 20: Boom positioned at an acute angle to the flow

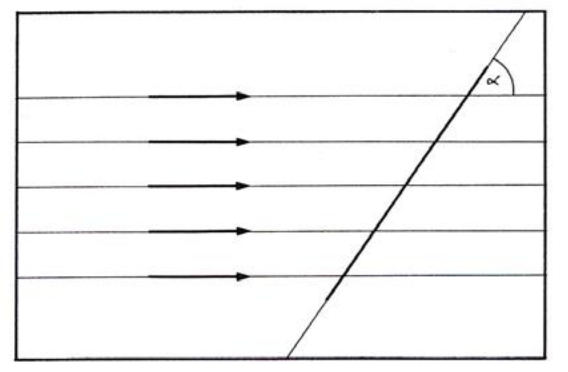


Table 2 shows angles between the boom and the current flow at which the boom should be positioned in order to avoid escaping of oil due to entrainment.

Table 2: Acute angles between the current and the boom as a function of the actual current velocity and the critical velocities

CURRENT VELOCITY [knots]	ANGLE BETWEEN THE BOOM AND THE CURRENT FLOW	
	CRITICAL VELOCITY 0.30 m/s (0.583 knots)	CRITICAL VELOCITY 0.36 m/s (0.7 knots)
1.0	36°	45°
1.5	23°	28°
2.0	17°	20°
2.5	13°	16°
3.0	11°	13°
3.5	10°	12°
4.0	8°	10°
4.5	7°	9°

Given figures are applicable only if water depth is 5 times the boom's draught or more, as in very shallow waters critical velocities are less than normal (0.6 to 0.7 knots) and accordingly given values for angles corresponding to certain current velocities are not correct.

4.2 Moored Booms

If booms are used in a stationary mode, they have to be moored. The number of mooring points, the type of mooring gear, weight of anchors etc., will depend on the forces of currents, winds and waves that these mooring points are expected to sustain, and on the size of the boom used. Although it is not possible to exactly calculate the forces exerted on a boom, their approximate values can be obtained using the following two formulae:

(1) Force exerted by current: $F_c = K \times A_s \times V_c^2$ (where F_c = force exerted by current [kg], K = proportionality constant, a value of which is usually K = 26 or less, A_s = subsurface area of a boom [m^2], and V_c = current velocity [knots]).

(2) Force exerted by wind: $F_w = K \times A_f \times (V_w / 40)^2$ (where F_w = Force exerted by wind [kg], K = proportionality constant, usually 26, A_f = freeboard area of a boom [m^2], and V_w = Wind velocity [knots]).

As a current of a certain velocity and a wind of approximately 40 times greater velocity create equal pressures, V_w is divided by 40 in formula (2).

If both current and wind are acting in the same direction (the worst case), their combined forces will be equal to their sum (3): $F = F_c + F_w$.

For example, on a boom 100 m long, with freeboard of 0.6 m and draught of 1.0 m, the current of 0.4 knots and a wind of 20 knots, blowing in the same direction as the current, will exert a force of:

(1) $F_c = 26 \times (100 \times 1) \times (0.4)^2 = 416$ kg
(2) $F_w = 26 \times (100 \times 0.6) \times (20/40)^2 = 390$ kg
(3) $F = 416 + 390 = 806$ kg

Since more or less permanent position of a boom and correct angle of its deployment has to be maintained in order to ensure that a boom is effective, either anchors or concrete blocks are used to keep a boom in place. Recommended anchors include the fisherman's type anchor (for rocky bottoms) or the “Danforth” type (for sand, gravel, mud and clay).

Figure 21: Fisherman's type anchor

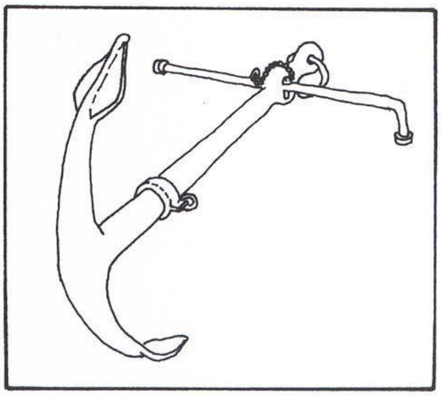


Figure 22: “Danforth” type anchor

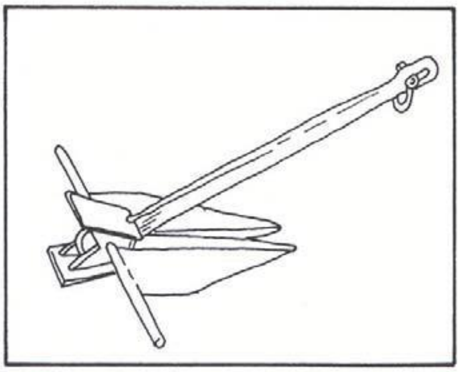


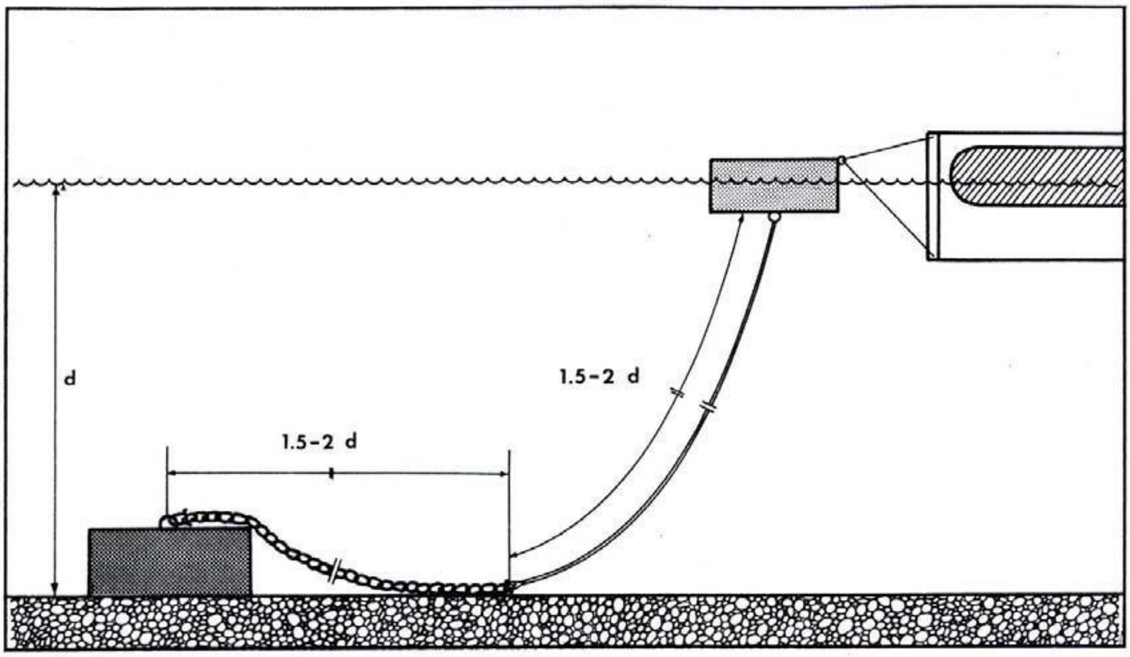
Table 3: Holding powers on different sea-beds of "Danforth" type anchors

ANCHOR WEIGHT [kg]	**HOLDING POWER** [kg]		
	MUD	**SAND / GRAVEL**	**CLAY**
15	200	250	300
25	350	400	500
35	600	700	700

In order to compensate for wave movement, swell and tides, a mooring line should be 3-4 times the depth of water at high tide. A section of heavy chain should be attached between the anchor (or a concrete block) and the mooring line in order to improve the holding power of the anchor.

In order to avoid submersion of the boom, the boom should first be attached to a buoy and the buoy to a mooring line.

Figure 23: A well-prepared mooring arrangement



If the boom is anchored to a shoreline, a certain length of boom has to be left lying on the ground. If possible, boom should be attached in a relatively smooth place, covered with sand or gravel, as rough surfaces (boulders, rocks) will damage the boom. On rocky shores, bags filled with sand should be used to smooth down the surface where the boom is attached.

If the boom is planned to be to be attached (either permanently or only in case of emergency) to a fixed place on a sea wall or a mole in a port, harbour or marina, it is advisable to prepare a watertight mooring arrangement in advance.

4.3 Towed Booms

Collection of oil in open seas is sometimes possible by using towed booms. This operation is very often restricted by adverse meteorological conditions or sea state. On the other hand, if conditions permit, it can be a very efficient way of eliminating the pollution risk of coastal resources.

Any offshore boom with sufficient tensile strength may be used for oil sweeping.

All estimates regarding escaping velocities of oil and forces exerted on a boom (paragraphs 4.1 and 4.2) apply to towed boom systems too, only the most relevant factor will now be towing speed rather than current velocity.

The successful outcome of a boom towing operation will greatly depend on the selection of towing vessels: these should have sufficient power and maintain their manoeuvrability under very low speeds (0.5 to 1.0 knots). It is assessed that 1 HP of an inboard engine is equivalent to 20 kg of pulling force. If two vessels are used, each should have approximately half of the required power. Twin propulsion vessels with variable pitch propellers and bow and stern thrusters are more likely to have necessary manoeuvrability than single propeller vessels.

Towing lines must be sufficiently long (at least 50 metres) to compensate for sudden stresses.

Since oil escapes from a boom in U - formation more easily than from a V - shaped system, the two sides of boom can be connected with thin wire bridles at regular intervals (see Figure 15) in order to maintain a V - formation.

Oil will not escape from a towed boom only if relative towing speed (relative velocity between towed boom and the opposing current) is less than critical velocity (0.5 to 0.7 knots), and if oil is removed from the collection point (at the apex of used formation) at the rate corresponding to the collection rate.

Relative velocity of the whole system in a very strong current can be maintained below the critical velocity by letting the towing vessels to drift sternwards.

Particular attention has to be paid to communications among vessels, because poor coordination may result in failure of the operation and in damage of equipment (booms) used.

SKIMMERS AND THEIR USE FOR OIL RECOVERY AT SEA

1. INTRODUCTION

Elimination of oil from the sea (water) surface on which it has been spilled is the main purpose of oil spill response activities, while its physical removal from the sea surface is generally the preferred method of response, as no additional substances are introduced into the marine environment and less oil is irreversibly lost.

Oil can be removed from the sea surface using either non-specific, manual and mechanical means, or purposely built equipment. This lessons provides information on physical removal of oil from the sea surface, using **specifically designed equipment**.

2. DEFINITION

The common name of various oil recovery devices is "skimmer". It is defined as any mechanical device specifically designed for the removal of oil (or oil/water mixture) from the water (sea) surface without altering its physical and/or chemical characteristics.

This definition comprises numerous designs and working principles utilised in skimmers' construction.

In most spill situations skimmers are used together with booms, but it is also possible to use them independently. It can be said that removal of oil, although closely linked, is not conditioned by the use of booms, in distinction from oil containment (by booms) which is effective only if collected oil is successively removed.

3. DESIGN

Commercially available skimmers are based on a wide variety of working principles applied in their construction. The principle used for removal of oil up from the water surface offers a possibility to categorize skimmers into two main groups: **mechanical** and **oleophilic** skimmers.

In each skimmer three main elements can be distinguished:

- oil recovery element;
- flotation; and
- oil transfer system.

Oil recovery element removes oil from the sea surface, flotation element enables a skimmer to float on the sea surface, and transfer system evacuates recovered oil to a storage container. Transfer system (pump, hoses, couplings) is either incorporated into the skimmer, or comes as a separate unit, i.e., the oil recovery element can be attached to an independent, external pump.

3.1 Mechanical skimmers

Mechanical skimmers comprise all the devices that are based on fluid flow properties of oils and oil/water mixtures, and on difference in density between oil and water. Different working principles applied to make use of the above mentioned physical properties of oils further define the **most common** (N.B. there are others!) **subcategories** of mechanical skimmers:

- **direct suction/vacuum skimmers –** the skimming head or suction head, manually held on the water surface or floating on it, directly sucks the oil.
- **weir skimmers –** weir positioned slightly under the water surface enables the flow of oil into the sump of the skimmer, from where it is pumped to storage.
- **conveyor belt skimmers** - an inclined, non-oleophilic, conveyor belt transports oil to the collection area (sump). In some skimmers of this type oil is transported **directly upwards** from the sea surface to the collection sump, and in the others it is first forced **beneath the water surface** (submerged) and then upwards, towards the sump.

Figure 1: Operating principle and an example of a direct suction / vacuum skimmer

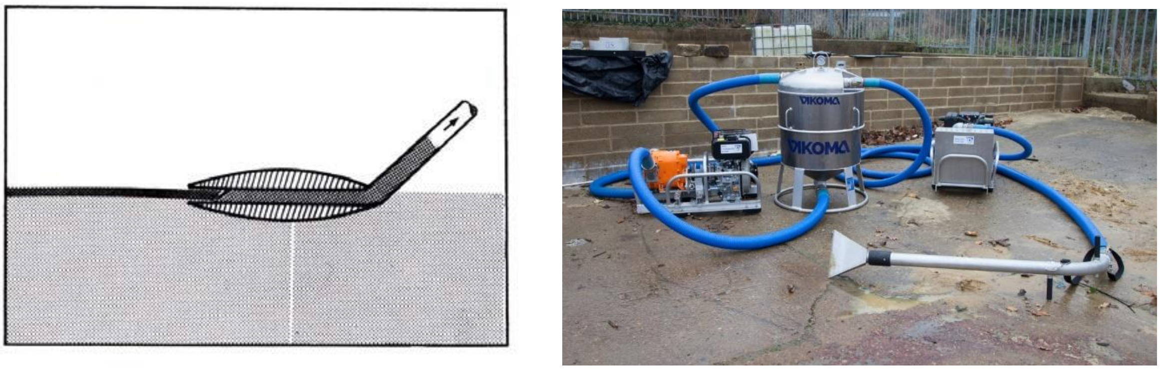


Figure 2. Operating principle and an example of a weir skimmer

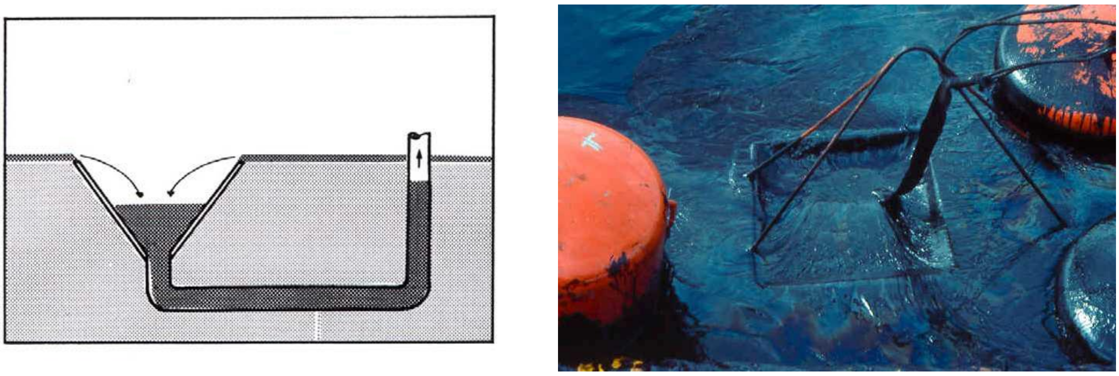
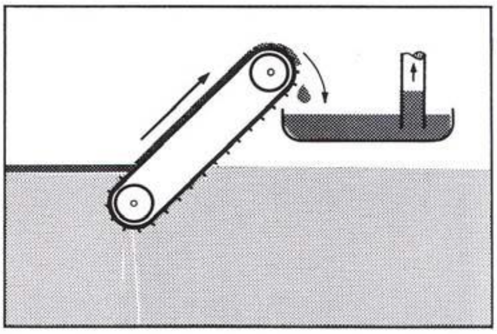


Figure 3. Operating principle and an example of a conveyor belt skimmer



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3.2 Oleophilic skimmers

Oil recovery principal of the second main category of skimmers is based on the characteristics of certain materials to have greater affinity for oil than for water. Such materials are known as “oleophilic” and include e.g. stainless steel, aluminium and some plastic materials (e.g. PVC). Consequently, skimmers that make use of this characteristic are called **oleophilic skimmers**. In accordance with the shape of the moving surface to which the oil adheres, the **most common** (N.B. there are others!) **subcategories** are.

- **drum** type **skimmers** – oil adheres to a rotating, horizontally positioned and partly submerged drum coated with some kind of oleophilic material. Rotation of the drum carries the oil towards the scrapers that remove it from the drum surface and deposit it into a sump, from where it is pumped to a storage container.

- **disc skimmers** – have a variable number of rotating discs made of an oleophilic material. Oil that sticks to submerged disc surface is wiped by scrapers which direct it into a sump to be pumped out.

- **brush skimmers** – oil clings to a series of partly submerged, continuously rotating brushes that transport oil to brush cleaners, from where it is pumped to a storage.

- **<u>oleophilic rope skimmers</u>** – oil adheres to a floating oleophilic rope that either revolves between two pulleys (one drive pulley and another "tail" pulley), or is suspended above the water surface from a vessel, or is trailed on the water surface by a vessel. In the first two types the rope is continuously passing through a set of squeeze rollers that remove adhered oil, while in the third one the rope is periodically wrung by a similar device after being saturated with oil. Collected oil is subsequently pumped to a storage.

Figure 4: Operating principle and an example of an <u>oleophilic drum</u> skimmer

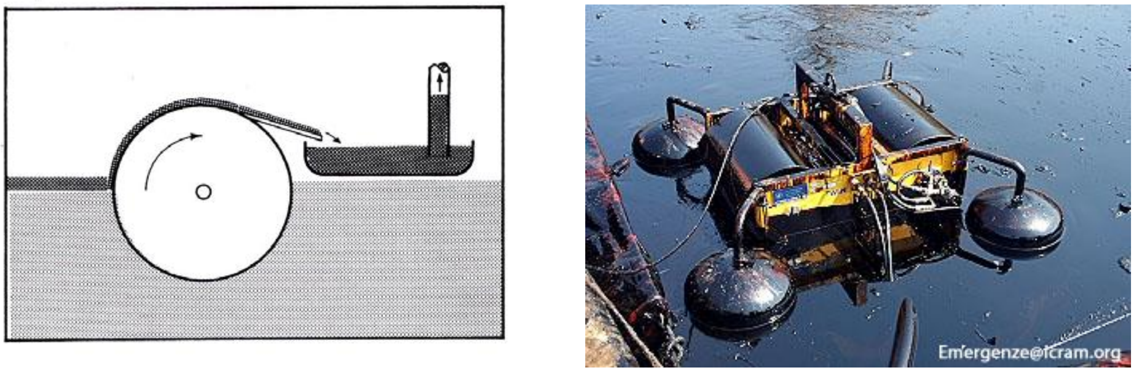


Figure 5: Operating principle and an example of an <u>oleophilic disk</u> skimmer

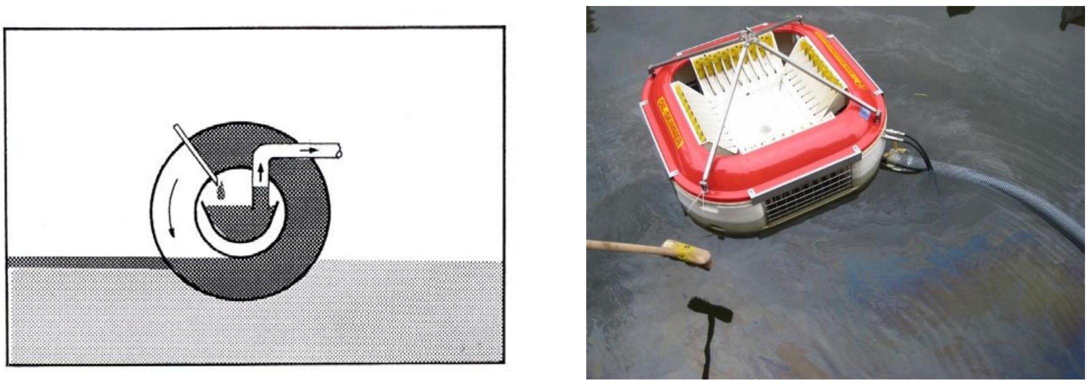


Figure 6: Operating principle and an example of an <u>oleophilic brush</u> skimmer

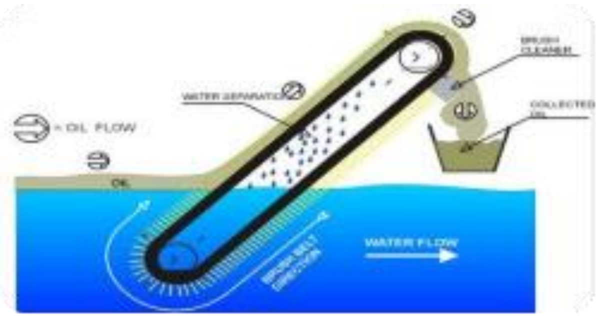
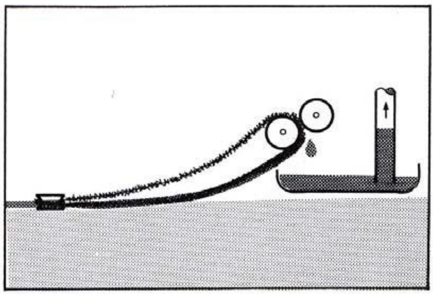


Figure 7: Operating principle and an example of an <u>oleophilic rope mop</u> skimmer



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Several manufacturers offer skimmers with **interchangeable** types of recovery unit (e.g. brush, disc and drum), while in some other designs skimmer has a **combination** of e.g. disc and drum recovery units built in.

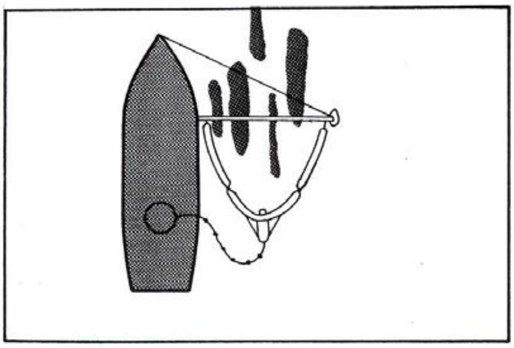
Oleophilic belts are also used as recovery units in some designs, However, these are more often used in oily water separators than in response to oil spills at sea.

3.3 Skimming barriers

Skimming barriers are recovery devices that comprise a section of boom with an integrated skimming device or a separate skimmer coupled with the boom. They are intended for use in the open sea or in polluted zones that are big enough to allow larger size vessels to navigate.

Skimming barriers have considerably high encounter rates, can operate in medium seas and are easy to deploy, but their efficiency is limited by the manoeuvrability of vessels from which they are deployed. Low operational speed required for their use (approx. 1.0 to 1.5 knots) makes critical the selection of suitable vessels. Small coastal tankers, dredgers, tugs and supply vessels are the most likely types of vessels to be used for deployment of skimming barriers.

Figure 8: Skimming barrier with incorporated skimming device deployed from a single vessel



3.4 Sweeping arms

Sweeping arms are rigid floating barriers with built in skimmer or oil pumping system, that are placed and attached close to a ship at an angle. As the ship moves forward through an oil slick, oil is guided by the hull of the ship and the sweeping arm towards its collection chamber from where the oil is pumped into the ship's storage tanks. In some designs the level of the entrance to the collection chamber can be hydraulically adjusted in order to increase the oil contents of the collected oil and water mixture.

Like skimming barriers, sweeping arms are designed for use with larger vessels (e.g. small coastal tankers, dredgers, supply vessels etc.) that have sufficient oil storage capacity on board to allow for a reasonably long period of operation at sea without the need to return to the port to discharge the collected oil.

Figure 9: An oil recovery vessel with sweeping arms attached to each of its sides

4. USE OF SKIMMERS AND THEIR LIMITATIONS

Skimmers can be used for oil recovery **offshore** (in open seas) and for **inshore** oil recovery (in coastal areas, ports, etc.). The main difference between these two options is the logistic support required for each of them rather than with the type of equipment used.

Most types of skimmers can be used either offshore or inshore (excluding skimming barriers and sweeping arms that designed for use in open waters), however, where and how skimmers will be used, as well as the selection of the adequate type of skimmer, depend on:

- characteristics of spilled oil;
- size of the spill;
- movements of the sea surface (waves, currents)
- availability of skilled personnel, energy supply and auxiliary equipment (e.g. cranes)
- availability of facilities for maintenance and repairs of equipment.

For obvious reasons it is not possible to use large skimmers in very shallow waters and places with restricted approach, simply because of their dimensions and weight, while the use of small, light-weight, portable devices is not possible offshore.

4.1 Performance of a skimmer

Successful mechanical recovery of spilled oil is limited by adverse weather conditions, oil viscosity and the effects of waves and currents. The amount of oil a skimmer can recover over a period of time is called the **encounter rate** (product of the swath width of a skimmer and the speed of skimmer's advance in relation to oil), and it depends on the degree of spreading and fragmentation of the oil slick.

Test performance criteria (recovery efficiency, throughput efficiency, and oil recovery rate) provide a useful indication of potential skimmer performance, however the encounter rate remains the main **limiting factor** of the actual performance of a skimmer.

Skimmers are usually tested in experimental tanks, under controlled conditions. The above mentioned, most common criteria are described as follows:

- **Recovery efficiency** (**RE**) is the percentage of oil in the fluid recovered by the skimmer. RE = oil recovered / total fluid recovered x 100 [%]. It the measurement of the selectivity with which skimmer recovers oil in preference to water.

- **Throughput efficiency** (**TE**) is the percentage of oil entering the skimmer that is recovered: TE = (oil recovered / oil encountered) x 100 [%]. It highlights the losses that occur from the boom and the skimmer itself. TE usually decreases when the operating speed increases and sea state worsens.

- **Oil recovery rate** (**ORR**) is volume of oil recovered per unit time. ORR = volume oil recovered / unit of time [m^3/h].

Unfortunately, the maximum pump capacity adjusted for typical oil viscosity and head loss ("**nameplate rate**") is very often taken as the only indicator of a skimmer's capacity. Albeit being important, the nameplate rate is only one of the elements (others are RE, ORR, and TE) that need to be considered in order to estimate the rate at which a skimmer is actually capable to recover oil, and how much free water will be collected together with oil.

Main characteristic of different types of mechanical and olephilic skimmers are summarized in **Tables 1 and 2** respectively. These have been modified from ITOPF's Technical Information Paper 05.

Table 1: Characteristics of mechanical skimmers

SKIMMER TYPE	RECOVERY RATE	OIL TYPES	SEA STATE	DEBRIS	ANCILLARIES
SUCTION / VACUUM	Dependent upon vacuum pump.	Most effective in low to medium viscosity oils.	Used in calm waters. Small waves cause collection of excessive water. Become more selective with the addition of weir.	Can be clogged by debris.	Vacuum trucks or trailers are generally self-contained, with necessary power supply, pump and storage.
WEIR	Dependent upon pump capacity, oil type etc. Can be significant.	Effective in light to heavy oils. Very heavy oils may not flow to the weir.	Highly selective in calm waters with little entrained water. In choppy waters can be easily swamped with increase in entrained water.	Can be clogged by debris, although some pumps can cope with small debris.	Separate power pack, hydraulic and discharge hoses, pump and suitable storage. Some skimmers have built-in pumps.
BELT	Low to medium	Most effective in heavy oils.	Can be highly selective with little entrained water. Operates well in choppy waters	Effective in small debris. Can be clogged by large debris.	Can deliver oil directly to storage at the top of the belt.

Table 2: Characteristics of oleophilic skimmers

SKIMMER TYPE	RECOVERY RATE	OIL TYPES	SEA STATE	DEBRIS	ANCILLARIES
DISC	Dependent on number and size of discs.	Most effective in medium viscosity oils.	Highly selective in low waves/current. In choppy waters can be swamped	Can be clogged by debris.	Separate power pack, hydraulic and discharge hoses, pump and suitable storage.
BRUSH	Generally mid-range. Throughput depends on number and velocity of brushes.	Different brush sizes for light, medium and heavy oils.	Relatively little free or entrained water collected. Some designs can operate in choppy waters, others could be swamped in waves.	Effective in small debris, can be clogged by large debris.	Separate power pack, hydraulic and discharge hoses, pump and suitable storage.
DRUM	Dependent on number and size of drums.	Most effective in medium viscosity oils.	Highly selective in low waves/current. In choppy waters can be swamped	Can be clogged by debris.	Separate power pack, hydraulic and discharge hoses, pump and suitable storage.
SKIMMER TYPE	**RECOVERY RATE**	**OIL TYPES**	**SEA STATE**	**DEBRIS**	**ANCILLARIES**
ROPE MOP	Dependent on number and velocity of ropes. Generally low throughput.	Most effective in medium viscosity oils, although can be effective in heavy oils.	Very little free or no entrained water. Can operate in choppy waters.	Able to tolerate significant debris.	Smaller units have built in power supply, larger units need separate ancillaries.

The characteristics of different types of skimmers quoted in the above tables are based on operational experience, but also on theoretical and technical knowledge resulting from both calculations and/or laboratory tests.

In any case, these tables only prove that such a thing as "universal" skimmer does not exist: each particular type of skimmer has its own advantages in certain spill situations and its drawbacks in others.

4.2 Oil recovery in open seas

Offshore oil recovery requires **careful planning** based on encounter and recovery rates of skimmers, capacities of the transfer pumps, capacities of the available tanks (on board vessel or floating flexible tanks), distances from the nearest port(s), speeds of vessels, etc.

Use of skimmers in the open sea (deployed from a vessel) can be restricted even in the most favourable conditions by **insufficient storage capacity** on board vessel from which the skimmer is deployed, thus necessitating a periodical discharge of oil to the shore. Using a (coastal) tanker to transfer to the shore the oil and water mixture collected at sea may help to overcome this limitation.

However, the main limitations for use of skimmers in the open seas are **weather conditions and sea state** that are usually less favourable in the open sea than closer to the shore.

In major past accidents only a relatively small part of spilled oil has been recovered from the open sea, because of the above outlined reasons, but also due to common difficulties in locating offshore spills and to the fact that oil recovery is difficult, if not impossible, during periods of poor visibility and during night. Nevertheless, no efforts should be spared in attempts to recover as much oil as possible while it floats offshore, as the environmental and economic damages are likely to be less pronounced in the open sea than near or on shore.

4.2 Oil Recovery in Coastal Areas

If only a **small volume** of oil has to be recovered, the use of more selective recovery devices is recommended.

On the other hand, if the **volume** of pollutant is **bigger**, the use of heavier equipment with higher recovery rates may be preferred, bearing in mind that the **draught of the skimmer** should be less than the depth of the sea.

The **type of spilled oil** will automatically exclude the possible use of skimmers that cannot cope with it. **Debris** mixed with oil (likely case near the shore) may reduce the effectiveness of certain skimmers, and its continual removal has to be provided for.

Topography of the recovery site on shore will strongly influence oil recovery operations in adjacent inshore waters. **Shoreline inaccessibility from land** will necessitate either the use of boats for deployment of skimmers or the use of self-propelled recovery vessels. Careful planning of the transfer of recovered pollutants to shore is therefore necessary, taking into consideration the same factors as those indicated for recovery at open sea. On the other hand, if the recovery site is accessible from land, the use of direct suction/vacuum skimmers in conjunction with vacuum trucks, or other types of skimmers that can be deployed from land would be a recommended option. Moreover, it may be possible to arrange for **temporary storage** of recovered oil in an immediate vicinity of the recovery site.

The **sea depth** near the shore will obviously limit the choice of equipment to those skimmers that have draught smaller than minimal sea depth at low tide.

The possibility of **boom(s) deployment** at envisaged recovery site also has to be evaluated, as containment will increase the thickness of oil and thus the recovery rates of skimmers. Conversely, if containment is impracticable the entire recovery operation may be ineffective.

As the efficiency of the majority of skimmers tends to be low in **waves higher than 0.8-1.0 m**, and only a few are claimed to be operational in waves of up to 1.0-1.5 m, both swell and, in particular, short waves of 0.8 m are likely to render oil recovery difficult, if not impossible. Choppy sea, common in the coastal areas of the Adriatic, is likely to influence the performance of skimmers much more than a long, regular swell.

Currents can sometimes increase the efficiency of skimmers in coastal waters by concentrating oil around the skimmer. On the contrary, if the current velocity is too high, oil can swamp the skimmer or pass under it. Therefore, it is necessary to establish the **direction and speed of coastal currents** prior to selecting the most suitable oil recovery site(s).

Finally, it is necessary to continuously monitor the performance of the skimmer in order to ensure is optimum efficiency, as well as the logistics of pumping, storing and disposing of recovered oil in order to keep delays in recovery to a minimum.

USE OF SORBENTS MATERIALS IN OIL SPILL RESPONSE

1 INTRODUCTION

Sorbents are products that fix liquid oil either by **absorption** (soaking, incorporating oil into the structure of a material) or **adsorption** (attracting and holding oil molecules to the surface of a material). Most products used in oil spill response are adsorbents, while absorbents are more often used in response to chemical spills, i.e. spills of HNS (hazardous and noxious substances) other than oil. In order to avoid confusion, the generic term “**sorbents**” is general used in the context of oil spill response. A sorbent should be both **oleophilic** (i.e. attract and absorb or adsorb oil) and **hydrophobic** (repel water).

The use of sorbents to fix and agglomerate spilled oil or other pollutants, and to facilitate their removal, is an efficient technique widely applied on shore, near shore, in sheltered sea areas and in ports to recover small contaminations, in particular in final stages of shoreline clean-up. Sorbents are generally not well adapted for use in the open sea, and are therefore rarely used away from shore. Cheap and immediately available natural materials can be used as sorbents, although synthetic sorbents are more effective as far as oil recovery rate is concerned.

2. MATERIAL AND FORM OF SORBENTS

Sorbents can be of both organic and inorganic origin, natural or synthetic products. They are either treated **inorganic** (**mineral**) materials (e.g. vermiculite, perlite, pumice), or treated materials of **organic** origin, either **vegetal** (e.g. straw, sawdust, wood shavings, ground corn cobs, cellulose fibres) or **animal** (e.g. chicken feathers, wool, human hair), or **synthetic** materials (e.g. polypropylene and other polymers).

Based on the form in which sorbents are marketed, they can be divided into:

- **loose bulk** material (e.g. granules, fibres,);
- sorbent material **enclosed in a mesh** (net), shaped as e.g. pillows, socks, booms;
- **continuous** materials shaped as e.g. mats, sheets, rolls, booms;
- **loose fibres** joint to form e.g. sweeps, snares (“pom-poms”).

2.1 Loose bulk sorbents

Loose bulk sorbents come as powders, fine particles and short mineral or organic fibres. These are often industrial wastes either raw or treated and conditioned to be used as sorbents. Loose sorbents can be spread manually and mechanically, by an air blower or a hydro-ejector. Wearing masks and goggles is essential in order to protect the eyes and respiratory organs of personnel applying loose bulk sorbents.

Their buoyance is usually good (spec. gravity 0.04-0.3), and their sorption capacity (by volume for light oil) ranges between 0.5 and 1.2.

2.2 Loose bulk sorbent material enclosed in mesh (nets)

Any loose sorbent material can be enclosed (packed) in a mesh or net. Various shapes od enclosed sorbents exist, but those shaped as booms ("socks") are the most common. These should not be confused with the *continuous* sorbent booms. Despite being called "booms" they are not efficient in containment of oil except in very calm conditions with no waves or currents.

Their use is limited to ports and sheltered areas, as well as to use in shoreline clean-up operations where they can be very useful for preventing oil to escape from a boom or for collecting any leaking oil downstream from a recovery site.

2.3 Continuous sorbent materials

Continuous sorbent materials are available as rags, pillows/pads, sheets/blankets, rolls/ booms ("sausages"). These are produced from synthetic fabric: polypropylene is the most common one, but polyurethane, nylon and polyethylene are also used. Continuous cylindrical sorbents shaped as booms are more homogeneous than enclosed sorbents in the form of boom, but have a lower surface area to volume ratio and oil does not penetrate deep into the boom. Continuous flat sorbents (sheets, pads, mats) have high surface area to volume ratio.

Continuous sorbent materials are not well suited to viscous oils.

2.4 Loose fibres

Loose fibre sorbents, made out of thread-like strands of polypropylene attached together to form snares ("pom-poms"), bundles or hanks, can recover heavier and more viscous oils than other types of sorbents. An effective sweep or boom for recovery of viscous oil can be obtained by attaching several snares to a rope.

The main use of snares is for manually collecting thick, viscous oil found in crevices or in small pools on shore.

3. USE OF SORBENTS

Sorbents are mainly used in nearshore or onshore clean-up operations when other recovery methods either give poor results or are inapplicable. This refers in particular to the recovery of oil floating so close to the shoreline that booms and skimmers cannot be used, and to collecting oil flushed into the sea during shoreline clean-up operations.

The use of sorbents at sea gives rise to various technical and logistic problems, and their use as a primary response tool for spills at sea, in particular bigger ones, **is not recommended**. The treatment of a certain volume of oil necessitates the use of at least an equivalent volume of sorbent, which hence needs to be supplied, stocked, transported to the zone of incident, applied, recovered after mixing with oil and then disposed of. All these problems render the use of sorbents limited to small or medium size spills in sheltered areas near the shore.

If loose bulk sorbents are nevertheless used at sea, the agglomerated oil can be recovered relatively effectively by a special surface trawling net system with detachable end (bag) that is towed by two vessels. The bag (end of the trawl net) is removed once filled and replaced by an empty one, while the full bag can be towed away by another vessel.

In addition to their direct use as spill response tools, sorbents are extensively used for clean-up and decontamination of personnel and equipment on or near the clean-up sites, and to line and protect pathways in clean-up area.

In general, sorbents can be best used in oil spill response to:

- assist oil containment and recovery in case of small spills on water or on land, in particular in coastal areas, ports, harbours, estuaries and on rivers;
- assist in oil spill containment in association with standard booms, by providing and improving watertight seal;
- facilitate protection of areas that are difficult to clean (marshes, reed beds, shores made of broken stones, etc.);
- fix and recover floating oil in stagnant waters;
- collect leaking oil below recovery worksites during shoreline clean-up;
- absorb effluents from clean-up of rocks and man-made structures; and
- absorb (filter) suspended oil near water intakes.

The table below highlights the key benefits and disadvantages of available types sorbent materials. It was reproduced, with minor changes, from the ITOPF's Technical Information Paper 08.

Table 1: Benefits and disadvantages of various types of sorbent materials

	MATERIAL	BENEFITS	DISADVANTAGES
BULK	• **Organic**: e.g. straw, bark, sawdust, wool, chicken feathers, etc. • **Inorganic**: e.g. vermiculite, pumice • **Synthetic**: primarily polypropylene	• Often naturally abundant or widely available as waste by-products of industrial processes. • Can be low cost. • Can be used to protect wildlife at haul-out sites.	• Difficult to control, can be spread by the wind. • Difficult to retrieve. • Oil and sorbent mixture can be difficult to pump. • Disposal of oil sorbent mixture more limited than oil alone.
ENCLOSED IN MESH OR NET	• All of the above materials can be enclosed in mesh or nets.	• More straightforward to deploy and retrieve • Enclosed boom has a greater surface area than continuous boom.	• Structural strength limited to that of the mesh or net. • Organic booms can rapidly become saturated and sink. Oil retention is limited.
CONTINUOUS	• **Synthetic**: primarily polypropylene.	• Long term storage • Relatively straightforward to deploy and retrieve • High oil recovery ratio possible if used to full capacity.	• Limited efficiency for weathered and more viscous oils. • Do not readily decompose thus limiting disposal options.
LOOSE FIBRES	• **Synthetic**: primarily polypropylene.	• Effective on weathered and more viscous oils.	• Less effective on fresh light and medium oils.

4. FACTORS AFFECTING THE EFFECTIVENESS OF SORBENTS

In general, the information concerning effectiveness of sorbents should be requested from their **manufacturers**, in particular those concerning the following characteristics having an influence on the effectiveness:

Buoyancy: sorbents must have and retain high buoyancy when saturated with oil and water, in order to be used effectively on floating oil. Some light sorbent materials may remain on top of viscous oils and required mixing to ensure saturation with oil.

Saturation: the level of saturation of a sorbent is generally difficult to judge. Some can quickly become saturated with oil and start releasing it, therefore their quick removal is essential. Sorbent sheets are saturated quickly and their use is thus limited to small scale incidents requiring recovery of small volume of oil. On the other hand, incomplete saturation will lead to the wastage of sorbent material.

Oil retention: is one of the main aspects of sorbents' performance. Some sorbents start releasing oil if not retrieved quickly, while some others start releasing it when lifted from the water. Besides the characteristics of the sorbent material itself, the rate of release directly depends on the viscosity of oil (light, less viscous oils are released more rapidly).

Strength and durability: it is important that sorbent material is durable, in particular if sorbents are left in place where they had been used for a certain time before being recovered. In such cases, sorbent may start to degrade rapidly due to wave action and contact with rocks. Strength of sorbent booms made of enclosed loose material depends on the strength of the net (mesh). If the netting (fabric) is damaged in adverse weather conditions, sorbent material may be lost and cause a secondary contamination.

SHORELINE CLEAN-UP

1. INTRODUCTION

Despite all efforts to recover as much oil as possible at sea, it is most likely that part of the spilled oil will reach the shoreline, in particular if the release of oil has occurred not far from shore. Past experience shows that almost all spills that occurred relatively close to the shores result in a more or less severe coating by oil of beaches, rocks or any other coastal formations.

The decision to clean the affected shoreline, and to what extent, will depend on:

- the possibility to reduce environmentally detrimental effects of stranded oil;
- the probability that stranded oil may subsequently re-contaminate another, sometimes more sensitive, part of the coastline;
- the necessity to use the coastal zone for commercial purposes (fisheries, tourism, industry, etc ...);
- the feasibility of clean-up operations.

The method of shoreline clean-up will be determined by another group of factors including:

- type and quantity of stranded oil;
- type of affected coastline;
- period of the year;
- meteorological conditions;
- accessibility from land or sea and load bearing capacity of the contaminated area;
- availability of personnel and materials.

Both groups of factors have to be considered in the relevant **contingency plan**. The first group will determine **priorities for protection** and clean-up, while the second will give guidelines for **selection of appropriate clean-up method**. The most efficient way to achieve both of these goals is to present the entire coastal zone in so called **sensitivity maps**, in either electronic or paper format. Such maps indicate the nature of the coastline and its sensitivity to oil, natural (wildlife types, their habitats, areas of ecological interest, fish spawning areas, etc.) and economic resources (viz. fishing areas, fish farms, shell fish beds, industrial installations, amenity beaches, yacht marinas, harbours, etc.), accessibility of each sector of the shore, possible landing sites and temporary storage sites for collected oiled material, etc.

Well prepared sensitivity maps facilitate the decision making process (i.e. the selection of appropriate clean-up methods and extent of clean-up efforts), since the only new elements that need to be taken into consideration are data specific for each particular spill situation (i.e. the nature and quantity of oil, weather and sea conditions, period of the year, etc.). In the absence of sensitivity maps decision makers should rely on advice from local population and authorities, as well as scientists familiar with the affected area.

2. GENERAL CONSIDERATIONS

2.1 Oiled shoreline assessment

The selection of the appropriate clean-up method should be preceded by a ground survey of the affected area, known as **oiled shoreline assessment**, whose objective is to provide (a) rapid but exhaustive overview of shoreline oiling conditions, and (b) accurate, systematic, georeferenced information, using standardized methods and terminology with a view to providing comparable data. The standardized method for oiled shoreline assessment is known as **SCAT** (Shoreline Clean-up Assessment Technique).

Basic principles of SCAT include:

- a division of the coastline into homogeneous geographic units or ‘segments’;
- the use of a standard set of terms and definitions;
- systematic assessment of all shorelines in the affected area;
- a survey team that is objective and trained; and
- the timely provision of data and information for decision making and planning.

Detailed information on SCAT can be found in the “Oiled Shoreline Assessment Manual”, prepared by a group of leading European institutions active in the field of accidental marine pollution preparedness and response, under the EU financed POSOW project.

2.2 Sequence of operations and time factor

Oil that has affected a certain part of a shoreline can either be stranded on the beach and fixed there, or remain partially floating near the shore. As the quantities of pollutant may vary from a continuous layer to sporadic patches of oil, a certain sequence of operations should be followed:

- **Stage 1** (**emergency phase**) - removal of **large quantities** of oil, especially if it is still afloat - if this is not done first, winds, waves, currents and tidal movements can shift the oil to another (not affected or more sensitive) part of the coast;
- **Stage 2** (**project phase**) - removal of **stranded oil** that is **fixed** on the shore – this step may be delayed if there is no chance for the already stranded oil to be dislocated and/or if more oil is expected to arrive on the same shore;
- **Stage 3** (**polishing phase**) - removal of **small, scattered patches** of oil.

Once all the oil has reached the shore and a decision to clean the shoreline has been taken, the clean-up operations should commence **promptly** since a delay will result in stabilizing the oil in sand, on rocks or vegetation, more oil will penetrate (deeper) into the beach sediment and consequently it will be more difficult and expensive to deal with.

2.3 Setting up a base/headquarters for the clean-up operation

Shoreline clean-up operations should be planned and co-ordinated by an On-Scene Commander and his/her response team, who will need a base or headquarters from where to operate. It should be established close to the working area, easily accessible, signposted if necessary, and equipped with necessary **means of communication** (internet, telephone, radio, etc.) and an **office space** including a room for briefings, computers, maps, etc.

2.4 Communications

Permanent contact should be kept between the headquarters of the response operation and operational and support teams: supervisors of working teams should regularly report to the base. Mobile phones (if the polluted area is covered by the mobile phone network) and portable radio equipment are standard means of operational communication, while telephone and email are used for long(er) distance communications.

2.5 Surveillance

A good knowledge of the actual situation is essential for correct planning of future actions. Obtaining reliable information is less challenging than in combating oil spills offshore as monitoring of the progress of clean-up efforts can be done by regular ground inspection, however it is essential to regularly report the findings to the base. Surveying the polluted shore by a helicopter, a fixed wing aircraft or an UAV (drone) is the ideal way of getting an overall picture of the situation, especially if more oil is expected to come ashore. Principles of surveillance and remote sensing are explained in more detail elsewhere in this training programme.

3. NOTES ON DIFFERENT TYPES OF COASTLINE

3.1 Man-made structures

These are generally environmentally non-sensitive and therefore any suitable method can be applied. Initial removal of floating oil (by skimmers, pumps, sorbents), followed by low and high-pressure water flushing, steam cleaning and possibly sand-blasting (using water instead the air as a carrier medium) give the best results. Use of specially designed cleaning agents can be acceptable. Sea defences are very difficult to clean, as the oil penetrates deep into the structure, between rocks and concrete tetrapods.

3.2 Rocky shores, cliffs

Rocky shorelines are less biologically active. They are usually colonized by algae or small invertebrates and recolonization can be rapid following an oil spill. Short-term impacts are typical for these shorelines.

Clean-up should be considered only if necessary. High and low pressure flushing of oil can give good results, but if more severe methods are used, attention should be paid to avoid excessive abrasion of rocks. Manual cleaning of vertical rocks/cliffs (very rarely necessary) presents a hazard to the personnel involved and hence strict safety measures have to be applied.

3.3 Boulders

Manual cleaning and flushing are recommended if cleaning is required but results will generally be poor. If flushing is selected as clean-up method, only sea water should be used. Boulders can be removed by heavy machinery but it will almost surely result in changing the character of the shore.

3.4 Tide pools with scattered rocks / rock pools

Rock pools are shallow pools of seawater that form on rocky intertidal shore. Various marine vegetation and invertebrates may live in them, in particular in low tide zone. Tide pools are one of the most difficult types of shoreline to clean, but if oil is not removed, it can re-contaminate other areas for long periods.

Use of sorbents gives good results as well as manual clean-up and flushing. Sea-water should be used for the latter method. Use of booms and skimmers will be necessary to prevent recontamination of adjacent areas.

3.5 Cobbles, pebbles, shingle, gravel

Clean-up of this type of beaches is usually indispensable because of their recreational value, however these are among the most difficult to clean because the oil can penetrate into spaces between the stones and deep into the beach.

Both mechanical and manual methods of oiled-material removal are most commonly used, but flushing with sea water can also give good results if the oil is not too viscous. Material that was removed has to be returned after cleaning (off or on site), or replaced with material of similar size and type. All methods of natural clean-up can also be applied. If the beach is polluted before the season of storms and big waves, natural cleaning or pushing beach sediment into intertidal zone may give very good results. If heavy machinery is used for clean-up, the bearing capacity of the beach must be checked prior to its arrival, in order to prevent the machinery and vehicles used for transport of the collected material being immobilized. Use of booms and skimmers to prevent recontamination of other beaches is indispensable if flushing is selected as the clean-up method.

3.6 Sand

Besides their usual recreational use and hence their commercial value, sandy beaches are less biologically active and environmentally not too sensitive. Short-term impacts are typical for sand covered shorelines. If sand particles are fine, only a thin top layer of beach will be contaminated, but even in coarse sand, oil will not penetrate too deep.

Mechanical and manual removal of oiled sand are the most recommendable clean-up methods. Machinery should not be operated over the contaminated beach in order to avoid burying of oil. Only absolutely necessary quantities of oiled sand should be removed. If a large quantity of sand is removed, it should be replaced by the clean sand of the same sized particles. Replacement of removed sand by coarser or finer one can result in deterioration of the beach.

3.7 Muddy coasts

Mud flats are low energy shorelines, used by many vertebrate and invertebrate species. Long-term impacts are generally caused by oil penetration in sediments caused by trampling or oil penetration through worm burrows.

They should be cleaned only if it is environmentally justifiable. Flushing the oil with low-pressure water is recommended provided that flushed oil is then contained and recovered. Skimmers and vacuum units can be used for this purpose. Use of heavy machinery is not recommended since it will bury the oil that normally remains on the surface. Use of sorbents may render good results too. Very often the best solution is to leave the oil to degrade naturally.

3.8 Salt marshes with vegetation

These are environmentally the most sensitive type of coastline of high biological importance. Plants are relatively resistant to oiling, which will depend on growth cycle. Long-term impacts are due to oil penetration in the substrate affecting the root system.

Virtually any attempt to clean up the salt marsh will do more harm to the system than the oil itself. If possible, priority should be given to protection of salt marshes by booms. However, ecologists should be consulted prior to taking any action. Collection of oil with sorbents (preferably organic), combined with manual recovery, is one possible clean-up method, but even this can disturb the salt marsh environment.

4. SHORELINE CLEAN-UP METHODS

Basic and most common methods and techniques for shoreline clean-up, developed on the basis of experience gained from past oil spill accidents, can be categorized into three main groups:

- Removal (manual and mechanical) of oil and oiled material;
- Flushing of oil and washing oiled material (with sea water);
- Leaving/assisting oil to degrade naturally.

Skimmers, pumps and sorbents are obviously also used for oil recovery on shore or near it, as well as booms for its containment: the principles of their use remain the same as those described in other lessons. Compatibility of different clean-up methods with the main types of coastline are presented in **Table 1**.

Table 1: compatibility of main shoreline clean-up techniques with main types of shorelines

CLEAN-UP METHODS RECOMMENDED: SOMETIMES APPLICABLE NOT RECOMMENDED NOT APPLICABLE			TYPES OF COASTLINE							
			MAN-MADE STRUCTURE	CLIFFS/ROCKS	BOULDERS	TIDAL POOLS AND SCATTERED ROCKS	COBBLES, PEBBLES, SHINGLE, GRAVEL	SANDY BEACHES	MUDDY COYSTS	SALT MARSHES WITH VEGETATION
REMOVAL	1	MANUAL REMOVAL								
	2	MECHANICAL REMOVAL								
	3	USE OF VACUUM TRUCKS								

	4	SCREENING / SIEVING								
	5	SAND BLASTING								
WASHING	6	STEAM CLEANING								
	7	HIGH PRESSURE FLUSHING								
	8	LOW PRESSURE FLUSHING								
	9	FLOODING								
ASSISTED SELF CLEANING	10	SURF WASHING (PUSHING INTO SURF)								
	11	PLOUGHING / HARROWING								
	12	NATURAL CLEANING / "LEAVE ALONE"								
	13	CUTTING THE VEGETATION								
	14	BURNING								

4.1 Manual recovery of oiled material

This technique can be used on any type of coastline for collection of oil and oiled material, particularly if contamination is not too heavy. It is the only applicable method for clean-up of inaccessible beaches or ecologically very sensitive areas. Manual removal is a very selective clean-up method but at the same time very labour intensive and hence expensive.

Conditionally, this method also includes:

- collection of fluid oil with sorbents (followed by manual removal of saturated sorbents);
- manual scraping of oil from, for example, man-made structures, rocks, boulders, ets.;
- manual cutting of oil contaminated vegetation (to prevent re-contamination).

Equipment and material required:

- rakes;
- shovels / scoops;
- scrapers;
- brushes;
- buckets;
- heavy duty plastic bags;
- metal or plastic drums;
- personal protective equipment;
- food and drinks.

Technique

Oiled material is collected by manual labourers and piled up to a maximum of 0.5 - 0.6 m. Piled material is then transferred into plastic bags, drums or barrels and transported for temporary storage and/or disposal.

The area to be cleaned up should be divided into several sectors. Workers should be grouped into small teams (5 to 10 men and a foreman) and each team allocated a sector to be cleaned in a given time (for example, day or half a day). Several such sectors should be supervised by a supervisor. Experience from past major accidents indicates an average collection rate of 1 to 2 m^3 of oiled material per person per day. This figure can be used as a guideline for planning the operation. If the clean-up rate is not adapted to the rate of removal (by trucks, boats, helicopters) of collected oily material, plastic bags or drums should be left above the high water line for removal later on. However, it has to be kept in mind that plastic bags that are left in strong sunlight for 1 to 2 weeks are likely to begin to deteriorate.

4.2 Mechanical removal of oiled material

Various earth-moving machinery (for example, graders, bulldozers, scrapers, front-end loaders) can be successfully used for oil and oily material removal from beaches (sand, gravel, pebbles, shingle). This method is less selective than manual removal (1 - 2% of oil in material collected by mechanical means as compared to 5 - 10% in manually collected material). Although it is faster than manual method, quantities of removed clean sediment are normally 3 - 4 times bigger. This method can be applied only on beaches that are accessible from land and have sufficient load bearing capacity. Mechanical and manual collection and removal can be combined.

Equipment and material required:

- motor grader;
- elevating scraper;
- front-end loader;
- bulldozer;
- personal protective equipment;
- fuel.

Technique

Motor graders and bulldozers are used for removal of the upper, oil contaminated layer of the beach sediment. They work either parallel to the surf line from the clean side of the beach towards the water's edge (grader) or perpendicular to the surf line from the low tide line up the beach (bulldozer). Collected material is then picked up either by an elevating scraper or by a front-end loader and moved to a temporary storage area. Use of geotextile and plastic sheets for lining of temporary storage pits will prevent leakage of oil. Machinery used for clean-up (including trucks) should not be operated over the contaminated area prior to cleaning in order to avoid burying of oil. Only absolutely necessary quantities of beach sediment should be removed. Removal of excessive amounts of sand or gravel, etc. will result in erosion and deterioration of the beach. Erosion may be prevented by replacing removed sediment with clean material of approximately same sized particles.

4.3 Use of vacuum trucks

This method which has been used in most major oil spills consists of picking up liquid oil from pools in shoreline depressions or oil floating at the water's edge by means of vacuum trucks or vacuum tank trailers (“honey wagons”). Alternatively, on tidal beaches trenches parallel to the water's edge or sumps can be dug, in order to concentrate oil prior to the use of vacuum trucks. If skimmers are not available, this method is the most convenient one for removal of floating oil.

Equipment and material required:

- vacuum trucks;
- vacuum tank trailers;
- hoses;
- protective clothing;
- personal protective equipment;
- fuel.

Technique

Vacuum trucks are backed up to the place where oil is concentrated and suction hoses are placed (manually) into the oil. Suction nozzles should be kept close to the surface in order to avoid picking up excessive quantities of water. Suction hoses should be of reinforced type with a diameter of 75 - 150 mm. Oil collection rate depends on various factors such as characteristics and quantity of oil, oil/water pick-up ratio, distance to the temporary storage or disposal site, etc., but 20 m^3 of oil per day per unit can be expected.

4.4 Use of beach cleaners

Beach cleaners are machines specially constructed for cleaning sand and gravel beaches from litter/debris, but can also remove tar balls and hard oil lumps and patties. Beach cleaners can be either automotive units or towed behind a tractor. The most common working principle is the one in which a layer of contaminated sand is sifted through the wire mesh screen and redeposited on the beach, while tar balls and debris are dumped into a built-in or towed refuse container, although some other designs also exist.

Equipment and material required:

- beach cleaner;
- (tractor);
- (refuse container);
- personal protective equipment;
- fuel.

Technique

Automotive beach cleaners or tractors are operated at a slow speed (3 - 10 km/h). Cleaning should start from backshore edge of the contaminated beach. A path parallel to the water's edge is cleaned along the entire length of the beach and the beach cleaner is turned around to clean the next path parallel to and overlapping the first one.

4.5 Sand-blasting

This method is included in "removal" methods although, strictly speaking, it does not belong among them. The use of sand-blasting equipment should be restricted to man-made structures requiring perfect cleaning. Occasionally, it can also be used on boulders or rocks that are not ecologically sensitive. Oil is removed by abrasive action of sand applied by sand-blasting equipment. The remaining oil, sand and surface material should be collected and transported to a disposal site.

Equipment and material required:

- sand-blasting unit;
- sand supply truck;
- sand;
- personal protective equipment;
- fuel.

Technique

Clean-up should start from the highest point of the contaminated structure and continue downwards. The remaining oil, sand and removed surface material can be removed either manually (shovels) or mechanically (front-end loader).

4.6 Steam cleaning

Very viscous, weathered oils can be removed from rocks, boulders or man-made structures by using steam. By raising the temperature of oil, steam will lower its viscosity and hence enable it to flow. As the use of steam is likely to destroy any living organism occurring on the contaminated surface, steam cleaning should be applied only if it is absolutely necessary to remove the oil and after assessing possible consequences for the environment. Generally, it should be used only on man-made structures.

Equipment and material required:

- steam cleaner (fed with fresh water);
- nozzles;
- plastic sheets;
- booms;
- skimmers / pumps / vacuum units;
- fresh water;
- personal protective equipment;
- fuel;

Technique

Virtually the same as high-pressure water flushing (**see below**). Special attention should be paid to strict application of safety measures while working with steam (up to 150 - 160 °C, 20 bar).

4.7 High-pressure flushing

Oil which has adhered to hard surfaces can be removed efficiently by cold or hot water under pressure. Commonly used pressures range between 80 and 140 bar, and if hot water is used, its temperature should be between 60 and 80 °C. The method is applicable on rocky shores, boulders and man-made structures. Since released oil is likely to re-enter the sea and to contaminate another part of the shore, either booms and skimmers (pumps, vacuum trucks) should be used to contain and recover it, or sorbents can be applied at the base of the working area. Operators of high-pressure water jets should be well trained, since unskilled workers can destroy all existing flora and fauna (e.g. shellfish) and even damage man-made structures.

Equipment and material required:

- high-pressure cleaning machines (self-contained, with heater);
- high-pressure hoses;
- nozzles;
- plastic sheets;
- booms;
- skimmers / vacuum trucks / pumps;
- sorbents;
- personal protective equipment;
- fuel.

Technique

High-pressure water flushing should begin at the top of the surface which has to be cleaned and proceed downwards to its base. Adjacent surfaces should be protected from contamination by plastic sheets which will also direct oil and water mixture to the collection point. Berms or trenches can be constructed to channel the flow towards these collection sumps. Oil removed from the contaminated surface can be recovered by skimmers, vacuum trucks or pumps. It is recommended to time the start of the clean-up operation in such a way that the base of the surface to be cleaned is reached at low tide.

4.8 Low-pressure flushing

Flushing with low-pressure sea-water can be used to remove light, not too viscous oil from practically any type of coastline. It will not significantly disturb the substrate and hence it can even be used in very sensitive areas. Since oil removed by flushing can re-contaminate another part of the shoreline, runoff should either be contained by booms or channelled to collection sumps and eventually recovered by skimmers, pumps or vacuum units.

Equipment and material required:

- pumps;
- hoses with nozzles;
- (booms);
- recovery devices (skimmers, vacuum trucks, pumps);
- sorbents;
- personal protective equipment;
- fuel.

Technique

Since direct flushing may either push oil deeper into the beach substrata or cause damage to flora and fauna, it is recommended to gently flood the beach substrate in order to float the oil off. If flushed oil is likely to enter the sea, booms should be properly moored near the shore around the working area. Flushing should begin at the highest contaminated point and continue towards the water's edge.

4.9 Flooding

This method involves saturation of contaminated sediments by flooding with the sea water in order to float the oil trapped among the sediment material.

Equipment and material required:

- high capacity transfer pomp (approx. 100 m^3/h);
- hoses;
- drainage pipe or pierced tube;
- direct water supply;
- boom (small or beach type);
- recovery devices;
- sorbents;
- personal protective equipment;
- fuel.

Technique

A flexible perforated pipe (drainage pipe or pierced tube) is laid longitudinally above the shingle/ gravel bar and abundantly supplied with seawater, in order to produce a flow from the upper end of the foreshore to flood the part of the shingle/gravel bar that needs to be cleaned. This technique is used in conjunction with flushing or washing operation to restrict the deep infiltration of oil due to the water pressure and to improve drainage towards the lower end of the bar. The work should proceed methodically along the beach. 10 operators are required per worksite. Released oil has to be contained and recovered (using booms, skimmers, pumps, sorbents) next to the shore being cleaned.

4.10 Surf washing (pushing oiled material into surf)

This technique can be used for the cleaning of slightly to heavily contaminated cobble, pebble gravel and sand beaches. It consists of moving sediments towards the lower end of the beach, in order to subject them to the natural cleaning effect of the sea. It can be particularly efficient if applied before or during the winter season when storms and heavy seas are expected. The contaminated layer of beach material is piled up and pushed into surf zone, where wave action and movement of material cleans it. Material that is pushed into the sea will be returned to the beach by natural wave and tidal movements. Cleaning of boulders by this method will result in the change of beach shape and character.

Equipment and material required:

- bulldozer, front-end loader;
- means of recovery (nets, sorbents);
- personal protective equipment;
- fuel.

Technique

A bulldozer is operated perpendicular to the surf line starting from the upper end of the beach. Only the contaminated layer of beach material is piled up and pushed into the intertidal area. The bulldozer is returned along the cleaned path and repositioned in such a way that a second path is cut parallel to and overlapping the first one. If possible, the released oil can be recovered on the foreshore together with the sorbent material that was beforehand spread on the beach, or using nets for a very viscous oil.

4.11 Ploughing and harrowing of lightly oiled sediments

If a lightly oiled sand or shingle beach has no recreational value, oil can be left to degrade naturally. This method does not remove the oil from the beach directly, but only increases the rate of natural degradation. Agricultural equipment (a plough or a disc-harrow), towed by a tractor, is used to achieve resurfacing of buried oil and/or mixing of the contaminated sand or shingle. Ploughing and/or harrowing breaks up the oiled sediments thus increasing the rate of oil degradation by naturally occurring bacteria and other micro-organisms. It increases the surface area of oil exposed to weathering and allows oxygen to better react with the contaminated sediment. Organisms dwelling in sediments may be affected by repeating this action.

Equipment and material required:

- tractor (tracked);
- plough;
- disc-harrow;
- personal protective equipment;
- fuel.

Technique

Ploughing and/or harrowing can be applied only on beaches with sufficient load bearing capacity to withstand heavy machinery. A tractor is operated alongside the entire length of the beach, parallel to the water's edge, starting from the backshore edge of the contaminated area. The next path should be parallel to the first one and slightly overlapping it.

4.12 Natural cleaning

In certain cases, the only possibility to deal with oil on shore will be to leave it to degrade naturally, that is, to do nothing. Natural cleaning (sometimes called "leave alone" method) can either be justified by very high ecological sensitivity of the contaminated area in which application of any other clean-up method would cause more damage than oil itself, or by the fact that the contaminated area is inaccessible and has no commercial, environmental or any other importance at all. If possible, bulk oil can be removed manually (e.g. by scrapers) and evacuated in bags.

This method can also be considered for use on high energy shores before or during the winter season when it is almost sure that waves and tidal action will remove the remaining oil before the next season. Most oil deposits are likely to disappear in a couple of years, except perhaps some traces of oil high above the high-water mark. On the other hand, oil incorporated in fine sediments or mud in sheltered areas degrades very slowly and may persist for number of years.

Technique

After removal of bulk oil, the stranded oil is left on the shore. Periodical monitoring, in particular after the winter period, is recommended in order to check the progress of natural degradation, and whether some additional clean-up action is required.

NOTE: natural degradation of oil can be enhanced by adding nutrients such as nitrogen and phosphorus to contaminated sediments. The process is known as **bioremediation**, and more specifically as "**biostimulation**". The operation has to be supervised by expert personnel having experience in bioremediation.

4.13 Cutting the vegetation

If the vegetation growing on or near shore (e.g. in salt marshes) is contaminated by oil, oil-coated plants can be cut without affecting the root system, in particular if the spill occurred at the end of the vegetation period (autumn, winter). Alternatively, this action can be postponed to a more favourable season.

4.14 Burning

Although burning appears to be a logical solution for removal of oil from contaminated shores, this method is hardly ever applied in the Mediterranean area. Besides being detrimental to flora and fauna living in the polluted area, it is not possible to burn the oil completely because of the cooling effect of beach substrata. Incomplete burning results in heavy air pollution and oily soot is most likely to contaminate adjacent localities. Addition of oxidizing agents or sorbent "wicks" could improve the combustion.

Equipment and material required:

- ignition source (flame thrower);
- firefighting equipment;
- (burning agents: diesel fuel, gasoline, chemical products);
- protective clothing.

Technique

In order to ensure controlled burning, a plan should be carefully drawn up and, if necessary, fire breaks provided for. The fire should always be started on the **upwind** side of the contaminated area. Flame thrower and burning agents may be necessary to ignite the fire. The fire may either be left to burn until exhausted or until it reaches a barrier.

Safety regulations should be strictly observed and it is imperative that firefighting equipment is kept on stand-by. Personnel engaged in the operation should always remain upwind of the fire.

NOTE: Controlled burning of dry, previously cut, vegetation contaminated with oil (not necessarily carried out *in situ*) could be regarded as the only effective application of this method, although in such cases the burning of oiled material should be considered rather as a disposal method than as a clean-up method.

5. USE OF CLEANING AGENTS

During later stages of response on shore oil is often solidified and even the use of high-pressure hot water is not sufficient to soften and detach it. Cleaning of contaminated surfaces (quays, walls, rocks, pebbles) can be in such cases facilitated by the use of **specially prepared cleaning agents** that should be used in conjunction with high- or low-pressure hot or cold water flushing, followed by recovery of removed oil.

The use of cleaning agents becomes a necessity after approximately a month of weathering of oil on the rocks.

Cleaning agents can be either **non-emulsifying** (which only help to detach the oil from the surface) or **emulsifying** (which in addition to cleaning help the oil dispersion).

The most efficient products are those containing light petroleum fractions, e.g. hydrogenated kerosene, with drastically reduced aromatic content that renders their use on shore possible.

Cleaning agents should be applied (by brushes or by spraying) onto the polluted surface 15-30 minutes prior to flushing. Volume of cleaning agent/estimated volume of oil ratio should be 1 to 3. Prolonged contact times favour the action of the cleaning agent, but these should not exceed 2 to 3 hours because of the risk of solvent evaporation.

6. USE OF DISPERSANTS ON SHORE

The use of dispersants in shore clean-up operations is normally **not recommended** since the environmental effects of dispersed oil are considered to be more harmful than the effects of the non-dispersed one.

If national regulations on the use of dispersants do not specify the rules for their possible use in shoreline clean-up, the following considerations should be borne in mind prior to using dispersants to **facilitate cleaning** of hard surfaces (man-made structures, rocks, boulders) and pebble, gravel and shingle beaches:

- Dispersants should **never be used** in the sensitive marine environments such as salt marshes, estuaries, etc.;
- Dispersants could **only be used for an additional clean-up**, after the removal of bulk oil by other methods, and if specialized **cleaning agents are not available**;
- Dispersants are either **sprayed manually** from "backpacks" or **applied with brushes** on surfaces to be cleaned. They should be applied either just before the rising tide, or their application should be followed by flushing with large quantities of sea water;
- Sometimes, when the application of dispersant **does not result in actual dispersion** of oil but only in its **detachment from a surface** to be cleaned, the oil that was so released should be contained and recovered using booms, skimmers or sorbents;
- Use of dispersants **is useless on exposed, high energy** cobble, pebble or gravel beaches, exposed rocky shores, etc. but **may be considered** if such shorelines are **sheltered** and need extensive clean-up for e.g. commercial reasons;
- The use of dispersants could be considered on **man-made structures**, but not close to the water intakes of power plants, refineries or desalination plants;
- Only types of oil that may certainly be removed by dispersants should be treated, i.e. the **<u>effectiveness of dispersants must be tested prior to their application</u>**.

HANDLING, TEMPORARY STORAGE AND TRANSPORTATION OF RECOVERED OIL AND OILED MATERIAL

1. INTRODUCTION

Handling, temporary storage and transportation of oil and oiled material collected during response to an oil spill incident are issues that should not be overlooked in the planning process. In fact, spill response activities can produce significant quantities of oil and oily debris which has to be continuously removed and temporary stored prior to finally disposing of it. If not carefully planned, this part of response activities may easily hamper, and even cause the interruption of the entire operation. The issues listed below have to be thoroughly analysed in advance (during contingency planning process) with a view to preparing a smooth removal and storage of the collected oiled material, and thus ensuring the uninterrupted progress of recovery operations both at sea and on shore:

- Are there sites, near the envisaged places of oil collection, where recovered oil and oily debris can be stored temporarily?
- What are the most suitable methods of temporary storage?
- Are there any fixed storage capacities (e.g. tanks, artificial ponds used by oil processing industry) in the inshore area that could be used for temporary storage of oil/oily material collected during spill response?
- Are there any nearshore sites (wasteland) that can be used for constructing improvised temporary storage capacities?
- Is it possible to obtain in advance the necessary permits for use of such site(s)?
- Is it possible to prevent any leakage of oil from envisaged temporary storage site(s), which could possibly contaminate underground water table?
- What are the distances and most suitable traffic routes between envisaged places of oil collection (including ports and harbours in case of oil recovery at sea) and potential temporary storage sites;
- Can these traffic routes (roads) be used, without disrupting regular traffic, by vehicles transporting oil/oiled material between collection points on shore and sites envisaged for temporary storage?
- Is it feasible to clean up the roads used for transport of oiled material from possible leakages during transportation (in order to ensure the traffic safety)?

If the above questions are clearly answered during the contingency planning process, the only unknowns that will have to be defined at the time of the incident and the ensuing response operation will be the **quantity of material** to be handled, transported, temporarily stored (and eventually disposed of), and the **characteristics of recovered material**, e.g. type of oil, viscosity, oil to water (sand, debris) ratio, type of contaminated sediments, etc.

2. TRANSPORT OF OIL AND OILED MATERIAL

When the quantity of spilled product is large, in particular if it is a crude oil or heavy fuel, transport of the recovered oil and oiled material can become a major logistic problem. Means of transportation will include vessels and land vehicles, and in certain, albeit rare, cases even helicopters. Regardless of the means of transportation used, all these should be equipped with some kind of leak-proof container(s) in order to prevent contamination of non-polluted areas.

Liquid oil collected during an oil spill recovery operation at sea can be stored and transported in:

- **built-in tanks** on board recovery vessels or auxiliary/support vessels, or in **tank containers** placed on deck of such vessels;
- **towable** floating (flexible) **tanks**; and
- **barges** (self-propelled or towed).

Picture 1: Recovery vessel barge with built-in tanks

Picture 2: Towable floating (flexible) tank

Picture 3: Towable rubber

If the viscosity of **persistent oils** (heavy fuels or crude oils) allows their recovery by skimmers, it is likely that these can also be pumped into any of the above mentioned receptacles. However, once filled these may become very difficult or even impossible to empty because of an increase in viscosity of oil due to e.g. formation of water-in-oil emulsions by pumps, settling of water which might have been used as vector for pumping, change of temperature, or turbulence caused by sea movement during transport. In order to avoid these problems, addition of emulsion-breaking chemicals to recovered oil whilst filling the tanks is recommended unless built-in tanks, tank containers or barges are provided with heating coils. Before taking a decision on its final disposal, the oil can either be left in these tanks, or transferred from vessels or floating receptacles to temporary storage capacities on land by:

- road tanker trucks;
- rail tank cars (tank wagons);
- vacuum trucks;
- tank semi-trailers; or
- vacuum tank trailers.

If only smaller quantities of oil are collected, these can be transported in standard **metal drums** of 200 litres capacity (known as 44-gallon drums in UK, and as 55-gallon drums in USA).

Less viscous (**non-persistent**) oils that are recovered at sea can be transported in the same types of receptacles, both at sea and on land, however their handling is not additionally complicated by the creation of emulsions.

Semisolid or **solid oiled material** (including high viscosity oils and emulsions, and oil contaminated beach sediments) are usually transported in **open top containers** (**skips** or **dumpsters**), as well as in **dump trucks**. Should there be a risk of oil leakage, these containers (including open-box beds of dump trucks) ought to be lined with heavy duty, sealed plastic or rubber sheeting.

3. TEMPORARY STORAGE

Often, the rate of **recovery of oil** (or oil and water mixture) at sea and near shore, or **beach sediment contaminated with oil** on shore, is higher than the rate of its final disposal, even when the methods of final disposal have been defined in advance (in the contingency plan). In such situations, **temporary storage capacities**, preferably as close as possible to the site where oil is being recovered, need to be set up. The following options are available:

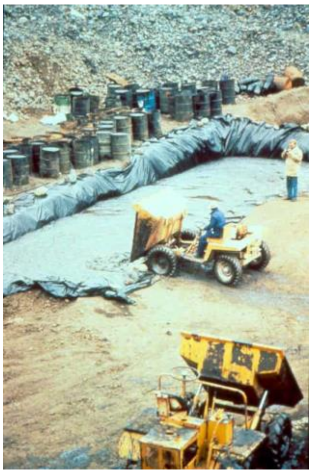
- **Flexible tanks:** If available, open top flexible tanks, with or without support, should be used for temporary storage of liquid oil, particularly at the beginning of clean-up operations on shore. They are not suitable for solid oiled material (e.g. pebbles, debris).

Pictures 4: Flexible (collapsible) tank **Picture 5: Weatherproof container for flexible tank**

- **Improvised pits:** If local conditions permit, one of simplest ways to provide temporary storage for collected oiled material is to dig pits in the ground. Experience shows that the most convenient pits are **long** (approximately 10 m), **narrow** (2 to 3 m) and **not too deep** (1.5 to 2>m). To prevent leakage of oil and possible contamination of the underground water table, pits should be **lined** with heavy gauge plastic (polyethylene, PVC) or oil-resistant rubber sheeting. Before lining the pit with oil-proof material, it is useful to **cover the hole** with a layer of sand, felt or geotextile in order to prevent possible puncturing of the plastic or rubber lining by stones. Collected oiled material is dumped into these pits and left for further treatment and/or transportation to the final disposal site.

In case of expected rain, pits should be only partly filled with oily waste in order to prevent possible overflowing caused by rainfall. Following the removal of temporarily stored material, the land used for temporary storage must be restored to its original state.

Alternatively **earth walls** (**dikes**) can be constructed (1 to 1.5 m high) to form rectangular reservoirs above the ground, which should also be lined to prevent leaching of oil. If earth walls (dikes) are used, care should be taken that these are not damaged by vehicles transporting oiled material.



Picture 6: Improvised pit near a recovery site on shore

Picture 7: Improvised pit near a refinery

- **Open top (metal) oil drums:** These are usually available in large quantities, and can be used for temporary storage of any kind of collected oil and oiled material. As they are also suitable for transportation, oil drums can be particularly useful for handling of very viscous oils and emulsions. To avoid contamination of land utilised for storage of oil in open top drums, it should be protected by a layer of geotextile, covered by plastic or oil-resistant rubber lining.

Picture 8: Filling an open top oil drum

- **Heavy duty plastic bags** and "**big bags**" (**flexible intermediate bulk containers** - **FIBCs):** The most suitable way of storage and transportation of oiled material collected manually from beaches. The site on which filled plastic bags are to be stored prior to their transportation to the final disposal should be protected (with geotextile and then plastic or oil-resistant rubber sheeting).

Picture 9: Oiled material collected in plastic bags **Picture 10: Big bag being loaded on**

during response to a major spill in South Korea a truck for transportation

CAUTION: If left in strong sunlight for 1-2 weeks, plastic bags may start deteriorating and releasing collected oily material. Plastic bags may also be difficult to empty at the final disposal site.

- **Fixed storage capacities:** If in the area where oil spill clean-up activities are envisaged to take place there are refineries, oil terminals, port reception facilities for oily mixtures, etc., it may be possible to arrange with owners or operators of such facilities to use their available storage tanks for temporary storing liquid oils or oil-water mixtures. Such arrangements, the possibly available tank capacities, as well as types of oil which can be temporarily stored in this way, should be considered during the contingency planning process.

MANAGEMENT OF LIQUID AND SOLID WASTES GENERATED DURING SPILL RESPONSE ACTIVITIES

1. INTRODUCTION

As already indicated in the lesson concerning transportation and storage of oil and oiled material generated during spill response operations, the waste storage and disposal tend to be somewhat neglected parts of marine pollution response. Nevertheless, experience shows that these are also its most expensive and time-consuming elements. Regardless of the spill size, **persistent oils** (including crude oil, fuel oil, heavy diesel oil and lubricating oil) are likely to produce a volume of oiled waste material that is much larger than the volume of the spilt oil.

It is estimated that a spill of **1000** m^3 of e.g. crude oil can generated up to **750** m^3 of liquid wastes and up to **30,000** m^3 of solid wastes that need to be processed and disposed of. The multiple increase in volume is mainly due to the process of emulsification of water into oil, and to vast amounts of contaminated sediments generated by shoreline clean-up operations.

On the other hand, **non-persistent oils** (such as gasoline/petrol, light diesel oil and kerosene) usually dissipate and disintegrate naturally in a very short period of time, which often prevents the recovery of spilled product at sea and much less severe contamination of the affected shoreline. Consequently, the volume of waste material to be dealt with after a spill of such oils is normally small.

Response priority should be to minimize waste production as much as possible, following the hierarchy: **REDUCE ⇨ REUSE ⇨ RECYCLE ⇨ RECOVER ⇨ DISPOSE**.

This lesson aims at summarizing the **basic principles** of oiled waste management, and should be read together with the separate lesson on oiled waste **transportation and storage**.

2. TYPES OF WASTE

Liquid wastes are produced during oil recovery operations at sea, in port/harbour areas, or during shoreline clean-up (drainage). They include more or less pure oil and oil/water mixtures with various contents of water.

Solid and varied waste is produced during shoreline clean-up operations. Wastes created during initial clean-up contain relatively high percentage of oil, while those produced during later stages contain oil mixed with oil-contaminated material including sediments, material of vegetal and animal origin, used response products (e.g. sorbents) and personal protective equipment, plastic linings, bags, etc.

Waste production significantly varies from one pollution incident to another and is not directly proportional to the volume of spilled oil. Other factors that affect the amount of generated waste *inter alia* include:

- type of spilled oil;
- type of polluted area;
- sea and weather conditions;
- season of the year;
- response techniques used;
- organization of response.

The table below, reproduced from CEDRE's Operational Guide "Oil Spill Waste Management", shows the most common categories of waste and average contents of its usual components.

Table 1: Waste categories and their characteristics

CATEGORY	% OIL	% WATER (free)	MINERAL MATTER	ORGANIC MATTER	COMMENTS
LIQUIDS	> 10 %	0% - 90%	< 10 %	< 10 %	1
PASTE AND SOLIDS (sand, …)	> 10 %	10% - 20%	> 10 %	< 10 %	2
POLLUTED PEBBLES / STONES	> 10 %	1 %	> 80 %	< 10 %	3
POLLUTED SORBENTS	> 5 %	< 10 %	< 10 %	< 5 %	4
POLLUTED SEAWEED	> 5 %	< 20 %	< 20 %	> 80 %	5
POLLUTED SOLID WASTE	> 5 %	< 10 %	< 10 %	variable	6
POLLUTED FAUNA	> 5 %	< 15 %	< 10 %	> 70 %	7

[1] Remove as much water as possible by settling. [2] Define threshold according to pollutant.

[3] Choice criterion: degree of surface polluted. [4] Bulk, mops, pillows, sheets, pom-poms.

[5] Fermentable substances: **may cause** olefactory disturbance/unpleasant smells.

[6] Including gloves, boots, overalls, … [7] Bird and mammal corpses.

3. BASIC RULES

The French centre of expertise CEDRE suggests observing the following set of basic rules with a view to dealing with collected oil and oiled waste in the most efficient and the least costly way:

- **Rely upon** the relevant provisions of the updated **contingency plan** (concerning e.g. the identification of temporary storage sites and final disposal methods, the existing agreements with contractors specializing in waste handling and disposal, etc.).
- Keep **quantities** of generated waste **to a minimum**.
- Avoid **contamination**/**soiling** of unaffected environment.
- Prevent **overflow**.
- Prevent **congestion** and **standstills**.

- **Sort waste** since the initial phases of response.
- Ensure **transparency** and **traceability** of all processes.
- **Recycle** or **upgrade** as much treated waste as possible.
- Promptly **restore all sites** on land where waste was collected, handled and/or stored.

4. SEPARATION OF OIL FROM WATER AND SOLID MATTER

Oil collected during the spill response operations inevitably contains a certain amount of sea water and/or solid materials. The purest is the oil collected by skimmers from the sea surface (up to 90% of oil), while beach material collected during the shore clean-up may contain only 1 to 5% of oil. The separation of oil from other substances (water, sand, pebbles, stones, wood, plastic materials, sorbents, etc.), which had been collected together with it, facilitates:

- recovery of as much oil as possible for re-use,
- reducing the volume of material which has to be handled, transported and stored,
- the final disposal of oiled material.

The most frequently used separation methods include:

4.1 Gravity separation

Mixtures of oil and water can be separated making use of differences in their respective densities. Oil which is lighter than water, tends to rise to the surface (from where it is skimmed and pumped into tanks) and water settles at the bottom of the settling tank (from where it is successively removed). Gravity separation can be carried out in purposely built settling tanks (API separators, circular clarifiers, corrugated plate separators, etc.), or in various receptacles e.g. open top tanks, skips, storage tanks on board vessels and even in open top oil drums.

Stable water-in-oil emulsions can also be separated by this method if chemical additives (emulsion breakers or demulsifiers) are added and thoroughly mixed with the emulsion that is being treated. If the available settling tanks are provided with heating coils, heat (up to 80 °C) can be used to break unstable emulsions.

4.2 Collection of leaking oil

Collecting the oil that drains from temporarily stored beach sediment/material is the simplest way of separating liquid oil from other oiled material (sand, pebbles, gravel, debris). Oil should be channelled into collection sumps and from there pumped into suitable tanks.

4.3 Removal of debris

If relatively clean oil contains pieces of debris (seaweed, wood, plastic, etc.), these can be removed by screening the oil through a wire mesh screen. Filtration of dry solids on a woven or non-woven material can also be used. This operation may precede gravity separation.

4.4 Sieving

Oil collected in the form of solid lumps or tar balls, can easily be separated from sand either by manual or mechanical screening (coarse mesh – few cm to dm) or sieving (fine mesh – few mm).

4.5 Washing

Cold water washing of oiled material collected during beach clean-up operations, may release oil which has adhered to solid material (cobbles, pebbles). Washing can be carried out in temporary storage pits which should, for this purpose, be rather shallow and of a larger surface. Better results are obtained by washing contaminated stones in concrete mixers. Resulting oil and water mixture is then transferred to settling tank(s) for gravity separation.

4.6 Extraction

Theoretically, oil can be recovered from oiled beach material by solvent extraction, however, the method needs to be further developed.

5. FINAL DISPOSAL METHODS

Three groups of methods can be used for the final disposal of oil and oiled material from a spill:

- Recovery of oil for reuse.
- Stabilization of oil and oiled material.
- Destruction of oil.

If possible, priority should be given to the methods that enable collected oil to be reused. If these are not feasible, stabilization of oiled material and, finally, destruction of oil can be considered.

The following outlines of various disposal options are only informative, as the final disposal of oiled material generated during a spill response will be probably left to specialized contractors.

5.1 Reuse of oil

Reprocessing and reuse of oils collected during a spill clean-up operation can contribute to reducing the total cost of the operation. Potential users of such oils include refineries, waste oil recycling plants, power plants and cement works.

Specifications of oils which each of these plants can use should be indicated in the **contingency plan**. The specifications normally cover the contents of water, solids and salts, and oil viscosity. Oil that meets the necessary requirements can either be blended with fuel oil for internal use in the plant or in the case of crude oils, blended with feedstock for refining.

5.2 Stabilization of oiled material with binding agents

Oiled material can be stabilized by mixing it with binding agents and then using it for e.g. land reclamation and construction of service roads. The most commonly used binding agent is **quicklime**, but other materials such as cement, zeolite and pulverized flue ash can also be used. 5 to 20% of quicklime (exact ratio has to be determined experimentally), is mixed with the oiled material either in specialized mixing plants, or by spreading out oiled waste on a flat surface (in layers of 20-30 cm) and mixing it with quicklime. Before applying this technique, it is necessary to verify that there is no possibility of ground water contamination by leaching oil.

As the process is highly exothermic, it may generate **excessive heat** and cause a violent reaction (fire/explosion). Therefore, the exact ratio of oil/quicklime has to be established for each specific waste. Mixing oiled material with quicklime also generates a large quantity of **corrosive dust**, and has to be carried out in **uninhabited areas**. Operators must use appropriate **personal protective equipment**.

The material resulting from stabilization process is clean and stable, does not release oil and can easily be stored and transported. The method can be particularly suited for the areas in the Mediterranean in which quicklime is readily available in sufficient quantities.

5.3 Land-farming of oil and oily debris

Land-farming is based on the well-known fact that certain microorganisms can oxidize hydrocarbons, thus causing the natural biodegradation of oil. The main requirement is a relatively large area of low value land (to be defined in the relevant local contingency plan!). The permeability of the substrata should be low to prevent possible contamination of water table. The only equipment required is common agricultural machinery.

The selected piece of flat, low value land, must be provided with runoff diversion channels and a catchment pool, for collection of runoff caused by rainfall. It is first harrowed and then a layer of oiled material (of up to 0.2 m thick) is evenly spread over the surface, and left to weather. When it is no longer wet and sticky, it is mixed with soil (using a plough, a disc harrow or a rotavator). The substrate has to be mixed periodically in order to increase the aeration. The rate of biodegradation can be increased by adding fertilizers, e.g. urea and ammonium phosphate. Complete degradation of oil treated by this method can be expected in one to three year's period.

Following the biodegradation of oil, the land can be used to cultivate almost any kind of plants including grass, decorative plants and trees. If crops (for human or animal consumption) are grown on land previously used for aerobic decomposition of oil, these should be monitored for possible heavy metals content.

5.4 Composting

Composting is biological conversion of oily waste into stable, humic material. It is achieved by adding oiled waste to domestic refuse or by mixing oiled material with domestic waste and depositing the mixture in shallow pits sealed with a layer of clay and covering it with soil. These techniques are suitable for treating only limited quantities of oiled material because of a low percentage of such material that can be successfully composted.

Composting can also be achieved by piling oiled natural sorbents (e.g. straw, wood shavings, etc.) or oiled seaweed into heaps. However, it can be applied only if natural sorbents are used in clean-up operations, or if seaweed has been soiled by oil, none of which is very common.

5.5 Landfilling

Direct disposal of oiled material is often the first reaction to the disposal problem although this method should be applied only if any of the previously described ones cannot be applied. **If national regulations allow** direct disposal of oil contaminated material, it must be carefully planned. The selected landfill site has to be checked beforehand for imperviousness to avoid possible contamination of underground waters with hydrocarbons. Waste to be disposed in a landfill should have less than 20% of oil. Spreading of oiled waste above ground level should be given priority over filling of holes and/or depressions. Substrata near the landfilling site should be analysed periodically to determine any possible leakage of hydrocarbons.

If allowed by regulations, oiled material with **low oil content** can be placed with **domestic waste** in **municipal** waste disposal sites, or otherwise in sites designated for **hazardous wastes**. Domestic refuse absorbs oil leaching from disposed oily material, thus preventing its further leaching to the ground. The layer of oiled material should be thin (10 cm) and spread on top of at least 4 m layer of domestic waste and then covered by 1-2 m of it, to prevent oil from re-surfacing.

5.6 Burning

The direct burning of collected oily waste is rarely feasible. Incomplete burning, air pollution and disposal problems of tarry residues are some of the drawbacks of this method. However, if tests prove that it is possible to burn collected oily debris, this technique can be applied particularly in remote places. Before the start an operational plan should be drawn up and, if necessary, fire breaks provided for. The fire should always be started on the **upwind** side of the burning site. Flame throwers or burning agents may be required to ignite the fire. **Safety regulations** should be strictly observed and **firefighting equipment** must be kept on stand-by. Personnel engaged in the operation should always remain upwind of the fire.

5.7 Incineration

Mobile incinerators have been developed for high temperature incineration of oiled material near the clean-up site. The rotary kiln type is particularly useful for incineration of oil with high (up to 80%) solid contents. Products resulting from incineration are environmentally acceptable gases and clean, inert solids (gravel, sand, etc.). Addition of fuel may be required if treated material has a low calorific value.

Industrial waste incinerators (in **hazardous waste collection centres**, **cement works** (co-incineration) and **lime kilns**) are suitable for oily wastes with more than 30% oil content that satisfy specific, precisely defined, criteria. **Domestic waste incinerators** can also be used, providing that oiled debris has a low oil content.

DEMOBILIZATION OF RESOURCES, CLEANING, STORAGE AND MAINTENANCE OF SPILL RESPONSE EQUIPMENT AND PRODUCTS

1. INTRODUCTION

There is group of activities that, if not planned and conducted properly, can jeopardize any response operation that might be necessary in of case of an oil pollution incident. These particular activities aim at ensuring the desired state of preparedness of equipment and products for response to oil spill (and spills of other HNS).

Equipment used in the spill response operations and, in particular, in shore clean-up operations belongs generally to two main categories:

- specifically designed oil spill response equipment;
- non-specific equipment (used normally in e.g. agriculture, construction, transport, communal services, etc.).

While the latter category is likely to be provided (rented or otherwise procured) by subcontractors who operate such equipment on a daily basis, and accordingly have established maintenance routines, specialized oil spill response equipment, or at least part of it, is likely to come from national, regional or local stockpiles.

Such equipment, including the one kept at the local level, has been procured for use only in case of emergency. Its working regime is therefore very irregular, characterized by long periods of rest that are only occasionally interrupted by relatively short periods of very intensive use, meaning that it is exposed to an enormous stress when it has to be used for responding to a spill. In order to maintain the equipment in good working order and ready for use in case of emergency, it has to be regularly maintained, inspected and tested.

On the other hand, the equipment that has been used intensively during a spill response operation, has to be demobilized, cleaned and repaired prior to be returned to the storage.

The present lesson outlines key issues that person in charge of stockpiles of spill response equipment and products has to bear in mind with a view to having these resources always ready for use when the need arises.

2. DEMOBILIZATION

As discussed elsewhere in this training course, the active phase of oil spill response is terminated when it becomes ineffective or its continuation may pose an unacceptable risk of additional damage to the environment or economic activities in the affected area. Once the decision to terminate the active phase of response has been taken, the resources used for it should be demobilized. The On-Scene Commander (OSC) is responsible for overseeing the process of demobilization, which is usually gradual. Likewise, the OSC must ensure that:

- the equipment that was used is properly cleaned;
- the equipment is repaired and maintained in accordance with the instructions of the manufacturer;
- the stockpiles of equipment and products are restocked and inspected;
- the equipment and products are properly stored; and
- the equipment is ready for use when another spill occurs.

3. CLEANING, WASHING AND DECONTAMINATION OF EQUIPMENT

During spill clean-up operations equipment that is used should be regularly (daily, if possible) cleaned and inspected in order to identify and repair any wear or damage. This applies, in particular, to booms and skimmers, but also to any other mechanical device, hand tools and personal protective equipment.

A **washing facility** should be set up at the beginning of response activities and operated until the terminations of operations, and it should have the following elements:

- a **washing area** easily accessible for personnel and equipment, having a gentle slope;
- a **sealed dike**, with a **sump** for effluent removal, to prevent run-off;
- **fresh water supply** and high **pressure wash**;
- **cleaning agents**;
- **tanks** or **separators** for water/oil separation;
- **container for** separated waste **oil**;
- **fork lift and crane** for handling heavier equipment;
- **floodlighting**, if overnight repair work is envisaged.

Once the washing facility is operational, the following cleaning procedures should be observed:

- wash dirty equipment using water only or special cleaning agents;
- pump oily water from dike to separator;
- discharge separated water to drain and transfer oil into storage container.

After the termination of operations all collected waste material (oil) should be removed to the waste disposal site/facility, and the site of washing facility should be restored to its original state.

As regards cleaning of **skimmers**, it might be possible to use high pressure hot water or steam or hydrocarbon solvents for oil removal, however **dispersants and detergents must not be used on oleophilic skimmers** (discs, drums, brushes, rope-mops). In order to retain their oleophilic properties, these can be cleaned with **diesel oil**.

Booms need to be cleaned after use in spill response operations, in particular if they were in contact with oil. Booms that were used only for protection of a certain area and were not exposed to oil should only be washed with fresh water prior to storage. Oil contaminated booms will require more drastic cleaning methods, including the use of hot water and dispersants. Whatever the cleaning method chosen, its compatibility with the boom material, according to the manufacturer's specifications, should be ensured prior to cleaning.

4. STORAGE

If possible, equipment should be stored in a **dry**, **properly ventilated** storage facilities. In order to increase the life span of the material, humidity and temperature must be controlled and **exposure to UV rays avoided**. In addition, material should be protected against pests. Booms that are stored folded or rolled up should be unfolded and unrolled regularly in order to prevent sticking of the material and forming permanent creases which could weaken the material.

Within warehouses there should be an empty space (surface) where equipment can be cleaned up from oil and sea water and where certain maintenance work can be carried out. It is essential that the equipment is easily accessible in order to enable both inspection and maintenance. Access of vehicles and lifting gear, needed to rapidly dispatch equipment and products in case of emergency, should also be ensured at all times. Security measures have to be in place in order to prevent acts of vandalism or thefts.

Skimmers and their power packs should be protected from damage and damp salty atmosphere causing corrosion. Oleophilic mops and brushes made of synthetic materials, rubber conveyor belts and plastic material incorporated in skimmers can perish if exposed to direct sunlight for prolonged periods. Accordingly, skimmers should be stored in properly ventilated, covered sheds or warehouses.

4.1 Ageing and storage of dispersants

Dispersants are complex formulations consisting of several surface-active agents dissolved in solvents. They may also contain water and additives for stabilizing the mixture.

Aging of dispersants does not generally present problems and different components change only slightly with time. Crystallization and settling have be noticed after a long period (several years) of storage without movement. In such cases the upper phase becomes richer in solvent and lower in surfactants. Conventional, hydrocarbon based products (also known as 2nd generation or Type I dispersants) are more sensitive to these changes. Agitation of the dispersants' containers prior to use should normally provide for the homogenization of the product.

Ageing of dispersants over very long periods (10 years and more) is poorly known, and periodic checking of their main properties (effectiveness and toxicity) is therfore required.

Dispersants alone are not significantly corrosive, as they do not attack metal. However, they increase wetting of metal and can thus accelerate corrosion in the presence of fresh and, in particular, sea water. Manufacturers usually deliver dispersants in metal drums coated internally with epoxy coating, paint or varnish, or in containers made of a synthetic material.

Main corrosion problems concern **storage of piled metal drums in the open air**, due to external corrosion that is not caused by the dispersant action. In order to prevent external corrosion drums should be sheltered from rain.

Use of **plastic drums** gives rise to other types of problems: plastic materials age quickly in the open air and due to dispersant's action, drums placed at the bottom of the pile deform and may finally collapse under the weight of the drums place on top of them.

Accordingly, it is recommended to store dispersants in coated containers or in internally and externally protected metal drums.

5 MAINTENANCE OF SPILL RESPONSE EQUIPMENT

5.1 Regular maintenance

The best way to ensure a good working order of spill response equipment is to regularly **inspect** and periodically **test** it. Testing is best done through exercises, which at the same time serve to **train oil spill response personnel** designated to operate the equipment in case of an incident. **Table 1** indicates recommendable regular intervals for testing different categories of equipment, but it can also help the officers in charge of maintenance to plan regular training of operational teams.

Mechanical equipment (e.g. skimmers, power packs, pumps) should be **serviced** regularly, in accordance with the manufacturer's maintenance instructions.

Table 1: Recommended intervals for testing main categories of spill response equipment

TYPE OF EQUIPMENT	INTERVAL	TEST
Oil pumps	monthly	start the pump
	every 6 months	handling training/instruction
Skimmers (mechanical recovery devices)	every 6 months	operational trials (without pollutant)
Booms	every 6 months	- deploy (in water) a considerable length (at least 3 sections) - unfold (on land) the entire length
Skimming barriers	once a year	operational trials/instruction
Floating, flexible and rigid barges and containers for collected oil	once a year	- inflate inflatable units - mount/erect other units - fill with water
Spraying equipment for - dispersants - loose sorbents	once a year	instruction session for personnel responsible for handling
Storage capacities for spilled oil treatment products	once a year	- check storage conditions - agitate drums

		- oldest products in stock may be used for trials

NOTE: Whenever the equipment used in exercises was in contact with sea water, **it should be rinsed with fresh water prior to storing it again**.

5.2 Maintenance during response operations

During spill response operations there will be a need for two different types of maintenance: **preventive maintenance** and **repair of breakdowns**.

Preventive maintenance should help keeping the need for repair of breakdowns to a minimum. If the equipment is used by **trained operators**, observing the established rules of **good housekeeping**, under **conditions recommended by the manufacturer** and **without exceeding the limits of the material resistance**, the need for emergency repairs during spill clean-up will be drastically reduced.

In case of an oil spill, maintenance facilities should be, if possible, made available relatively close to the spill response (clean-up) site. The personnel should comprise a mechanic, a fitter and an electrician, who should have access to required materials, tools and spare parts. The availability of fuel and lubricants for vehicles, boats and different machinery used in clean-up operations should be ensured since the beginning of activities.

A large part of spill response equipment, and **skimmers** in particular, has been designed to use **hydraulic power**. Hydraulic power is very well adapted to difficult working conditions, it is safe, reliable and allows for a good transmission of energy required for running the specialized equipment.

Regular checking of tightness of hydraulic circuits will ensure efficient operation of the equipment, while a good supply of couplings required for various attachments will enable the multiple use of each hydraulic power-pack.

Most **boom** manufacturers provide emergency repair kits that should always be available during clean-up activities in order to enable prompt repair of minor damages which could, if not mended, render one or more boom sections unusable.

Dispersants are **strong degreasing agents** and particular attention should be paid to checking that lubricants in various pieces of equipment are not contaminated with dispersants if these are being used. This refers in particular to tail motor assembly of helicopters. Dispersants also attack exposed rubber components and various paint coatings, and may cause slight crazing of stressed Perspex used in windscreens and windows of vessels and aircraft. Thorough hosing of all vessels, aircraft and other machinery exposed to dispersant spray is necessary to prevent potential damage to the equipment.

COURSE / MODULE 3

SITUATION AFTER AN INCIDENT

MONITORING OF OIL POLLUTION AND SAMPLING OF OIL AND OILED MATERIAL[3]

1. INTRODUCTION

Marine oil pollution is monitored more or less regularly by all coastal states in Europe and in the Mediterranean region. It is carried out for various purposes and the term “monitoring” therefore applies to a number of diverse activities. The “monitoring” can apply to monitoring of sea surface from satellites or any kind of aerial vehicles, to monitoring of various parameters of the sea water by means of chemical analyses, to observing changes in the coastal part of the marine environment, etc.

In case of chemical analysis of samples of water and those of oil, or samples containing oil mixed with water or solid matter or both, there is need to take samples that will serve the specific purpose for which the analysis is being carried out. Sampling is the process of taking samples of oil, water, sediments or biota, for analysing or testing.

This lesson **aims** at outlining the basics of **monitoring** related to marine oil pollution and of **sampling** water, oil and oiled matter, as the participants in the Programme might be requested to assist in these types of activities before an oil pollution incident, during response to it, and in the aftermath of direct spill response and clean-up operations at sea and on shore.

[3] In the preparation of this lesson the authors used “Tecnical Information Paper 14 - Sampling and Monitoring of Marine Oil Spills“, ITOPF, London, UK, 2012.

2. MONITORING

Reasons for monitoring are multiple, and include *inter alia*:

- a **standard control** of the sea **water quality**;
- **regular monitoring** of the sea, aimed at **detecting** and **identifying** offenders of regulations concerning protection of marine environment from ships (and from land based sources too) and at **providing evidence** for their prosecution in case of illegal discharges;
- in case of pollution **incidents**, when the source is usually known, monitoring serves:
    - to predict the **movement**, **behaviour** and **fate** of the spilled product;
    - to help making decisions concerning the **selection of** appropriate **response methods**;
    - to support **conducting** spill **response operations**, at sea and on shore.
- post-spill monitoring is carried out to assist **identifying** suitable **remediation** methods **for the affected sites**, and to **control** their **progress** and success.

The relevant **monitoring programmes** are developed and implemented by specialists in each of these fields.

In general, the **first step** in designing a monitoring programme is to define the **objectives** and to agree on the **information and data required** to achieve these objectives. In Europe, the objective is usually to establish the level of contamination in sediments in key sites oiled during the incident. The monitoring activities include collection of sediment samples from beaches and shallow waters from polluted sites, over a period of e.g. 3 months, and their analysing for total hydrocarbon content (THC) and polycyclic aromatic hydrocarbons (PAH). Often, the results of monitoring have shown that most of the sediment was relatively unaffected.

2.1 Monitoring of the sea water quality

It is a routine procedure, carried out regularly, in accordance with the regulations prescribed by the relevant national and EU legislating. It involves the measurement of **standard physical,**

chemical and biological parameters of the sea water, such as the temperature, salinity, suspended solids, various anions and cations, COD (chemical oxygen demand), BOD (biological oxygen demand), the level of eutrophication, etc. The **contents of hazardous compounds and elements** (e.g. heavy metals, organohalogen compounds, polycyclic aromatic hydrocarbons or PAHs, etc.) is also regularly controlled. **Hydrocarbons**, which are the key component of mineral oils, are expected to be measured too, however regulations concerning the monitoring of this group of compounds are less stringent than for the other, more noxious ones.

Regular monitoring of sea water parameters is carried out by the competent, certified, state institutions, although specialized scientific institutions also implement specific monitoring programs for research purposes.

2.2 Monitoring related to detection of illicit discharges

It is usually carried out by aerial or satellite reconnaissance, as described in **Lessons L 1.7 and 1.8** respectively.

2.3 Monitoring related to marine pollution incidents

Two types of monitoring are usually carried out when an oil pollution incident occurs. The first type can be described as **operational**, and the second one as **environmental**, scientific monitoring. The latter is only mentioned in this lesson, and further discussed in **Lesson L 3.2**.

Operational monitoring **provides** information of direct relevance to the oil spill response management, **serves** to assess actual situation during an oil pollution and **comprises** both aerial surveillance (either by aircraft, preferably helicopter, UAV/drone or satellite), and collecting/analysing samples from the sea and shore. In fact, the first action in any response to an oil pollution incident should be to initiate operational monitoring, and then continue with it on a daily basis throughout the duration of active response, in order to assess the effectiveness of response activities.

Three complementary approaches to monitoring are possible:

- comparison of post-spill and pre-spill data;
- comparison of data from contaminated areas and uncontaminated reference sites; and
- monitoring changes over a period of time.

In certain cases, such as e.g. spills of small volume of light non-persistent products, in unfavourable weather/sea conditions, operational monitoring may be the only action required.

In addition to already mentioned reasons for monitoring during a pollution incident, the decision to implement a monitoring programme, as part of spill response, may be made for one or more of the following reasons:

- to measure concentrations of hydrocarbons in the sediment or water to assist in making decision on whether to continue with response operations or to terminate the activities;
- to establish whether there is a risk to transfer contaminants into the human food chain;
- to establish the effects of the pollution incident on commercial fish and shellfish to support making decision on whether to impose fishing restrictions;

It is emphasized that any reasonable costs associated with operational monitoring of the spill situation and its development can be legitimately included in the costs of response, and their reimbursement claimed from the polluter or his insurer, or in case of a massive spill of persistent oil, from the IOPC Funds (International Oil Pollution Compensation Funds).

2.4 Post spill monitoring

It includes **standard monitoring of the sea water quality** and specific **environmental monitoring** aimed at supporting **environment remediation measures**, that is described in Lesson L 3.2, as already indicated.

3. SAMPLING

In case of illegal discharges of oil from ships, the obvious reason for sampling is **to identify** offenders and **to provide evidence** for their prosecution. In case of an oil pollution incident, the source of oil is usually known, and therefore sampling serves primarily to **help making decisions** concerning the response operations, and subsequently concerning **remediation of the affected sites**.

Taking oil samples should not present a serious problem when there is a sufficient quantity of it, that is, when the layer of oil at sea or on shore is thick. The only issue to be considered in such a case is the cleanliness of containers in which samples are taken. Problems may arise when the pollutant is spread in a very thin layer, but these can be overcome by using purposely designed sampling devices and techniques.

The procedures for taking samples are defined by official national and international regulations (protocols), and the sampling will be, under normal circumstances, carried out by the staff familiar with the required procedures. Nevertheless, as already indicated, persons engaged in spill response may be occasionally required to assist in sampling oil or oiled material.

Types of sampling related to oil spills include sampling of **spilt oil**, **water**, **sediments** and **biota**. In general, samples of **oil** are taken primarily for **qualitative** analysis either in order to confirm its source (see paragraph 2.1) or to determine the appropriate response methods, while samples of water, sediments and biota are required for quantifying hydrocarbon contamination, which may be important for planning spill response operations, and subsequently environmental remediation and reinstatement.

Quantities of oil or oiled material that are needed for analyses are usually small. Table below shows typical amounts of sample required for the analysis of hydrocarbons.

Table 1: Guidelines for the amount of sample typical required for hydrocarbon analysis

Description	Indication of minimum required quantity (per sample)
Pure oil source sample	30 – 50 ml
Contaminated oil (e.g. oil from sea or shore, sandy tar balls, emulsified oil, etc.	10 – 20 g
Debris with oil, oil stained sand	Sufficient quantity that oil content is approx. 10 g
Oiled feather	5 -10 feathers depending on oil quantity present
Fish, shellfish (flesh and organs)	Multiple individuals of same species totalling 30 g
Water sample with visible oil	1 litre
Water sample with no visible oil	3 – 5 litres

Reproduced from "Technical Information Paper 14 – Sampling and Monitoring of Marine Oil Spills", ITOPF, London, UK, 2012

3.1 Spilt oil sampling

Samples of oil floating on the sea surface can be collected directly by **sampling jars**, sorbent **pads**, and **buckets** on a rope or on an extension pole. If a sample is taken **from a boat**, it should be taken from the bow, in order to avoid sheens from the boat's hull, engine exhaust or cooling water.

Fine-mesh sampling nets or cones, sorbent cartridges or special sponges are used for taking oil samples from thin oil films on the sea surface. Clean, unused sampling nets or pads, should also be provided to the laboratory as references for analysis alongside the sample.

Oil stranded on a shore and attached to a hard surface can be collected by **scraping** and gathering it into a sample container.

The proper “chain of custody” of samples comprises **storage**, **labelling** (location, date, time ...), **sealing** (in the presence of witnesses), **packaging** (in padded boxes with dividers) and **shipping** to the laboratory. Each of these steps must be properly documented.

Oil samples should be **kept** (**stored**) in glass, metal or Teflon® containers (as certain plastic materials may react with hydrocarbons), at the temperature of 4-5 °C (but not frozen), and sent to the laboratory as soon as possible. **Stabilization in the field** may be required, if a delay in sending samples to the laboratory is expected, however it should be done by qualified personnel.

In case of a deliberate discharge of oil, the identification of the source of pollution through samples taken from the sea surface or from shore will be accepted as a sufficient legal evidence only providing that a sample of suspected oil cargo or oil from the machinery space of a suspected ship is also available and can be compared with the sample taken from sea or shore. A standard operating practice for commercial vessels is to keep on board samples of oil taken during loading of cargo and bunkers (in case of commercial disputes). If these are not available, samples have to be taken from the cargo and machinery spaces of the suspected vessels upon their arrival in the nearest port.

3.2 Water sampling

Water quality measurements can be done *in situ* by **field sensors** (that can provide **general data** on pH, salinity, conductivity, COD, BOD, or **oil-specific data** on e.g. concentrations of dispersed oil) or by **collection of samples** and sending them to a laboratory for analysis, which is still the most common practice. In order to avoid contamination by oil films present on the water surface, samples are taken from water column by sampling devices that are lowered to a desired water depth when closed, then opened and closed again prior to retrieval.

3.3 Sediment sampling

Sediments can be taken from sub-tidal or inter tidal zones. In the first case samples are taken by shallow grabs, and in the second case by using surface scrapers or special devices for taking core samples. Training is needed for operators of both types of devices.

3.4 Biota sampling

Samples of biota may involve both wild species and farmed species. The method used depends on types of species that are required: species living near the seabed or in the water column, species living on the seabed or in sediments, as well as birds and mammals. Samples from mariculture facilities are taken jointly with the operators of these facilities, while samples of commercially exploited species may be purchased from fishermen or be collected jointly with the them.

Samples from birds and mammals can be taken from carcases of death animals, or in non-intrusive manner (e.g. from fur or feathers), from live animals. Taking samples of biota also requires specialized, trained personnel.

ENVIRONMENTAL MONITORING[4]

1. INTRODUCTION

Environmental monitoring usually aims at quantifying the **hydrocarbon contamination**, and it is therefore necessary that it focuses on the sediments or other components of the area that has been potentially contaminated, and **not on the oil** that was spilt and was the target of monitoring during spill response operations.

The reasons to conduct environmental monitoring, that are relevant to the present Programme, are primarily to **follow environmental recovery**.

This lesson aims at providing participants in the Programme with basic knowledge concerning **post-spill response** monitoring, as they might be requested to assist in the monitoring programme activities after direct spill response operations have been terminated.

2. ENVIRONEMTAL MONITORING

For the purpose of this lesson, the environmental (scientific) monitoring will mean any type of monitoring that is undertaken for purpose other than providing information to guide the response to an oil spill. It starts after the direct spill response has been terminated, and should be subject to a prior agreement between the relevant (national, regional, local) authorities and the polluter or his insurer. Scientific environmental monitoring aims at establishing the **long term impact** of the pollution on the sites, populations and species in the affected area, serves as a basis for

[4] In the preparation of this lesson the authors used Tecnical Information Paper 14 - Sampling and Monitoring of Marine Oil Spills, ITOPF, London, UK.

environmental restoration activities, and is necessary for **reasonable environmental reinstatement** after a pollution incident.

It should first investigate whether reinstatement is feasible, then follow its progress, and finally establish when the reinstatement has reached a sufficient stage to be concluded.

It is emphasized that in case of small spills that do not threaten any specific resources, **the post-spill monitoring is not necessary**.

The decision to implement a monitoring programme after a spill can nevertheless be made to:

- measure concentrations of hydrocarbons in the water or sediments;
- establish when a risk of transferring contaminants into the human food chain ceases to exist and the fishing restrictions can be lifted;
- establish whether any observed environmental effects can be attributed to increased oil concentrations related to a specific pollution incident;
- determine the decline of hydrocarbon concentrations in the marine environment and to monitor recovery;
- identify conditions appropriate for initiating and sustaining restoration measures;
- demonstrate that damage caused by the spill has been evaluated, that recovery is underway and that oil concentrations in the marine environment are returning to background levels.

The **aim** of any monitoring programme must be to provide **reliable**, **objective** and **useful** information to answer specific, rational concerns about the presence of oil spilt in the environment. Specific objectives of a programme are set by the competent authorities, or in response to specific claims against the polluter, and this has to be done at an early stage in cooperation between all parties involved.

2.1 The cost of monitoring

Regardless of who is expected to pay for the monitoring programme, it is good practice to prepare a proposal containing an itemised budget. The proposal could be discussed with the parties paying compensation prior to the start of monitoring.

Table 1: typical components of a monitoring budget proposal

BACKGROUND	SAMPLING	ANALYSIS	LOGISTICS
• case, name dates, location • names / affiliations of scientific team • objectives, methods, procedures	• period, frequency • geographic scope • sample types	• laboratories undertaking analyses • analytical plans and related costs • data commitment for publishing report	• description of costs of equipment and materials • costing of any special logistic support • costing of travel and accommodation

Reproduced from "Technical Information Paper 14 – Sampling and Monitoring of Marine Oil Spills“, ITOPF, London, UK, 2012

Generally, the cost of monitoring should reflect the level of effort involved, the frequency of surveys, the number of samples, the types of analysis and it has to be proportional to the scale of the issues being addressed.

2.2 Monitoring shoreline and land contamination

Scientific environmental monitoring of shoreline contamination aims at determining the long term impacts of the pollution on materials, the environment and the species residing in the affected area. It requires an in-depth knowledge of the types of the affected shores. The results of the monitoring should include:

- a detailed account of the progress of shoreline contamination, and of the removal of the pollutant;

- a summary of physical and chemical degradation of the shore by the pollutant and its natural or assisted reinstatement;
- a record of the impacts on characteristic species and habitats in the affected area (long term consequences on flora and fauna).

Contaminants can also be carried by wind and waves from the shoreline towards the land (up to several hundred meters in extreme cases). If contamination of land has occurred, it may be necessary to monitor it too.

Such long term environmental monitoring is carried out by botanists and specialized biologists. If botanical restoration is planned, the techniques to be used may range from simply pruning back the vegetation to promote new growth, to planting cuttings after cleaning the soil.

Monitoring on land comprises:

- damage assessment;
- planning the restoration;
- preparing and overall account of natural restoration and operations that were conducted.

2.3 Monitoring water contamination

It aims at determining the long term impact of the pollution incident on the water column and the populations living in water. This type of monitoring is carried out by oceanographers, with a support of chemists, biologists and ecotoxicologists. The main types of monitoring in this group include:

- monitoring of the concentration and breakdown (including biodegradation) of the pollutant in the water column;
- specific monitoring of the levels of contamination that correspond to the known danger thresholds, for particularly dangerous molecules compounds;
- monitoring of bioaccumulation of pollutants and progressive decontamination of aquatic animals and plants; and
- monitoring of the consequences on the biological balances in the affected environment and the progressive restoration of such balances.

2.4 Monitoring of coastal marshes

Coastal (and in particular maritime) marshes and their populations are among the prime victims of oil spills. In addition, their nature practically excludes the effects of natural clean-up, while their sensitivity severely limits clean options, including manual clean-up operations. Infiltration of oil or other pollutants into such areas is promoted by regular alternation of arrival and evacuation of water during tidal cycle.

Consequently, coastal marshes should be given a high priority for long term environmental (ecological) monitoring of both:

- qualitative parameters (specific diversity); and
- quantitative parameters (abundance and evolution of the pollutant, abundance of species, evolution of the biomass).

MEASUREMENT OF OIL SAMPLES[5]

1. INTRODUCTION

The results of monitoring activities undertaken before, during and after an oil spill will entirely depend on the results of chemical analyses of the samples taken as part of the monitoring programmes.

Analyses is normally carried out in certified (licensed) laboratories, that may be either public or private.

Analysis of oil and oiled samples taken from sites contaminated by a pollution incident is a highly specialized work that is necessarily performed by professionals in that field.

The **aim** of this lesson is only to inform the participants in the Programme of the different analytical technics that are used and their purpose.

2. ANALYTICAL METHODS AND TECHNIQUES USED

There are no universally applicable standards or guidelines for analysis of oil pollution samples, however there are various relevant protocols at international and national levels that can be followed during sample analysis. These include protocols published by the following organizations:

[5] In the preparation of this lesson the authors used Technical Information Paper 14 - Sampling and Monitoring of Marine Oil Spills, ITOPF, London, UK, 2012.

- European Committee for Standardization (CEN);
- American Society for Testing and Materials (ASTM);
- American Petroleum Institute (API);
- US Environmental Protection Agency (US EPA);
- Canadian Council of Ministers of the Environment (CCME).

Prior to the start of analyses, the samples received in the laboratory need to be cleaned to remove extraneous materials (e.g. debris) and to concentrate hydrocarbon compounds (usually by solvent extraction and chromatography). These preliminary procedures are then followed by one or more of the following analytical techniques.

2.1 Ultra violet fluorescence (UVF)

UVF is a qualitative and quantitative analytical method used for detecting the presence of oil in samples. It is capable of detecting very low concentrations of oil in water (down to 0.1 µg/l), and can also determine 1.0 mg/kg of oil in sediments.

It is considered as a quick and valuable technique for confirming the presence of oil, but is not routinely used to confirm a source sample, as this necessitates the analysis of individual oil components. UVF is not appropriate for “fingerprint” analyses because some non-hydrocarbon molecules can interfere with the signals emitted by polycyclic aromatic hydrocarbons (PAH) that characterize each oil.

2.2 Gas chromatography – flame ionization detection (GC-FID)

GC is an analytical technique for separating complex mixtures of hydrocarbons in oil into component molecular groups, while FID is a sensor that responds to ions released by combustion of molecules washed out from a GC column. The results are computer processed and show peaks corresponding to the compounds that are present in higher concentrations.

GC-FID can be used for relatively rapidly screening and fingerprinting of oil samples, but is also used for quantitative measurement of hydrocarbons.

2.3 Gas chromatography – mass spectrometry (GC-MS)

The coupled GC-MS consists of gas chromatograph linked to a mass spectrometer, which detects and analyses each molecule separately, and enables the accurate, high resolution detection and identification of molecules. Its resolution is high, which makes it a first choice technique for the identification of biomarkers, volatile organic compounds (VOC) and specific PAHs. The limits of detection for GC-MS are very low (0.1 µg/kg).

2.4 Selection of the appropriate technique

The selection depends on the objectives of the monitoring programme.

For proving that a spill sample was derived from a suspected source, the sample is subject to qualitative analysis using GC-FID screening, and GC-MS analysis of biological markers (biomarkers).

If the monitoring programme envisages following total hydrocarbon contents in samples taken in the affected environment and recording the return to background levels, UVF and GC-FID will be used.

GS-MS is used for analysis of biota and, in particular, for analysis of species intended for human consumption, when measurement of the concentrations of PAH is required.

REMEDIATION OF MARINE ENVIRONMENT AFFECTED BY AN OIL SPILL

1. INTRODUCTION

The terms remediation, restoration and reinstatement are often used interchangeably in the context of environmental damage caused by oil pollution incidents, although certain legislations define each one differently. For the purpose of the present Manual remediation is used primarily as a substitute for "bioremediation", while "reinstatement" (or "restoration") is used for any action aimed at restoring the environment to its former state.

Claims Manual of the International Oil Pollution Compensation Funds (IOPC Funds) states that "…the aim of any reasonable measures of **reinstatement** should be to re-establish a biological community in which the organisms [that are] characteristic of that community at the time of the incident are present and are functioning normally". Lesson **L 3.5** addresses such "reasonable measures", while the present lesson focuses on basic concepts of bioremediation.

The **objective** of the lesson is to provide participants in the Programme with basic information concerning bioremediation as a method of restoration of coastal marine environment that has been affected by an oil spill.

2. BIOREMEDIATION

Bioremediation refers to the use of either naturally occurring or deliberately introduced microorganisms to consume and break down environmental pollutants, in order to clean a polluted site (source: Concise Oxford English Dictionary, 11th edition, 2005).

It is a process for treatment of a contaminated environment (water, soil and subsurface material) by altering environmental conditions, aimed at stimulating growth of microorganisms and at degrading oil. As already indicate in Lesson **L 1.3**, there are numerous bacteria, moulds, fungi, yeasts, and other microorganisms that are present in the marine environment and can biodegrade oil, or rather hydrocarbons in it. When bioremediation of oil is planned to be used as a method of restoration of contaminated sites, the main requirement is that such microorganisms are present in sufficient quantities to degrade oil relatively rapidly.

Biodegradation is most useful for degrading oil on land, not exactly on shoreline, as the physical, chemical and biological factors can be controlled. Several biodegradation techniques have been developed, and are used, to increase the natural rate of oil degradation. These can be applied **on the site that has been contaminated** (*in situ*) or **in another place**. The advantage of using biodegradation *in situ* is that it is cost effective and non-destructive, while applying it off site requires excavation of the polluted material, its transportation to treatment site and its return to the original site, which drastically increases costs. The two most common bioremediation techniques include:

2.1 Biostimulation

The method is based on **addition of nutrients** (that could limit the growth rate of microbial population if exhausted) to accelerate biodegradation of oil by indigenous (naturally present) bacteria. Nutrients that are added must be rich in nitrogen and phosphorus. Effective bioremediation requires that nutrients remain in contact with the oiled material, and their concentrations should be sufficient to support the maximal growth rate of the oil-degrading microorganisms. “Land-farming” techniques (mentioned in Lesson **L 2.8**) could be applied, if possible, in order to further facilitate biodegradation.

2.2 Bioaugmentation

Bioaugmentation is a bioremediation technique based on **adding oil degrading microbes** to oiled material in order to supplement the existing microbial population. However, as the population of hydrocarbon-degrading microbes rapidly increases naturally in the presence of oil, it is almost impossible to further increase the size of the population above the size that is achieved by biostimulation alone.

REASONABLE ENVIRONMENTAL REINSTATEMENT[6]

1. INTRODUCTION

Each specific marine environment supports the plants and animals that live within it, as well as various human activities carried out on shore and at sea. An oil spill can affect both the normal functioning of the natural ecosystem and human economic activities that depend on its proper functioning. Therefore, the reinstatement of the marine environment to the state it was before being affected by spilt oil may be necessary, particularly in case when the coastal area has been affected by a larger spill.

On the other hand, it has to be taken into consideration that marine environment is naturally very resilient, being subject to an extreme range of physical conditions, and very often following an oil spill of limited size and effects reinstatement measures may not be required at all.

The Claims Manual of the International Oil Pollution Compensation Funds (IOPC Funds) states that "the aim of any reasonable measures of **reinstatement** should be to re-establish a biological community in which the organisms, characteristic of that community at the time of the incident, are present and are functioning normally".

This lesson focuses on the reinstatement measures that are considered reasonable according the above definition and aims at providing participants in the Programme with basic information concerning such measures.

[6] In the preparation of this lesson the authors used "Guidelines for presenting claims for environmental damage", IOPC Funds, London, UK, 2018.

2. REINSTATEMENT MEASURES

Whether or not reinstatement measures will be needed depends on the **sensitivity** of the affected resources to contamination by oil and their **natural rate of recovery**.

Some species suffer sub-lethal effects such as impaired feeding and reproduction and juveniles, eggs and larvae are particularly sensitive to toxic components of oil. Nevertheless, such impacts can be **rarely observed at population levels** in the environment, due to e.g. recruitment from adjacent unaffected areas.

The aim of reinstatement measures should be to **enhance the recovery** of damaged environments.

The alternative concept of bringing back the affected site to a theoretical condition that would exist had the spill not occurred, is not usually practical as the exact state of the environment before the spill is not known.

In order to be considered reasonable, the reinstatement measures should:

- aim at enhancing the recovery of the damaged component of the environment;
- have a realistic prospect of significantly accelerating the natural process of recovery;
- be based on sound scientific principles;
- aim at preventing further damage as a result of the incident;
- not result in the degradation of other habitats or in adverse consequences for other natural or economic resources;
- be designed with a view to ensuring that there is a link between the measures taken and the damaged component of the environment; and
- be technically feasible.

Last but not least, the costs of the reinstatement measures should be in proportion to the extent and duration of the damage and the benefits likely to be achieved.

3. POTENTIAL REINSTATEMENT MEASURES FOR DIFFERENT HABITATS

HABITAT	POTENTIAL REINSTATEMENT MEASURES
Sand beaches	Re-profiling beach, sand replenishment
Sand dunes	Re-planting of dune plants
Rocky shorelines	Re-colonisation or replanting to restore local populations
Salt marshes	Re-colonisation and replanting programmes to restore and enhance habitat
Sea grass communities	Habitat reinstatement through replanting and reseeding programmes to restore and enhance local communities
Coral reefs	Habitat reconstruction and recolonization

* Modified from the “Guidelines for presenting claims for environmental damage”, IOPC Funds, London, UK, 2018.

4. POTENTIAL REINSTATEMENT MEASURES FOR DIFFERENT POPULATIONS

POPULATION	POTENTIAL REINSTATEMENT MEASURES
Marine mammals	• Capture, clean, rehabilitate and release • Captive breeding and release
Marine reptiles	• Capture, clean, rehabilitate and release • Collection and relocation of turtle eggs • Predator control
Birds	• Capture, clean, rehabilitate and release • Predator control
Fish and shellfish	• Restocking fishery

* Modified from the “Guidelines for presenting claims for environmental damage”, IOPC Funds, London, UK, 2018.