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Barcelona Convention

REMPEC

IMO INTERNATIONAL MARITIME ORGANIZATION

Guidelines for the use of dispersants for combating oil pollution at sea in the Mediterranean region

Part II

Basic information on dispersants and their application

2025 Edition

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Note

This activity is financed by the Mediterranean Trust Fund (MTF) and is implemented by the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC).

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Foreword

In a large part of the Mediterranean coastal States, the use of dispersants as a response method for combating accidental oil spills at sea has not as yet been covered by specific national regulations.

Controlled and appropriate use of selected dispersants on types of oil amenable to chemical dispersion, is widely recognized as one of the useful methods for combating accidental oil spills, and in particular the massive ones. Moreover, under certain sea and weather conditions the use of dispersants might be the only applicable response method for protecting sensitive natural resources, coastal installations or amenities.

However, the opportunistic attitude regarding the use of dispersants is hardly acceptable. Selection of products which might be used, definition of zones in which their use is either allowed or prohibited and their place in the general strategy of pollution response need to be adequately regulated if the use of dispersants is expected to produce desired results without creating additional risks for the environment.

Considering the developments in the field of dispersants since the October 1998 edition of the "Guidelines for the Use of Dispersants for Combating Oil Pollution at Sea in the Mediterranean Region", the Ninth Meeting of the Focal Points of the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC), Malta, 21-24 April 2009, tasked the Mediterranean Technical Working Group (MTWG) to review their content.

This new edition of the Guidelines, endorsed by the Tenth Meeting of the Focal Points of REMPEC, Malta, 3 to 5 May 2011, has been prepared with the technical support of the 'Centre of Documentation, Research and Experimentation on Accidental Water Pollution' (Cedre) and reviewed by the Centre in collaboration with the MTWG.

They aim at assisting the Mediterranean coastal States in developing and harmonizing national laws and regulations regarding the use of dispersants in response to oil spills at sea. It does not refer to the use of dispersants on shore.

The Guidelines are divided into four independent parts addressing different issues. Each part has been developed with a specific objective and is aimed at different end-users:

PART I **REGIONAL APPROVAL**

Part I which remains unchanged when compared to the version adopted by the Eighth Ordinary Meeting of the Contracting Parties to the Barcelona Convention (UNEP (OCA)/MED IG.3/5, Appendix I, Antalya, Turkey 15 October 1993), provides regionally approved guidance for the development of national laws and regulation on the use of dispersants.

PART II **BASIC INFORMATION ON DISPERSANTS ANDTHEIR APPLICATION**

Part II provides theoretical information on dispersants and their application. It is aimed at providing background information on the matter to any person interested in the subject.

PART III **OUTLINE AND TEMPLATE FOR A NATIONAL POLICY ON THE USE OF DISPERSANTS**

Part III has been prepared with a view to assisting coastal States in the development of their national policy on the use of dispersants. It has been developed as a template which can be followed and adapted by the authorities in charge of the development/ maintenance of the national policy on the use of dispersants and can also be used for the implementation of national or local contingency plan for dispersants.

PART IV **OPERATIONAL AND TECHNICAL SHEETS**

Part IV is based on the publication entitled “Using dispersant to treat oil slicks at sea. Airborne and shipborne treatment. Response manual” (CEDRE 2005). It provides a set of practical technical sheets which point out the different operational issues when using dispersants. It has been developed for operational users with a view to providing them with the required knowledge for efficient dispersant application.

In order to keep the coastal States regularly informed of the current situation regarding the use of dispersants, REMPEC shall update this document to include any new and significant developments in the research field.

GUIDELINES FOR THE USE OF DISPERSANTS FOR COMBATING OIL POLLUTION AT SEA IN THE MEDITERRANEAN REGION

PART II

BASIC INFORMATION ON DISPERSANTS AND THEIR APPLICATION

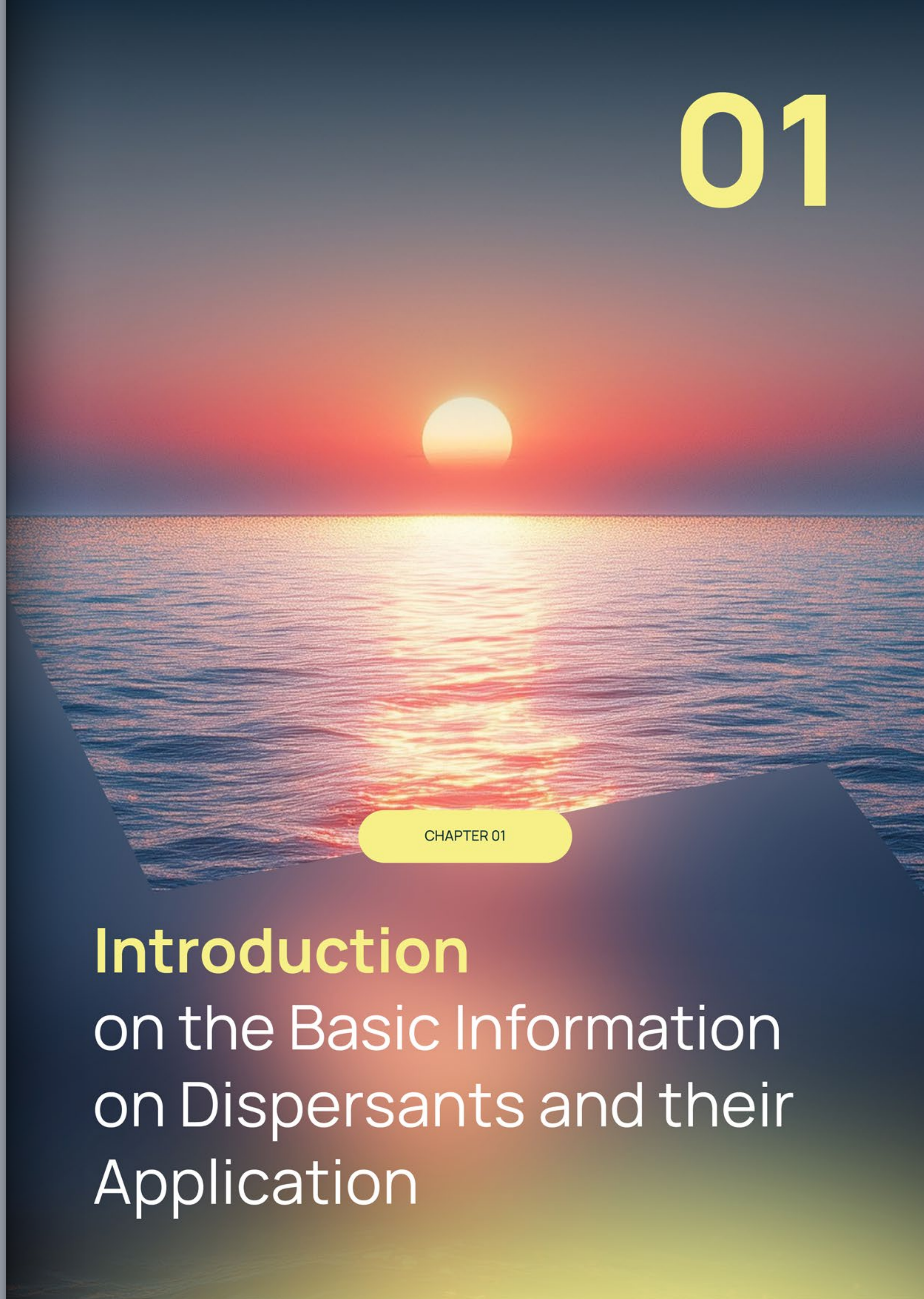
Table of Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

Cedre: Centre of Documentation, Research and Experimentation on Accidental Water Pollution
CERA: Consensus Ecological Risk Assessment
CRA: Comparative Risk Assessment
CRCC: Coastal Research Response Center
DOR: Dispersant-to-Oil Ratio
EMSA: European Maritime Safety Agency
ERA: Ecological Risk Assessment
IBC: Intermediate Bulk Container
ISPRA: Italian Institute for Environmental Protection and Research
LSFO: Low Suflur Fuel Oil
MAP: Mediterranean Action Plan
NEBA: Net Environmental Benefit Analysis
OSRL: Oil Spill Response Limited
PAH: Polycyclic Aromatic Hydrocarbon
SIMA: Spill Impact Mitigation Assessment
SPAMI: Specially Protected Areas of Mediterranean Importance
WAF: Water Accomodated Fraction



01

CHAPTER 01

Introduction on the Basic Information on Dispersants and their Application

PART II

BASIC INFORMATION ON DISPERSANTS AND THEIR APPLICATION

1. INTRODUCTION

Since their first application on a large scale (in the aftermath of the "Torrey Canyon" oil spill in 1967), the use of dispersants as a response method for combating accidental oil spills has remained a controversial issue. Although often recognized by cleanup specialists as one of the most effective methods for dealing with oil spills, chemical dispersion of spilled oil has numerous setbacks. The controversy partly stems from lack of information, prejudice and misunderstanding of the action of dispersants. The opposition to using dispersants is often also inspired by the results of their insufficiently planned or improper application. The use of dispersants, especially the decision-making process as well as the application process, need to be planned carefully at national level and supported by an appropriate rational stated in a policy.

A relatively small number of countries in the Mediterranean region have a clearly defined policy regarding the use of dispersants. The current status on the policy of use of dispersant in Mediterranean Coastal States can be consulted on REMPEC's Country Profile *(https://www.rempec.org/en/knowledge-centre/country-profiles)* available on REMPEC's website (www.rempec.org). The lack of a clear policy regarding dispersants and their use inevitably results in heated discussions at the time of the spill.

The objective of this document is to provide relevant, up to date information on dispersants and their place in oil spill response strategy, which may help the Mediterranean coastal States in creating their policy regarding the use of these products in combating accidental oil pollution. In this respect the document proposes, in Part III, a standard policy for the use of dispersants to be used as a model and adapted by States which would set their National Policy on the Use of Dispersant.

Generally speaking, a policy for the use of dispersants should be based on a full understanding of the action of dispersants and currently utilized application methods and operational practices, as well as on adopting compatible and, if possible, standardized procedures for testing and assessing efficiency, toxicity and biodegradability of dispersants and oil/dispersants mixtures.

The first part of this document is devoted to the main physical, ecological and socio-economic characteristics of the Mediterranean Sea. This is followed by a presentation of the main aspects of dispersants, their use, their effects on the environment and the tools for selecting their use in the context of an oil spill. It concludes with some brief recommendations on the use of dispersants in the Mediterranean context.

The Mediterranean Sea: Principal Feature

2. THE MEDITERRANEAN SEA: PRINCIPAL FEATURES

This chapter focuses on the main environmental and economic characteristics of the region as a whole. The specific features of each country are therefore not discussed. Its aim is to highlight the main elements that **could influence the use of dispersants as a means of combating accidental oil pollution.**

2.1 Physical characteristics of the Mediterranean Sea

2.1.1 Geography and geomorphology

The Mediterranean Sea, whose Latin etymology refers to "a sea in the middle of the land", is the largest intercontinental sea, with a basin covering 2.51 million km^2 and a total volume of seawater estimated at 3.842 millions km^3. From east to west, this semi-enclosed basin extends for almost 4,000 km between the Strait of Gibraltar, which connects it to the Atlantic Ocean, and the coasts of the Levant. At its widest, it is 800 km between Algiers and Genoa, and 140 km between Sicily and Cap Bon in Tunisia. The Strait of Gibraltar separates Spain and Morocco by just 14 km. To the northeast, the Mediterranean Sea is connected to the Black Sea by the Dardanelles Strait in the Sea of Marmara. To the southeast of the basin, the Suez Canal has joined the Mediterranean and Red Seas since 1869.

It is generally accepted that the Mediterranean Sea is divided into two main geographical zones, at the level of the Strait of Sicily, which themselves include several inland seas. These are :

i. The **Western Mediterranean**, influenced by the Atlantic, which includes the Alboran Sea, the Algerian-Provençal Basin and the Tyrrhenian Sea, and has a surface area of 0.85 million km^2 and

ii. The **Eastern Mediterranean**, comprising the Aegean, Ionian, Adriatic, Libyan and Sicilian seas and the Levantine and Pelagian basins, covering some 1.65 million km^2.

Figure 1. Map of the Mediterranean Sea (©Cedre).

Basic information on dispersants and their application

The Mediterranean Sea has numerous straits and channels, which are particularly important geomorphological features for the exchange of water masses, not only between the various sub-basins of the region, but also with adjacent seas and oceans. The Mediterranean basin is drained by 19 major rivers, including the Nile, Rhône, Po and Ebro.

2.1.2 Bathymetry

In the Mediterranean context, the 200 m isobath is commonly used to distinguish the continental shelf from the slope, representing respectively less than 25 % and 60 % of the entire basin. The continental shelves are relatively narrow, except in a few areas (Adriatic Sea, Aegean Sea and the shelf between Sicily and Libya), and the continental slope, which corresponds to the transition zone between the continental shelf and the deep environments of the abyssal plain, is characterized by a steep slope. The abyssal plain occupies around 15 % of the seabed. The average depth of the Mediterranean Sea is 1,536 m, and the deepest isobaths are located in trenches at 2,855 m in the western part of the basin and 5,121 m in its eastern part.

Terrigenous deposits from rivers contribute to the development of the basin's bathymetry, mainly in its coastal zones.

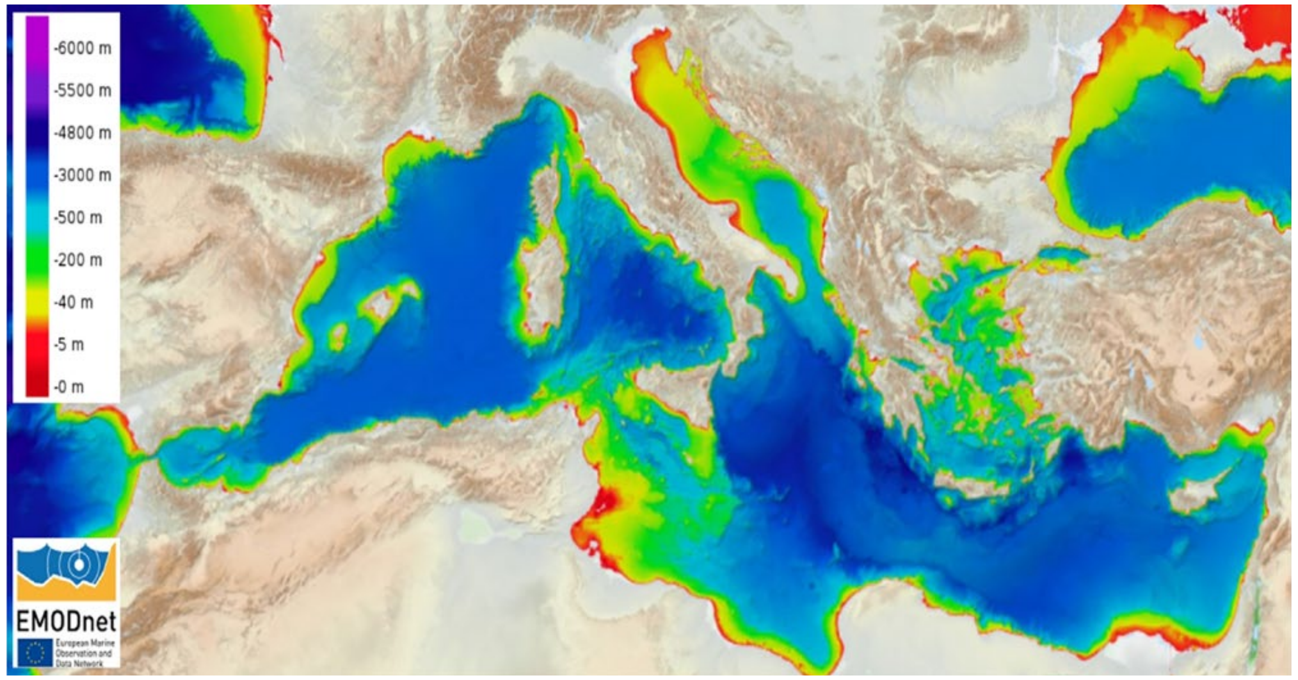


Figure 2. Map of the bathymetry of the Mediterranean Sea.

Bathymetry is a limiting factor in the application of dispersants, since it determines the dilution required to ensure that dispersed oil concentrations quickly have the least adverse effect on the environment. The map above shows the zones (1, 2, 3 and 4) where bathymetry could be a limiting factor for the correct use of dispersants.

2.1.3 Hydrology, temperature and salinity

- **Hydrology**

The numerous continental reliefs bordering the Mediterranean basin are the source of cold, dry regional winds from the north (e.g. Tramontane, Mistral, Bora, etc.), which cause significant volumes of water to evaporate, as well as heat loss from surface waters. These winds and the region's climate influence the water balance of the Mediterranean Sea, which is negative over a multi-year period. Water losses to the atmosphere due to evaporation outweigh gains from precipitation and river inflow.

Total precipitation is marked by strong spatio-temporal variability, and is below 200 mm/year in North Africa and the Arabian Peninsula, while it can reach 2,000 mm/year in the more mountainous regions to the north. Depending on the area, winter rainfall accounts for between 30% and 80% of total annual precipitation.

- **Salinity**

Due to high freshwater evaporation rates, the salinity of Mediterranean waters is high: it varies from 37 to 39.50 g/L from west to east, except near estuaries or large river deltas, where it can be lower due to freshwater inflows. For information, the average salinity of the world's seas and oceans is around 35 g/L.

- **Temperature**

The Mediterranean basin is subject to seasonal variations, with significant annual thermal contrasts. In summer, surface water temperatures range from 21°C to 30°C, due to strong sunshine, while in winter they fall to around 10°C to 15°C. There is also a positive temperature gradient from west to east.

Table 1. Summary of the main physical and chemical characteristics of the Mediterranean Sea

Surface area (total)	2.51 x 10^6 km^2
2000 – 3000 m depth contour	30 %
less than 200 m depth contour	20 %
Volume less than 200 m depth contour	55.5 10^3 km^3
Salinity of surface water	37 to 39.5
Temperature of surface seawater (average)	10 to 30°C

2.1.4 Circulation and currents

The Mediterranean Sea is made up of three water masses:

- a surface layer of relatively warm, low-salt water from the Atlantic Ocean;
- an intermediate layer and a deep layer of colder, saltier and denser water.

Water from the Atlantic enters the Mediterranean basin via the Strait of Gibraltar. Less dense than the resident water masses, it remains on the surface and determines the currents in the surface layer. The Atlantic waters are then disseminated eastwards in the southern regions, returning westwards in the northern parts. The thermohaline circulation thus generated describes a general counter-clockwise circuit in each basin. This current is strongest in summer, when evaporation is highest.

Locally, whirlpools and other currents of lesser magnitude than the general current are generated by the morphology of the northern coastline, as well as by the numerous islands in the Mediterranean Sea.

In the overall of the Mediterranean, tidal currents are of low intensity, of the order of a few mm/s. There are, however, local exceptions, such as in the Gulf of Gabès and the northern Adriatic, as well as in passage areas such as the Strait of Gibraltar, the Strait of Messina and the Sicilian Channel, where tidal currents can sometimes reach a few meters per second.

2.2 Ecological characteristics

The Mediterranean basin is characterized by environmental disparities, due in particular to its particular hydrological pattern, which results in a higher nutrient content of the waters at the western end than at the eastern end. As a result, organic production decreases from west to east and from north to south.

2.2.1 Biodiversity

The Mediterranean region is internationally recognized as one of the world's "ten biodiversity hotspots". Depending on the taxon, it is home to between 4 % and 18 % of the world's known plant and animal species, yet accounts for less than 1 % of the oceans' total surface area. It is home to 21 species of marine mammals, 750 species of fish, 5 species of sea turtles and over 360 species of breeding seabirds. It is estimated that 30 % of these species are endemic to the Mediterranean.

2.2.2 Sensitive and endemic habitats

The Mediterranean includes a wide variety of ecologically valuable benthic habitats. These provide essential functions for marine species in terms of feeding, reproduction and shelter. They also provide multiple ecosystem services to human populations.

Several of these are nevertheless considered sensitive and are threatened by various pressures, mainly of anthropogenic origin, generating direct or indirect negative impacts. These include Posidonia meadows, endemic ecosystems of the region occupying between 20 and 50% of the coastal seabed, coralligenous seabeds, deep coral reefs and underwater caves.

2.2.3 Protected areas

In 1976, the Barcelona International Convention was adopted for the protection and sustainable management of the Mediterranean marine environment and coastline. The 22 Parties are: Albania, Algeria, Bosnia-Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Slovenia, Spain, Syria, Tunisia, Turkey and the European Union. It is the most important regional multilateral agreement on environmental protection in the Mediterranean, with a legally binding dimension.

The Convention is supported by seven protocols adopted as part of the Mediterranean Action Plan (MAP). Among these, the protocol on specially protected areas and biological diversity encourages the contracting parties to create marine protected areas, which can be included in the list of specially protected areas of Mediterranean importance (SPAMI).

In 2020, 8.33 % of the Mediterranean Sea benefit from official protection status through three types of protected areas:

- **Marine Protected Areas (MPAs)** and **Specially Protected Areas of Mediterranean Importance** (SPAMIs), designated as such at national level by the signatory states of the Barcelona Convention. There are currently 75 such areas;

- **Natura 2000** sites, limited to the 8 signatory parties who are members of the European Union, and

- the **Pelagos Sanctuary** which is the only MPA in the Mediterranean with international status, thanks to an agreement between France, Italy and Monaco. Covering an area of 87,500 km², this marine area was created to protect marine mammals.

Other areas benefit from special protection efforts, including fishing restriction zones designed to protect essential fish habitats and deep-water benthic habitats, where dredging and trawling techniques at depths greater than 1,000 m are prohibited.

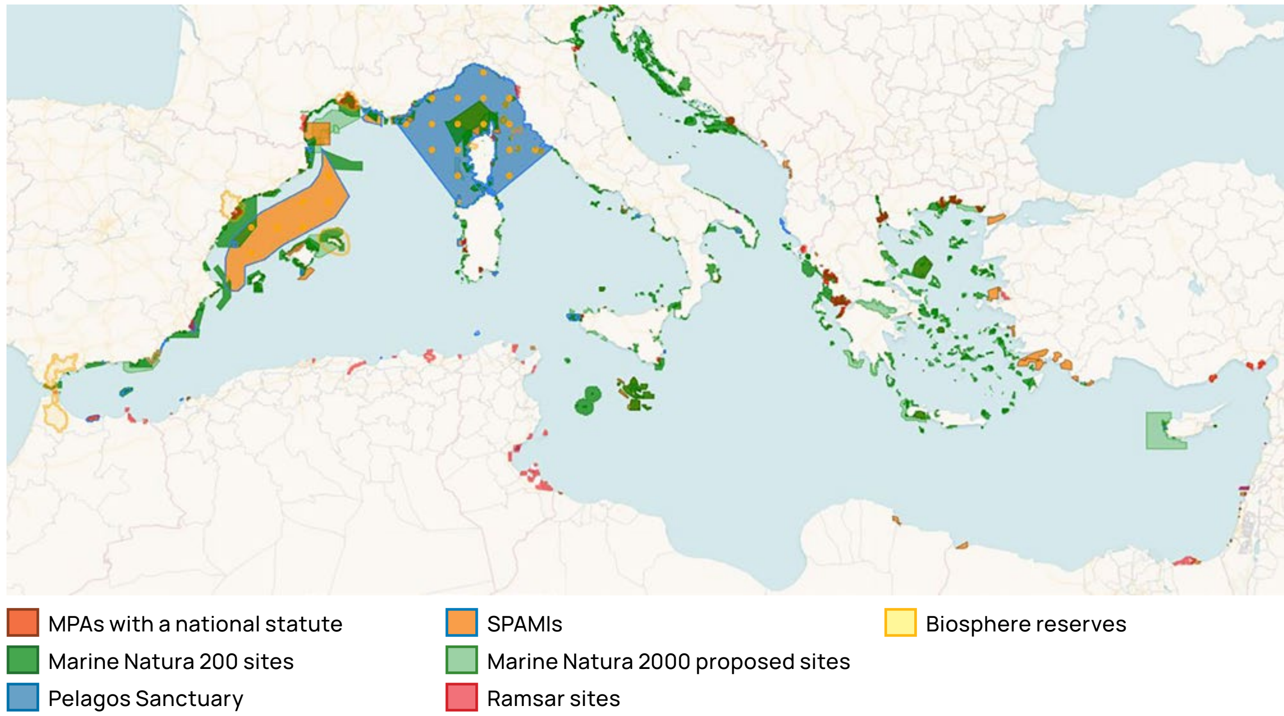


Figure 3. Example of some protected areas and areas of conservation importance in the Mediterranean basin (interactive map available on: https://www.mapamed.org/).

2.2.4 Protected species

Several species living in the Mediterranean basin are threatened with extinction and therefore benefit from special protection status. Some are endemic, such as the Mediterranean Monk Seal (*Monachus monachus*) or the Posidonia (*Posidonia oceanica*). A total of 87 species of flora and fauna are protected in the Mediterranean Sea, thanks to international conventions (e.g. Barcelona, Bonn and Bern conventions), European directives and national and local decrees and orders.

In addition, 12 of these species are on the International Union for Conservation of Nature (IUCN) Red List, which lists the conservation status of plant and animal species worldwide according to precise criteria.

Table 2. Number of plant and animal species with special protection status present in the Mediterranean basin. According to the IUCN Red List, each species or subspecies can be classified in one of the following nine categories: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), Not Evaluated (NE).

Taxa	Number of species	IUCN Red List species
Plants	20 including 15 species of algae	
Sponges	10	
Cnidarians	4	
Molluscs	17	
Echinoderms	3	
Crustaceans	6	
Fishes	17	Sea lamprey (NT), Twait shad (VU)
Reptiles	1	Loggerhead sea turtle (DD)
Mammals	9	Fin whale (NT), Bottlenose dolphin (NT), Mediterranean monk seal (VU), Long-finned pilot whale (VU) Risso dolphin (VU) Sperm whale (VU), Common dolphin (DD), Ziphius (DD), Striped dolphin (LC)

2.3 Economical activities

Marine and maritime resources are the foundation of most economic activities in the Mediterranean, including fishing and aquaculture, tourism, maritime transport and port activities, and offshore energy. This so-called blue economy generates 450 billion dollars annually in the region.

2.3.1 Fisheries and aquaculture

Commercial fishing represents a considerable part of the Mediterranean basin's economy, in terms of both financial benefits and job creation. Today's fleet numbers some 87,600 vessels, over 80 % of which are small-scale artisanal fishing vessels of less than 20 meters in length.

The combined use of a high number of small vessels and very small-mesh trawls catching small individuals has contributed to the overexploitation of almost 80% of the fish stocks assessed in this region.

In response to this trend, aquaculture has developed strongly over the last 20 years, and total production of fish and shellfish from aquaculture is estimated at 2.4 millions tonnes. Turkey, Greece, Italy and Spain account for over 80% of total production.

2.3.2 Tourism and maritime traffic

The Mediterranean ranks first among the world's tourist destinations, and is a major source of revenue for all its coastal countries. In just a few decades, the region has become the world's second-largest cruise destination after the Caribbean. The region boasts 36 major ports, handling more than 120,000 passengers a year, of which 25 are located in the western part of the basin, seven in the Adriatic and four in the eastern Mediterranean.

Thanks to its strategic geographical location, at the crossroads of three major sea crossings (the Strait of Gibraltar, the Suez Canal and the Strait of Bosphorus), the Mediterranean is an important route for international maritime traffic, particularly for the transport of oil. The combined fleet of the region's coastal states accounts for 13 % of the world's total shipping capacity.

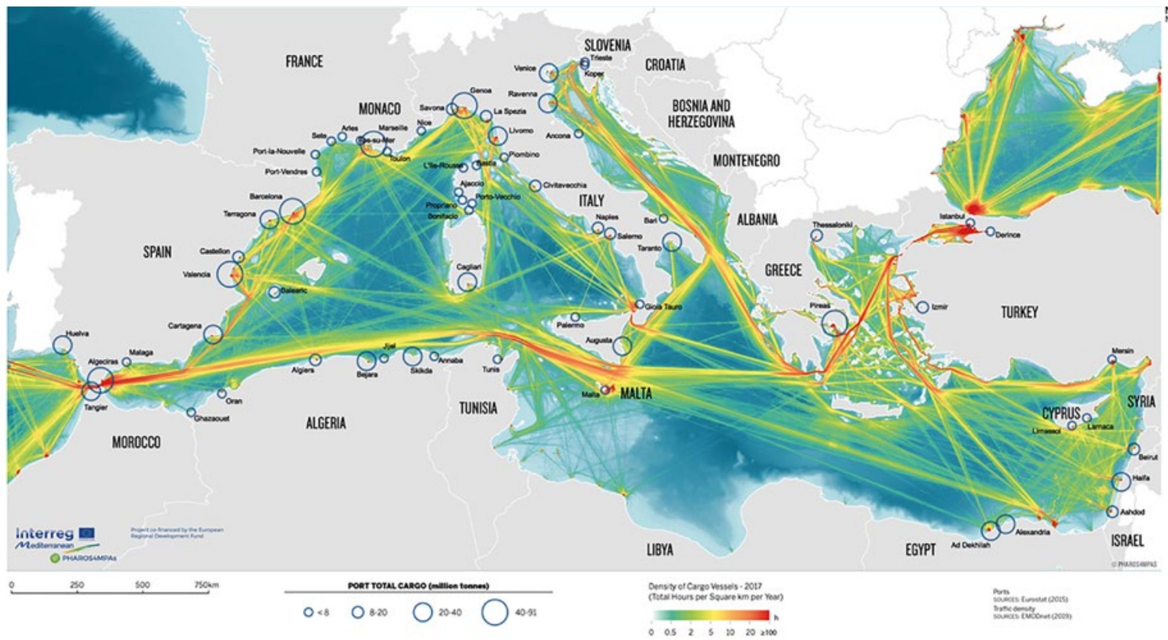


Figure 4. Maritime transportation routes in the Mediterranean Sea with an example of annual density of cargo vessels transiting in this sea (©Plan Bleu).

2.3.3 Industries

- **Extracting industries**

The Mediterranean has 323 oil and gas fields, whose production represents only a small proportion of global output. However, a considerable proportion of the world's oil, mainly from the Persian Gulf, is refined in the region by the refineries and petrochemical plants located in several of its major ports.

On the other hand, since the 1980s, Mediterranean offshore gas production has grown faster than offshore oil production. Egypt is the main producer of offshore gas in the region, followed by Italy.

- **Desalination plants**

Since the early 1980s, seawater desalination plants have expanded rapidly in the Mediterranean basin to offset the water deficits caused by an increasingly arid climate.

At present, there are regional disparities in this activity, with the southern part of the basin having fewer plants than the northern shore, but nevertheless higher production capacities: between 3,014 m³/day and 84,850 m³/day respectively, compared with 120 m³/day to 4,700 m³/day in 2023. Israel, Morocco, Algeria, Tunisia and Egypt are the countries with the highest production capacities.

03

CHAPTER 03

The Use of Dispersants

3. THE USE OF DISPERSANTS

3.1 General notions on dispersants

3.1.1 Definition

Oil spill dispersants are mixtures of surface-active agents in one or more organic solvents, specifically formulated to enhance the dispersion of oil into the seawater column by reducing the interfacial tension between oil and water. Natural or induced movement of water causes a rapid distribution within the water mass of very fine oil droplets formed by the dispersant action, thus enhancing the biodegradation processes. At the same time, oil that is dispersed is no longer subject to the action of wind which makes it drift towards the coast or other sensitive areas. Moreover, dispersants prevent coalescence of oil droplets and reforming of the oil slick.

3.1.2 History of dispersants

The idea of applying the well-known principle of removing a greasy substance by mixing it with a dispersing agent (soap, detergent) and washing it with water was first proposed in the early sixties.

The first extensive use of mixtures of industrial detergents and hydrocarbon aromatics solvents used as dispersants (first generation), in response to the **Torrey Canyon** oil spill in March 1967, unfortunately demonstrated that their toxicity was much too high and that devastating impact on marine life outweighed their efficiency as pollution cleanup agents.

Very soon after, new formulations environmentally acceptable made of less toxic surfactants much less toxic low-aromatic or non-aromatic hydrocarbons (e.g. low aromatic kerosene or high boiling solvents containing branched saturated hydrocarbons) appeared on the market. These new products became known as “second generation” (or Type 1 in the UK) dispersants or referred to as “conventionals” and are not approved for use in many countries nowadays, since new formulations have been developed.

Dispersants of “the third generation” often referred to as “concentrates” appeared by the mid-seventies. These mixtures of emulsifiers, wetting agents and oxygenated solvents which have a higher content of active components (surfactants) and less solvents are more efficient than “the second generation” dispersants and therefore can be used at lower dispersant – oil dosage than the conventionals. They can be applied from boat neat or pre-diluted into seawater, or by aircrafts (always neat). Most of the products marketed today belong to this category.

Since their appearance, dispersants have been used during numerous oil spills of various sizes all over the world and they became an important tool in responding to oil spills. The development of application techniques and significant scientific research in the field of environmental effects of dispersants and dispersed oil was followed by the development of new products.

In 2010, the major **Deep Water Horizon** accident in the Gulf of Mexico (USA) marked a turning point in the use of dispersants that were then known for their surface applications.

The spill started as a blowout and explosion occurring from a mobile offshore drilling unit. The rig then sank, and the 2,000 to 2,500 m³ of oil on the rig either burnt off or was released into the sea. Oil and gas were continuously released at sea during 87 days at high pressure.

The application of dispersants on the surface was quickly decided as a technique response as well as the unprecedented **subsea injection of dispersants** at the wellhead (1 300 m depth), without any knowledge of the potential effects of these products in the deep-sea environment.

The objectives of this intervention were to:

- **reduce the quantity of oil resurfacing** from the damaged well;
- **reduce the amount of volatile** in the atmosphere close to the damaged well (for security reason);
- reduce the amount of oil liable to be drifted to the **sensitive Louisiana shoreline** (environmental issue).

Approximately 771 272 US gallons of dispersant were injected subsea, which corresponds to around 42 % of the total quantity of dispersants used for the entire response. In terms of efficiency, uncertainties remain on the real effect of dispersants (e.g. what was really dispersed by the dispersant and what would have been naturally dispersed).

The preliminary report of the scientists community was “that the use of dispersants and the effects of dispersing oil into the water column has generally been less environmentally harmful than allowing the oil to migrate on the surface into the sensitive wetlands and near shore coastal habitats” (“Deep Water Horizon” Dispersant Use Meeting Report – May 26-27, 2010 CRRC).

It should be highlighted that the usual recommendations for regular dispersant application on surface slicks may not be suitable to the sub-sea application of dispersant on a sub-sea blowout plume. In sub-sea application the oil is fresh with its light ends, (the most toxic fractions) while surface slicks are usually partly weathered.

Considering ultra-deep environment, the environmental conditions are so different (temperature, ecological sensitivity and diversity, temperature, ***hydrodynamic conditions***, etc.) in comparison with surface water (photic zone) that the way to assess the possible impact of chemical dispersion must be carried out with particular care.

Figure 5. A U.S. Air Force chemical dispersing C-130 aircraft as part of the Deepwater Horizon Response on the surface (© US Coast Guard photo)

For further information on subsea dispersion, please consult the **part IV** of the IMO document “Guidelines on the Use of the Dispersants for Combatting Oil Pollution at Sea”, that is dedicated to this subject.

3.1.3 Nomenclature of dispersants

Since their first use in the late 60s, dispersants have constantly evolved to ensure that their formulations combine optimum efficiency in dispersing oils, with the lowest possible impact on the environment.

The nomenclature of these products has also changed, and so-called 1st generation dispersants are no longer used.

Currently, there are two types of dispersants:

- **Conventional** (or 2nd generation), which have a low surfactant content in water-immiscible solvents. Older, their use (at a rate of 30 to 100% in relation to oil) is now rather rare.

- **Concentrates** (or 3rd generation), mainly used neat but sometimes diluted, are products with a higher surfactant content in partially water-miscible solvents. More recent, their use (at a rate of 5 to 10% in relation to oil) is now widespread.

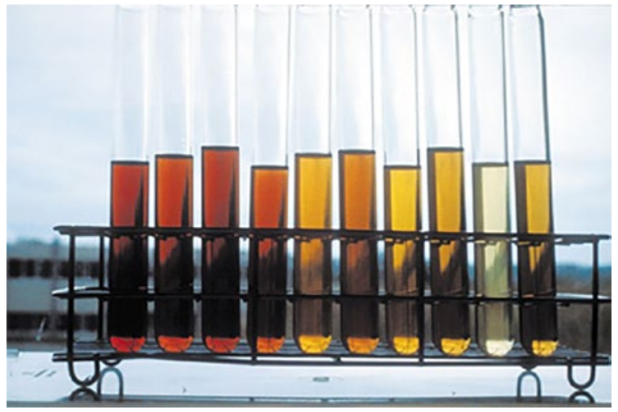


Figure 6. Different types of dispersants during tests.

3.1.4 Composition of dispersants

Oil spill dispersants are composed of two main groups of components:

- surfactants and
- solvents.

Surfactants (or surface-active agents) are chemical compounds with molecules composed of two dissimilar parts: a "water-loving" (hydrophilic) part and an "oil-loving" (oleophilic) part. Surfactants act as a 'chemical bridge' between oily materials and water and enable these two phases to mix with each other more easily (in other words the surfactant molecules when migrating to the oil – water interface, contribute to reduce the interfacial tension between oil and water). Therefore, the natural agitation (e.g. waves) can break the oil into myriads of tiny droplets which disseminate as a plume into the top layers of the water column.

In order to improve the performance of the dispersant, several surfactants are often combined but only nonionic and anionic surfactants are used in modern formulations:

- nonionic surfactants: sorbitan esters of oleic or lauric acid, ethoxylated sorbitan esters of oleic or lauric acid, polyethylene glycol esters of oleic acid, ethoxylated and propoxylated fatty alcohols, ethoxylated octylphenol.

- anionic surfactants: sodium dioctyl sulfosuccinate, sodium ditridecanoyl sulfosuccinate.

Solvents are simple or mixed added to dispersants in order to dissolve solid surfactants, to reduce the viscosity of the product thus enabling uniform application, to enhance the solubility of the surfactant in the oil and/or to depress the freezing point of the dispersant. Solvents may be divided in 3 main groups: (a) water, (b) water miscible hydroxy compounds and © hydrocarbons. Hydroxy compounds used in dispersant formulations include ethylene glycol monobutyl ether, diethylene glycol monomethyl ether and diethylene glycol monobutyl ether. Hydrocarbon solvents used in modern dispersants include odourless, low aromatic kerosene and high boiling solvents containing branched saturated hydrocarbons.

Figure 7. Aircraft from the US Coast Guard spraying dispersants (©US Coast Guard).

3.1.5 Next generation dispersants

The new generation of dispersants, also called "green dispersants", are non-volatile, non-toxic and from bio-based sources. They can be used as less environmentally damaging alternatives to traditional synthetic chemical dispersants, whose surfactants and solvents can be persistent and potentially toxic.

Recent research has tested green dispersants with surfactants and solvents that are plant-derived, from bacterial and fungal strains and also from fish and shrimp protein hydrolysates. Their reduced toxicity is notably due to the absence of organic solvents and toxic chemical compounds, which increases their biodegradability.

However, some formulations still contain synthetic chemicals as solvents but the surfactants remain bio-sourced. As with synthetic dispersants, the effectiveness of these new dispersants still depends on the operational conditions of use (type of oil, dispersant concentration, salinity and temperature of water, mixing energy, etc.). Studies have shown that their effectiveness varies widely, from 50 % to 90 %.

3.2 Physical and chemical characteristics of dispersants

Some physical properties of dispersants may have practical consequences on the use of these products (application, fire hazard, conservation). For this reason, some countries include in their approval procedure some requirements concerning the viscosity and/or pour point, flash point, and stability/shelf life.

3.2.1 Viscosity

The viscosity of a liquid is defined as its resistance to flow. The units most commonly used in the Mediterranean region for quantifying viscosity are the dynamic viscosity in "centipoise" (cP) and the kinematic viscosity in “centistoke” (cSt).

Note: in this context, as dispersant density is not far from 1, especially for the concentrates, the units centipoise and centistoke are roughly equivalent.

The viscosity of dispersants depends of the temperature. Typical viscosity range are indicated in the table below.

Table 3. Dipersant typical viscosity range

Dispersant typical viscosity ranges cP / temperature °C	0 °C	20 °C
Conventionals	10-50	5-25
Concentrates	60-250	30-100

Viscosity has an effect on the dispersant droplets size. In this respect, some countries may require some limitations in the dispersant viscosity (e.g. France dispersant viscosity must be below 80 cP at 20 °C).

3.2.2 Specific gravity

Specific gravity relates to the ratio of the weight of a solid or a liquid to the weight of an equal volume of water, at some specified temperature.

Conventional dispersants have generally lower specific gravities (0.80-0.90) than concentrates (0.90 - 1.05).

3.2.3 Pour point

The pour point of a solution is the temperature at which the sample transitions from clear to turbid.

Pour point of most dispersants is well below 0 °C (-40 to -10 °C) and in the conditions prevailing in the Mediterranean these should never solidify.

3.2.4 Flash point

The fash point is considered as the lowest temperature at which vapours above the volatile substance will ignite in air when exposed to a flame.

Most dispersants have flash point above 60 °C and should be considered as non-flammable. For practical safety reasons some countries may limit the flash point (e.g. in France, dispersant flash point must be higher than 60 °C).

3.2.5 Stability / shelf-life

If stored in appropriate facilities (sealed containers that remain intact), dispersants will not decompose or alter as the surfactants and solvents are chemically stable. Most manufacturers claim a shelf-life of 5 years or more for their product. Periodical testing will ensure that dispersants stockpiles are still effective.

3.2.6 Toxicity

Toxicity can be defined as the negative effects on organisms caused by exposure to a chemical or substance. These negative effects may be:

- **lethal** (causing death) or,
- **sub-lethal** (causing negative effects that damage the organism in some way, but do not cause death).

Exposure depends on the concentration of the substance and the period of time for which the organism is exposed to. Toxicity is usually expressed as an effect concentration at a specific time, or as an effect time at a specific concentration. Most often, effect concentrations are expressed by ratios, as parts per million (ppm) or parts per billion (ppb), sometimes replaced by the mg/L and µg/L.

Lethal concentrations of dispersants have been the main concern around these products. And even if assessing the ecotoxicological consequences of dispersants should be ideally tested on organisms *in situ*, few reports of measurements of concentrations following the use of dispersants in the field exist. The impracticability of such field tests has led to the development of numerous laboratory testing procedures. Results of such tests should be interpreted very cautiously since the tests are not intended to be ecologically realistic or to predict effects of using dispersants in the field. Most tests use concentrations and exposure duration which substantially exceed expected field exposures. For instance, the duration of exposure in laboratory experiments is generally **1 to 4 days**, much longer than those expected in most dispersant use situations in open water where dispersant would be diluted progressively and generally rapidly. Besides exposure concentrations of reported sub-lethal effects normally are **1 or 2 orders of magnitude above highest** anticipated concentrations in field use.

While in some countries the toxicity of dispersants alone is studied, in others it is the potential ecotoxicity of dispersants and **dispersed oil droplets** that is tested. More information on this subject is available in Chapter 9 of the present document.

Apart from the lethal effects, certain sub-lethal effects including changes in reproduction, behaviour, growth, metabolism and respiration may also occur when organisms are exposed to levels well below lethal thresholds.

In conclusion, results of studies investigating the effects of dispersants suggest that major effects should not occur in the near-surface waters due to a dispersant alone, provided properly screened dispersants are used at recommended application rates.

Moreover, dispersants currently on the market have been formulated with chemical compounds that are less damaging to the environment. Once introduced into the marine environment, dispersants are rapidly diluted and subjected to natural degradation processes (biodegradation and photodegradation).

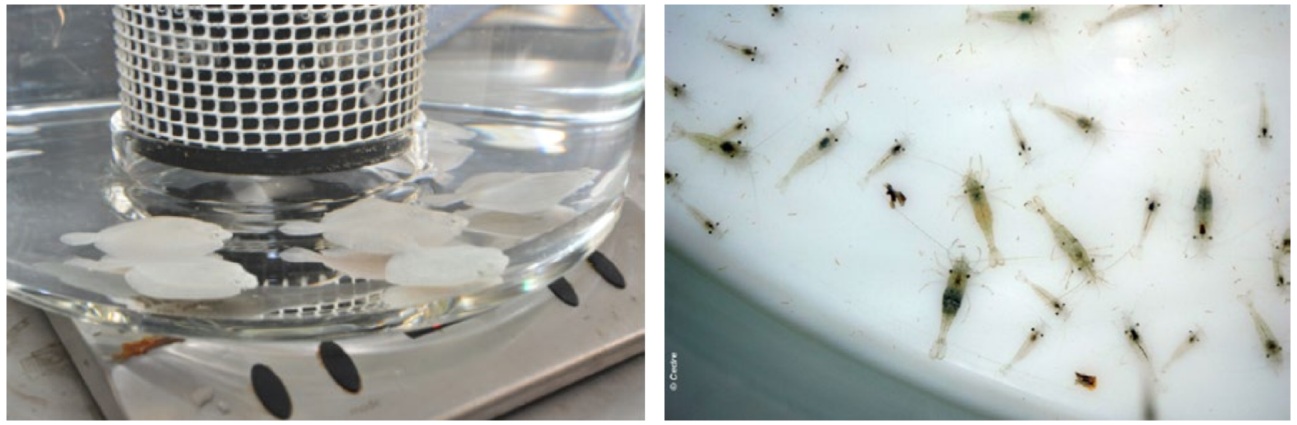


Figure 8. Toxicity tests on fishes (juvenile turbot) and shrimps conducted on pure dispersant in Cedre (© Cedre).

3.3 Storage of dispersants

If stored in appropriate facilities (sealed containers that remain intact), dispersants will not decompose or alter as the surfactants and solvents are chemically stable. Most manufacturers claim a shelf-life of 5 years or more for their product. Periodical testing will ensure that dispersants stockpiles are still effective.

However, some dispersants' components may cause the corrosion of the packages (drums or containers) in which the product is stored over the prolonged periods. Accordingly, regulations concerning dispersants in some countries require that the product does not contain such components.

3.3.1 Storage

Quantity of dispersants to be stored for emergency response needs to be assessed during the preparation of contingency plans. It will be calculated on the basis of the quantity needed to respond to the most likely size of spill during the period necessary to bring in replacement stocks. The time needed for stock replenishment (either by the manufacturers or from other sources) has also to be negotiated and determined in advance. As the dispersal window for most dispersible oils is relatively short, any delay in application and dispersant supply can significantly reduce the effectiveness of the response technique.

- **Types of containers**

There are several types of containers for storing dispersants, the choice of which is determined by: the size of the stock and the possibility of having to transport them by land, air or sea. Used in the right conditions, containers must guarantee the potentially unlimited shelf life of dispersant stocks. The table 4 resume the main types of older and currently used containers for the storage of dispersants.

Table 4. Different types of dispersant storage, past and present.

Drums	Historical dispersant storage. The steel drums had a capacity of **200 L**, which could be palletized but not stored in an optimal way. Subject to the risk of corrosion, they had to be stored in sheds. Drums could also be made of plastic. Handling this type of container was difficult.	
Intermediates Bulk Containers (IBCs)	Easier to store than cylindrical drums, IBCs are palletized and stackable. They are translucent or white high-density polyethylene (HPDE) cubes integrated in a tubular galvanized steel cage. Their capacity is generally **1,000 L**. They are fitted with a filler cap at the top and an integrated drain valve at the base. Today, dispersant suppliers generally deliver them in IBCs. They are easy to store, inspect and transport.	
Bulk tanks	Dispersants can be stored in bulk in tank trucks, ISO tank containers or ship tanks. However, this type of storage involves the risk of solvent evaporation and surfactant oxidation. In the case of ship tanks, contamination by seawater is also a major risk.	

It is recommended not to mix different types of dispersants in the same container, even if their compositions are similar. The result of such mixing could be a reduction in product efficacy and alter the operation of spraying equipment during use.

- **Storage facilities**

  Particular attention must be paid to the facilities in which dispersants are stored. High humidity, direct exposure to sunlight or salt water can cause considerable damage to containers. It is therefore advisable to store them in ventilated sheds or, if necessary, to cover them with suitable materials if they are outdoors.

  High temperatures or significant fluctuations in this parameter can also affect dispersant shelf life. It is therefore advisable to keep them at relatively low temperatures, which can be controlled using air conditioning for example.

3.3.2 Ageing and control of the stockpile

Dispersants are a complex mixture of various components, and with ageing their properties may be subject to changes, i.e. their stability is not necessarily good. During the prolonged storage, certain components may separate from the solution in layers or even crystallize. Usually dispersant deterioration results from bad storage conditions, dispersant quality may be altered (e.g. dispersant stock polluted by an external product or dispersant tank overheated under the sun for long periods…). Most often, deteriorations are reflected as a loss of effectiveness of the product. It is recommended that the general appearance of the dispersant in storage should be the subject of an assessment on a regular basis, particularly in terms of decantation and color, with reference to the safety data sheet for each product. A change in color is not always synonymous with product degradation, but it may prompt consideration of the need to re-test the product to verify its conformity. It is recommended that these inspections be recorded (via photographs, for example) to enable the general condition of the dispersant to be monitored.

Accordingly, general visual control of stockpiles is strongly recommended, at least every month.

This will enable us to identify any signs of deterioration in the containers, and to replace them quickly if necessary.

Countries which have established approval or acceptance procedures regularly require the information on shelf-life from the manufacturer of the product. Regardless of the manufacturer's declaration, the most reliable method for discovering changes in the original quality of the stored dispersant is to periodically test its effectiveness and to compare the results with the results obtained, using the same method and the same product when it was fresh. Such tests can be easily carried out every five years. These tests check the compliance of the physical and chemical properties of the dispersant stored in relation to the information contained in its safety data sheet, as well as its effectiveness.

3.3.3 Disposal of aged stockpiles

Aged dispersant stockpiles should be disposed when their characteristics, in particular the efficiency does not meet the technical requirements of the approval procedure. And as any industrial waste, they should be disposed through specialised service companies.

It's generally recommended that the dispersant manufacturer be contacted for advice on disposal.

3.4 Approval procedures for dispersants

Most of the countries that consider the use of dispersants as part of their oil spill response strategy have developed certain criteria or specifications with which dispersants should comply.

These specifications may be used for the selection of the most adequate products on an informal basis, while some countries have established formal approval criteria.

For the moment, there are no real agreements at international level on these criteria, despite the efforts made by intergovernmental bodies such as European Maritime Safety Agency (EMSA) or Bonn Agreement while trying to harmonise the use of dispersant in their respective region. However, on a case-by-case basis, instead of setting their own approval procedure, some countries follow other countries approvals for dispersants. For instance, Croatia accepts certain products approved in other countries such as Cyprus, France, and United Kingdom. Another example is Israel, which accepts products approved by Cedre.

Italy and France collaboration on dispersant approval processes

(Manfra *et al.*, 2017)

At the request of the RAMOGE[1] Executive Secretariat, a research project was conducted to identify the differences between dispersant approval procedures in Italy and France and to propose a way of harmonizing them.

The study has been performed by Cedre and ISPRA (Italian Institute for Environmental Protection and Research) with the following main objectives:

i. Comparing current approval procedures in Italy and France to identify similarities and differences;

ii. Leading toxicity tests using both procedures on two selected dispersants;

iii. Suggesting a harmonized method between the two countries.

The study revealed that differences in ecotoxicological tests and in the choice of assessment criteria used by each country lead to different results for the same product. Both tested dispersants met the French requirements for approval ($LC_{50} \geq 10$ times reference toxicant), but only one dispersant met the Italian approval criterion ($EC_{50} > 10$ mg/L).

One of the solutions envisaged for harmonization is to increase the diversity of organisms tested under the French procedure considering at least three trophic levels). Common criteria for assessing toxicity should also be discussed and approved.

1 The RAMOGE Agreement is an intergovernmental cooperation agreement created in 1976 between France, Italy and Monaco for the preservation of the marine environment.

Figure 9. Equipment used in France to measure a) the dispersant efficiency (IFP test) and b) the toxicity (©Cedre).

Most often the specifications are based only on the **effectiveness and toxicity testing** of products. In addition, some countries have set standards on the biodegradability of the product and/or dispersed oil. There are also countries which specify required physical characteristics of dispersants which may be used. On the basis of screening tests for any of these characteristics, individual competent national authorities develop their lists of approved products, which might be used in conformity with the approved response strategy.

All known testing procedures are based on laboratory tests. Such tests are not aimed at simulating real field situations and are accordingly designed to give relative values of tested properties to rank products with regard to their relative effectiveness, toxicity or biodegradability. Field experience shows that there are no significant discrepancies between relative values obtained in laboratory tests and behaviour of tested products in the field, although differences sometimes appear. The same applies to the comparison between results of different tests: although absolute values can largely differ for a specific characteristic of a tested dispersant, depending on the testing procedure used, products which show better results according to a certain procedure, normally also appear superior when tested in accordance with another procedure.

The main concern in the early years of the use of dispersants was their toxicity. With the development of new, low-toxicity formulations, more and more attention has been paid to the efficiency of dispersants. **At present, the effectiveness of dispersants is the most important selection criteria**. It is considered that toxicity, as well as biodegradability, of an ineffective product are irrelevant. The objective is to select a product with the best possible combination of relatively high effectiveness and relatively low toxicity.

Regardless of specific test procedures, a generally accepted testing pattern follows several common steps:

1. The **effectiveness** of the products is tested;
2. Products which pass this criterion are then tested on **toxicity** and **biodegradability**;
3. Results of toxicity and biodegradability **tests are compared** and,
4. The products which pass defined criteria are **approved for possible use**.

Basic information on dispersants and their application

3.4.1 Reglementary tests

EFFECTIVENESS TESTS

Most of these tests measure the degree and/or the stability of dispersion (droplet size distribution) either by visual observation or by analytical technique, after mixing oil and dispersants under standard conditions.

The measurement of the lowering of interfacial tension between oil and water following the addition of a dispersant or the speed of resurfacing of dispersed oil after mixing can also be used for the assessment of the dispersant's efficiency.

The differences in results and rankings often originate from differences in the parameters of the tests, and mostly from the type of oil but also temperature, oil and water volumes, dose rates, contact between the dispersant and the oil – application or premixed level and type of mixing energy, close test tank of continuous dilution, test duration, etc. (Table 5).

Laboratory efficacy tests often follow the following procedures:

- **The IFP test** (flow through test) procedure is used in France. According to the French standard AFNOR NFT 90-345, it is carried out in a test tank in which the water is renewed to reproduce the dilution which would occur at sea. In this test, the mixing energy brought by a wave generator remains gentle;
- **The LABOFINA test** (or WSL test, LR448) procedure is used in the United Kingdom. It is run in a separating funnel in rotation to provide strong energy to promote the dispersion process. Another test has been recently approved by the UK regulator Marine Management Organization (MMO) which consists in the modified baffled flask test that the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) recently adopted;
- **The Swirling flask test** is used in North America, following the ASTM F2059-06 Standard Test Method. It is carried out on oil samples premixed which dispersant in a very small funnel which rotate gently to promote the dispersion process;
- The **Mackay-Nadeau-Steelman** (MNS) is a very high energy test used in Norway and Australia.

Table 5. Effectiveness tests parameters.

Test ID	Energy source	Energy level	Water volume (L)	Oil/ water ratio	Dispersant application method	Dispersant/ oil ratio	Settling time (min)
IFP (French Institute of Petroleum) dilution test	Oscillating hoop	1-2 Low	4-5	1:1000	Dropwise	variable	1
Labofina rotating flask (using Warren Spring Laboratory LR448)	Rotating vessel	3 High	0.25	1:50	Dropwise	1:25	1
Swirling flask test	Shaker table	1-2 Low	0.12	1:1200	Premix/ dropwise	1:10 to 1:25	10
MNS (Mackay, Nadeu and Steelman)	High-velocity air stream	3 High	6	1:600	Drop-Wise	Not applicable	5

TOXICITY TEST

Test materials are usually dispersants, dispersed oil (oil/dispersant mixture) and sometimes oil alone. Test species could be fish, arthropods (usually decapod crustaceans), molluscs (pelecypods), annelids (polychaetes) and algae. Ideally, test species should be selected among locally significant populations. Tests may be acute (short term) single species, lethal or sublethal. The main goals of these tests are to determine the relative toxicity of a certain dispersant versus other previously tested products.

Due to the increase of toxicity with the increase of temperature, toxicity tests should take into consideration expected changes in seawater temperature. Measure of the **Lethal Concentration 50 (LC_{50})** in a determined period (usually 24 or 48 hours) is a common criterion used in toxicity tests.

Toxicity testing issue can be considered from two different approaches:

(i) either, checking **the intrinsic toxicity** of the dispersant in order to reject the most toxic ones, in that case only the dispersant is tested;

(ii) or, checking that **the dispersant does not increase the oil toxicity**; in that case the tests are performed on the oil alone and on the oil and dispersant mixture.

Since dispersing the oil in the water column leads to increase the oil toxicity of oil towards the pelagic organisms in the water column, the toxicity of the mixture oil and dispersant should be temporary higher than that of the oil alone. The more efficient the dispersant, the more toxic the mixture of oil and dispersant may appear as the oil will be better dispersed. Therefore, such approach can be more restrictive and eventually reject the most efficient dispersant. This is in contradiction with the goal of an approval procedure which should be designed to select the more efficient and less toxic ones.

Considering the objectives of the approval procedure (selection of the best products, i.e. the less toxic ones), the control of the intrinsic toxicity of the dispersant is sufficient. However, the issue of the toxicity of the dispersed oil remains a concern when considering the policy for the use of dispersants. As part of the NEBA process, the toxicity of the dispersed oil is required when defining scenarios (environmental conditions) for which the use of dispersant will remain environmentally acceptable.

BIODEGRADABILITY TEST

Dispersants and dispersant/oil mixtures are often tested for biodegradability. There is no consensus on a standard method for testing biodegradability of dispersants and various adapted standard tests on organic material are in use (e.g. the method used in France – Standard NF 90 346, in Italy “Closed bottle” method OECD 306:1992, in Spain Standard UNE 77,103:201).

OTHER TESTS

If required, standard analytical methods are used for testing other properties (density, viscosity, etc.).

3.4.2 Complementary tests

In the past 25 years, mesoscale test tanks have been designed to assist better spill response operations by investigating the chemical dispersion in more realistic and controlled conditions than in standard laboratory tests.

There are several types of mesoscales:

– - **straight flume tanks** are linear or straight canals (from 10 to 30 m long, 0.5 to 1.2m wide and 1 to 2 m deep) equipped with a wave generator to control the mixing energy level of the test environment, which is a key factor in dispersant efficiency;

– - **circulating flume tanks** or loop canals (around 10 m long, for 5 to 10 m^3) are specifically conceived to reproduce conditions at sea and to study the efficiency of dispersion while oil is weathering. The first tank of this type has been designed in Cedre in 1997 and is called the Polludrome® (Figure 16).

Characteristics

- Made of 4mm stainless steel
- Lenght: 12m
  Height: 1.4m
  Width: 0.6m
- Air Conditioned room (1-30°C)
- Water Volume: 7m^3 for a water depth of 90cm
- Wave generator with adjustustable wave height, amplitude and frequency
- Simulation of solar radiation by 2000W units which recreate the spectrum of natural light
- Air flow at the water surface simulated by a wind generator
- Removable covers and vapour extraction
- Variable speed current generation

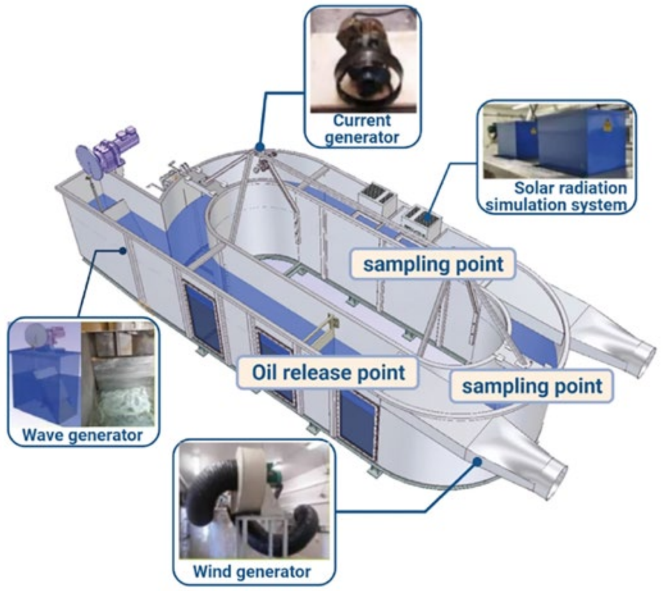


Figure 10. Cedre's Polludrome® circulating flume tank (from Merlin et al., 2021 and Cedre, 2014). Objective : identify the window of opportunity.

– **testing pools** are large water bodies equipped to produce controlled surface mixing and have therefore been designed to study the relationship between dispersant penetration and oil characteristics using realistic application systems.

– **floating cells** are square structures measuring 3 m on each side, each cell consists of an aluminium frame supporting a flexible plastic forming a curtain that plunges to a depth of 2.5 meters. This delimits a volume of water while remaining subject to the influence of weather and ocean conditions (waves, surface agitation, rain, wind, sunshine, etc.). The fate and behaviour of oil and chemical dispersant can be studied in these facilities while environmental conditions are continuously recorded by a weather station. Cedre has carried out a number of trials using floating cells, notably to compare the effectiveness of different treatments depending on the state of ageing of the oil or on different types of oil.

Figure 11. Floating cells used by Cedre for test under in situ conditions (©Cedre). Objective : conduct tests under natural conditions.

– **high-pressure tanks** as the hyperbaric chamber of the Southwest Research Institute in San Antonio (Texas, United-States) was used by Sintef to study sub-sea dispersion. More specifically, the aim of these studies was to check whether pressure could have an effect on dispersant injection, oil droplet size and dispersion effectiveness.

– **large water column testing tanks** are transparent vertical column with large windows to study the behavior of contaminants. In the case of dispersant use, the tests performed in the column focus mainly on the behavior of dispersed droplets in the subsurface.

Figure 12. Cedre's experimentation column (©Cedre). Objective: visualize the formation and stability of dispersed hydrocarbon droplets in the water column.

All these facilities enable more detailed study of the overall dispersion process but are limited by the closed environment and the difficulty of reproducing real wave conditions.

In response to these limitations, a large number of **sea trials** have been carried out since the 1980s to test the effectiveness of various control techniques, including the use of dispersants, under controlled spill conditions. These trials can be at small (e.g. 0.1 to $1 m^3$ released oil) and large scales (few to several tens of m^3 released oil).

However, these tests are more difficult to perform than mesoscale tests and also have certain drawbacks that are, for instance:

- the difficulty in assessing the quantity of oil remaining at the end of the trial;
- the fact that evaluations are based on local measurements or indirect techniques;
- the logistics required are greater than mesoscale tests at sea;
- the necessary authorizations to release oil into the environment.

04

CHAPTER 04

Use of Dispersants in Oil Spill Response Strategy

4. USE OF DISPERSANTS IN OIL SPILL RESPONSE STRATEGY

The behaviour of the spilt oil in the sea and the weathering processes affecting the oil products (formation of superficial slicks, formation of mousses, tar balls, sinking and submerged oil, etc.), together with the level of equipment and preparedness achieved at national or local level, will determine the choice of response strategy.

Chemical dispersion is one of the response options at sea among "mechanical recovery associated with containment", "do nothing and monitor the spill", and (for general reference) "in situ burning". It is critical to note that the choice to employ dispersants significantly reduces the effectiveness of other response options.

As every oil spill technique response, the use of dispersants has a number of advantages and disadvantages that can be summarized as follow:

Advantages

- By removing the oil from the surface it helps to stop the wind effect on the oil slick's movement that may otherwise push the surface slick towards sensitive areas (often the shoreline), reducing the need for shoreline clean-up operations;
- In contrast to containment and recovery, dispersants can be used in stronger currents and greater sea states;
- If used through effective processes, organisation and consideration of windows of opportunity, it's often the quickest response option;
- It reduces the possibility of contamination of some resources sensitive to the floating oil (surface slick) such as sea birds and mammals;
- It inhibits the formation of persistant water-in-oil emulsification ("chocolate mousse");
- It enhances the natural degradation of oil;
- It does not produce wastes to be disposed;
- If sprayed from an aircraft, dispersants offer the possibility to treat larger areas than most of the other oil spill response techniques, and
- It reduces the vapours at the water surface and thus enhances safety for the operators.

Disadvantages

- On significant pollution, chemical dispersion is not applicable in a too calm sea state (sea state 0, 1 possibly 2 according to the situation);
- By dislocating the floating oil into the water column, it may adversely affect certain parts of biota which otherwise would not be reached by surface oil (e.g. pelagic and benthic communities);
- If oil dispersion is not achieved, effectiveness of other response methods on oil treated by dispersants decreases;
- Dispersant are not efficient towards all oil pollutants, especially those which present a high viscosity;
- Its use is constrained by the environmental conditions of the site to be remediated and the volume of water must be sufficient to ensure rapid dilution of the dispersant and the dispersed oil;
- When initially efficient, chemical dispersion is applicable only for the first hours/days of the operation, before the oil becomes non dispersible;
- If used near the shore and in shallow waters, it may increase the penetration of oil into the sediments; similarly, if suspended sediments are present, dispersants facilitate the adhesion of oil to the particles;
- It introduces an additional quantity of extraneous substances into the marine environment;
- The "window-of-opportunity" for successful dispersant application is short.

Figure 13. Spraying dispersant by boat during a POLMAR exercise in Saint-Barthelemy (France) (©Cedre).

The possibility of balancing properly these advantages and disadvantages decreases in an emergency situation, and accordingly the use of dispersants and its place in a general response strategy for oil spills needs to be defined in advance.

Where and under which circumstances the use of dispersants will be given priority over other available combating methods needs to be analysed and decided during the preparation of the contingency plan.

By evaluating different interests for each particular zone, geographical boundaries may be defined within which dispersants may or may not be used. As a general rule, dispersants should not be used in the areas with poor water circulation, near fish spawning areas, coral reefs, shellfish beds, wetland areas, and civil and industrial water intakes (Refer to Part III of these Guidelines).

Massive oil spills also often necessitate international co-operation. Application of dispersants may be a part of the assistance offered to a country confronted with such a spill. In order to facilitate inclusion of offered assistance in the national response activities, some countries or groups of countries (Bonn Agreement countries) have agreed to mutually accept the application of products approved for use by each country, in case of emergency. Part I ("Regional Approval") of these Guidelines provides guidance on regional cooperation.

When such a general policy has been adopted in advance, a final decision on the use of dispersants in a spill situation will have to be taken only on the basis of given circumstances (type of oil, weathering, conditions, availability of material and personnel, etc.). The preparation of decision trees to help responsible officers greatly facilitates this process (Refer to the Annex of Part III of these Guidelines).

Taking a decision on the use of dispersants is one of the priorities in each spill situation since relatively shortly after the spillage most oils will no longer be amenable to chemical dispersion.

Once the decision to use dispersants has been taken, the strategy of their use becomes decisive for the positive outcome of the operation. From a strategic viewpoint, some basic principles in this regard can be defined:

– dispersants should be applied to the spill as early as possible;

– dispersant spraying operation should be terminated when the oil reaches the state of weathering (viscosity, mousse formation) in which it is not readily dispersed anymore;

– if the oil is approaching a sensitive area, dispersants should be applied to the part of the slick nearest to it.

In case of a massive oil pollution affecting an extensive area, it is possible and often necessary to use a combination of spill response methods. In such situations dispersants can be used on one part of the slick while oil is mechanically recovered on the other end of it.

On location, dispersant should be applied according to specific operational rules such as:

– dispersants should be applied to **thick and medium thick parts of the slick** and not to the low thickness areas (sheen);

– treatment should be **methodical**, **in parallel** and **contiguous** or **slightly overlapping runs**;

– it is important to treat the slick **against the wind**;

– vessels are suitable for treatment of smaller spills near the shore, but aircrafts permit a rapid response (less than 24 hours after the spillage), in particular when large offshore spills are concerned;

– regardless of whether dispersants are sprayed from vessels or aircraft, **spotter aircraft** should be used for guiding them and assessing the results.

Visual aerial observation (e.g., UASs, aircraft), complemented with photography, video recording or using one of the available remote sensing techniques should be used for evaluating the results of the application of dispersants. Such reports and records can be also used for record keeping purposes of the different phases of the operation.

Finally, from a practical viewpoint, countries which decide to consider the use of the chemical dispersion in the response strategy need to pay particular attention to:

a) storage of sufficient quantities of selected and approved products;

b) procurement and maintenance of adequate spraying equipment;

c) training of personnel on all aspects of dispersants use, including organizing practical exercises at regular intervals.

05

CHAPTER 05

Factors Affecting the Action of Dispersants

5. FACTORS AFFECTING THE ACTION OF DISPERSANTS

Regardless of the application **technique** and **dosage** used, dispersant action will primarily be determined by:

- type of oil to be treated;
- contact dispersant/oil;
- mixing;
- weather conditions;
- water salinity and temperature, and
- operational conditions.

5.1 Type of oil

Characteristics determining the **type of oil** which can be chemically dispersed are basically:

– VISCOSITY AND CHEMICAL COMPOSITION

Only oils with **viscosity at seawater (ambient) temperature** of not more than **5 000 cSt** (most fresh crudes, medium fuel oils) are considered to be chemically dispersible by presently existing products. Chemical dispersion of oils with viscosity between 5 000 and 10 000 cSt may be uncertain (reduced); chemical dispersion above 10 000 cSt (heavy, weathered and emulsified crudes, heavy fuels) is very little or non-effective. It is also relevant to underline that use of dispersants is not recommended if oil is "naturally" dispersible, with a viscosity value below 500 cSt.

The more viscous the oil is the more agitation (waves) is required for its chemical dispersion.

There is the so-called "window of opportunity" in which dispersants can be applied, which represents the period of time when oil spilled into the sea is "dispersible." This time period can be short (hours, some days) since weathering processes can quickly increase the viscosity of the oil, reducing significantly their effectiveness.

Several studies have focused on the influence of the chemical composition of oil on its dispersion. The main conclusions of Mukherjee *et al.*, 2011, which is the most in-depth study on the subject, are:

- the concentration of aromatics has a significant positive effect on dispersion efficiency;
- saturate and resin fractions interact to promote dispersion;
- a high concentration of saturates enhances the proportion of small (< 7 µm) and medium (7 – 20 µm) droplets;
- aromatics and asphaltenes interact to reduce the proportion of small droplets and promote the number of the largest droplets (> 20 µm).

As a recent propulsion energy source, Low Sulfur Fuel Oil (LSFO) presents significant challenges due to its physical and chemical characteristics. Its persistence in the marine environment, driven by low evaporation rates and high viscosity, could complicate clean-up efforts and require extended recovery operations. The rapid emulsification of LSFO in the Mediterranean's warm waters may exacerbate the problem, creating stable water-in-oil emulsions that are difficult to manage. The effectiveness of chemical dispersants would be further limited by LSFO's variable viscosity, often necessitating mechanical recovery methods that are resource-intensive and time-consuming.

– POUR POINT

Oils with a high paraffin (wax) content i.e., with a high **pour point**, can cease to be dispersible if ambient temperature is significantly lower than their pour point.

– OIL EMULSIFICATION

With the emulsification process occurring during the weathering of oil, the oil viscosity increases, and dispersant are generally not effective on waterinoil emulsions ("chocolate mousse"). However, when the emulsion is very fresh, (not entirely stabilized) research studies showed that dispersants may be effective. In such a case, the dispersant application can be undertaken in two stages: a first application to break the emulsion and therefore to reduce the oil viscosity, followed with a second application to carry out the dispersion itself.

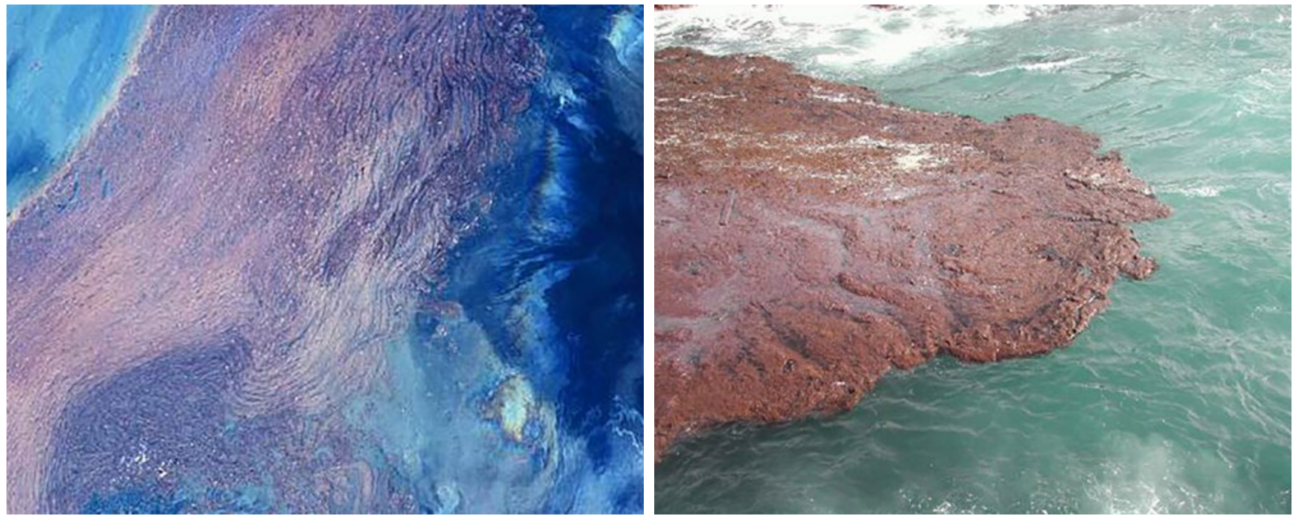


Figure 14. Weathered oil emulsion which dispersion remains uncertain (© Cedre).

5.2 Dispersant/oil contact

In order to achieve a good dispersant/oil contact, dispersants need to be sprayed onto the floating oil in such a way as **to reach the surface** of oil and **not to penetrate** through the oil layer. These goals are achieved by combining appropriate spraying technique and appropriate droplet size.

Optimal droplet size is considered to be in the range of **350 and 1000 µm**, or **approximately 700 µm**. Smaller droplets will be carried away by wind and may never reach the oil, while the bigger ones penetrate through the oil layer and enter directly in contact with the water without having sufficient time to bind themselves to the oil. Application spraying system should be chosen to reach such requirements.

It is also relevant to consider the type of dispersant use because they all have different properties and their efficiency might depend on the environmental conditions prevailing during the spill. The amount of dispersant used, often called the **dispersant-to-oil ratio (DOR)**, is another factor that needs to be taken into account to maximize dispersant efficiency. It depends on the effectiveness of the dispersant and the chemical composition of oil. In laboratory experiments, the DOR at which dispersion effectiveness is maximum is generally around **1:20 – 1:25 to 1:40** even if the amount of oil spilled is rarely known. It is also important to bear in mind that dispersant efficiency tests are only carried out on a limited number of oils.

5.3 Mixing

Once the dispersant has come in contact with oil and the oleophilic end of its molecule has been attached to oil, the dispersant/oil mixture needs to be agitated in order to be broken down in droplets and dispersed in the sea-water mass.

Natural agitation of the sea surface (waves) is required for completing this process (e.g. sea state 2, Beaufort 3).

If the wave energy is insufficient (very calm sea), the mechanical recovery is preferred. But, in some cases, on limited pollution, the used of dispersant can be decided. The mixing of dispersant/oil system and water must then be supplied locally:

- by sailing through the oil slick and stirring it with bow wave and propeller action;
- by mixing oil and water with fire hoses.

Figure 15. Ship applying dispersant (©Jason Engineering – Norway).

5.4 Weather conditions

Chemical dispersion of oil is less affected by adverse **weather conditions** than other spill response methods (e.g. containment and recovery). In addition, weather conditions do not directly affect the physicochemical process of dispersion, but rather the application of dispersants.

Winds may blow the sprayed dispersants away from the target area and consequently cause significant loss of product. In case of the aerial spraying of dispersants, high winds may also affect the safety of spraying aircraft.

Whilst **waves** provide the required mixing energy to enable the dispersion process (the more energy is provided, the better is the dispersion); large waves or breaking waves can also be an obstacle and render spraying operation difficult for boats. Interaction between dispersant and oil slicks broken by the wave effect can also be reduced since part of the dispersant would be sprayed directly on the water surface rather than on the oil.

Poor **visibility** affects dispersants' action only indirectly through impeding spraying operations.

5.5 Water salinity and temperature

Water salinity is an important factor considering the efficiency of dispersants as it reduces the dispersant's dissolution in the water, while encouraging the surfactants to combine with the oil.

Laboratory experiments have shown that dispersant efficiency is optimal for salinities around 30 – 40‰.

Air and water temperatures can also have an effect on the effectiveness of dispersants. For instance, high ambient temperatures promote evaporation of light oil compounds, leading to components on the water surface that may be more difficult to disperse. On the other hand, high water temperatures increase the solubility of the dispersant, leading to a great efficiency of the dispersion if the product is correctly applied.

5.6 Operational factors

Operational and logistical factors can also affect the effectiveness of dispersants as an oil spill method response.

– THE DISPERSIBILITY WINDOW

As soon as oil is spilled into the environment, it undergoes a natural "weathering" process that affects its physical and chemical properties. Its viscosity and density can rapidly change, making the oil more difficult to disperse. In this respect, the window of opportunity refers to the time available for effective use of a dispersant. It would vary according to the type of oil and the meteorological and oceanographic conditions (mainly temperature, agitation/wind) and it is roughly estimated to be around **12-24 hours** in cold conditions and between **24 to 72 hours** in temperate conditions.

The more the oil weathers, the more mixing energy is required for the application and the effectiveness of the dispersants. The decision as to whether or not to use dispersants is therefore made prior to the spill, when planning emergency measures in the event of a spill, and shortly after the spill.

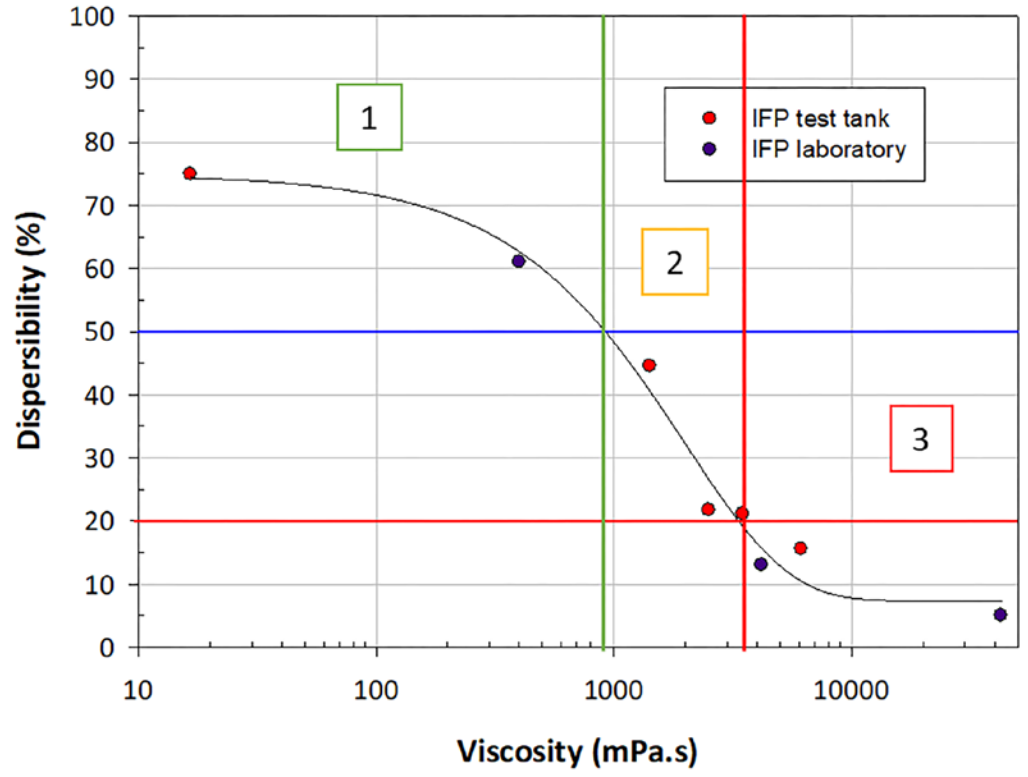


Figure 16. Ratio between dispersant efficiency and hydrocarbon viscosity. Results of tests carried out on crude oil at Cedre. Three zones are clearly identified: 1) the oil is easily dispersible; 2) the dispersibility of the oil is reduced and 3) the oil is so viscous that it cannot be dispersed.

- **Material availability and operating mode**

In the event of a spill, it is important to take into account the short- and medium-term availability:

– of dispersant stocks;

– of means of dispersant application (boat, plane, helicopter);

– of pumps and tanks.

It is also essential to ensure coordination of operations in the field, so that products can respond to pollution in the most effective way possible.

Furthermore, for the same product and spreading system, different parameters can influence the efficiency of the chemical dispersion.

These parameters include:

– dispersion speed (which influences droplet size (air shear) and application rate, particularly in aerial spraying);

– nozzle orientation (need to point downwards or backwards to limit the effect of air erosion effect by reducing the relative speed of the liquid compared relative to the air);

– the positioning of nozzles in relation to their environment (proximity to water, interference or turbulence created by the support (aircraft wing, ship's hull, etc.)).

So, while the effectiveness of dispersion depends in part on the environment, the pollutant and the dispersant, the mode of diffusion, and therefore the spraying/spreading system, is also an essential point.

- **Sensibility of the site**

The presence of animals, such as birds or marine mammals, in the vicinity of the operations area may restrict the choice of dispersant application methods and techniques.

The same applies in the event of a spill in a protected or sensitive natural area where pollutant recovery operations may require authorization.

06

CHAPTER 06

Systems for the Application of Dispersants

6. SYSTEMS FOR THE APPLICATION OF DISPERSANTS

Various dispersion methods exist or are under development, each with one or more implementation technologies. These must be selected according to requirements, and can influence dispersion efficiency: the aim is to create oil droplets small enough to be permanently transported in the water column. Indeed, dispersion stability is mainly linked to the size of the oil droplets formed: small enough (generally between 30 and 100 µm), they can remain suspended in the water column under the effect of natural turbulence; when they are larger, they rise more or less rapidly to reform the surface oil slick.

Chemical dispersion systems, also known as dispersant application systems, can be mounted on aircraft, ships or carried by operators. Regardless of the support, they are typically composed of:

- One or more **dispersant tanks**;
- A **filter**, to eliminate solid impurities likely to clog the system. Filters are generally placed above the pump, to protect it from fouling, and upstream of the nozzles, to protect them from clogging;
- A **supply pump**. Depending on requirements, different types of pumps can be used (peristaltic, centrifugal, piston, gear, diaphragm, etc.) ;
- **One or more supports for the nozzle(s).** These supports can, for example, take the form of ramps, gantries or lances of various types ;
- **One or more calibrated nozzles.** These nozzles are preferably fitted with valves that close when the pressure drops, thus preventing leaks and keeping the entire device full of dispersant when spraying stops.The entire piping system remains full when the pump stops, ensuring a very short response time when the pump is restarted. The nozzle influences flow rate, drop size (orifice diameter) and spray pattern (orifice shape). The nozzles can be :
    - Full cone shape ;
    - Hollow cone - concentrates the dispersant on the outer edges of the cone ;
    - Flat or fan-shaped - producing a narrow, elliptical spray pattern. Uniform distribution is achieved by overlapping the edges of adjacent sprays.

The development of dispersing devices now makes it possible to spray droplets of adequate size, and for some, to vary the dispersant/oil ratio in order to cope with different slick thicknesses.

Selection of the dispersants application system basically depends on:

- the type of dispersant available;
- the type of spraying device available;
- the size and location of the spill, and
- the location.

6.1 Aircraft mounted spraying systems

As a result of advantages offered by the aerial spraying of dispersants (good control and assessment of results, rapid response, high treatment rates, optimum use of the product, regardless of the sea state), a number of spraying systems have been developed for use with both fixed and rotating wing aircraft (helicopters). Existing units are either of a type which can be used by the aircraft of convenience or of the permanently installed type. Standard built-in spraying systems of crop spraying aircraft, widely used in agriculture, can be adapted for the spraying of dispersants.

Treatment quality is highly dependent on flight conditions. Treatment should be carried out at a **minimum altitude** and at speeds **not exceeding 300 km/hour**. At higher speeds, dispersant droplets are atomized very finely by the incoming air stream, and it is difficult to control their deposition on the slick surface.

Moreover, the use of aircraft poses a number of problems, such as the ageing of the fleet and the difficulty of obtaining flight authorizations to cross certain airspaces, due in particular to the ex-military status of certain spray aircraft.

Aerial application of dispersants depends on the visibility over the slick area and relies on wave energy for mixing dispersant with spilled oil.

6.1.1 Airplanes

Boom systems, designed and certified for specific aircraft types and models, include dispersant storage, a pump, spray booms with nozzles, and a remote-control system.

Ramps have been classified into **two families**:

- **Fixed ramps**, which can be located at wing level (above or below) or under the aircraft fuselage.
- **Modular ramps**, which can be deployed or installed as required.

In addition to the spray system itself, its positioning can influence dispersion efficiency. For example, it is assumed that under-wing positioning would be more favourable to dispersion by channelling the jet(s), as opposed to over-wing booms, which spray into a potentially highly turbulent under-pressure space.

FIXED WING RAMP: AGRICULTURAL MODELS

Crop spraying airplanes are readily available. However, it is advisable to modify the spraying nozzles because the application rate of dispersants is much higher than that of agrochemical products. They could not be used far from the shore due to limited tank capacity and insufficient safety offered by a single engine. These aircraft are designed for limited-scale pollution.

Figure 17. Crop spraying aircraft (Antonov 2) (© Cedre).

FIXED SPRAY ARM ON AIRCRAFT WING

Fixed systems for converted **multi-engine aircraft** comprise storage for dispersants, a pump including powerpack spray arms with nozzles and a remote-control system. As an alternative, some independent system (with tank, pump and spray booms), have being developed which can be clamped under the fuselage as a detachable pod (i.e. instead the luggage chest); these systems allow to convert quickly regular planes into spraying aircrafts.

Located directly on the surface of the wing, this type of ramp is not recommended for cold climates, as it can encourage the formation of ice on the wing.

Figure 18. Example of fixed systems on aircraft wing. Florida Air Transport DC-6 (N70BF) performing spray tests (Source: http://floridaairtransport.com/index.php).

FIXED UNDER-FUSELAGE ARM SPRAY

Oil Spill Response Limited (OSRL) and 2Excel Aviation have developed a dispersant spraying system named TERSUS (meaning cleaning in Latin), specially designed for use by jet aircraft.

This system delivers a variable flow rate of 500 to 1 200 liters per minute via two spray arms equipped with 15 nozzles each. The dispersant (15 000-liter tank) is applied at an altitude of 150 feet (about 45m) and a speed of 150 knots. This system is adaptable to different aircraft and compatible with nine types of dispersants.

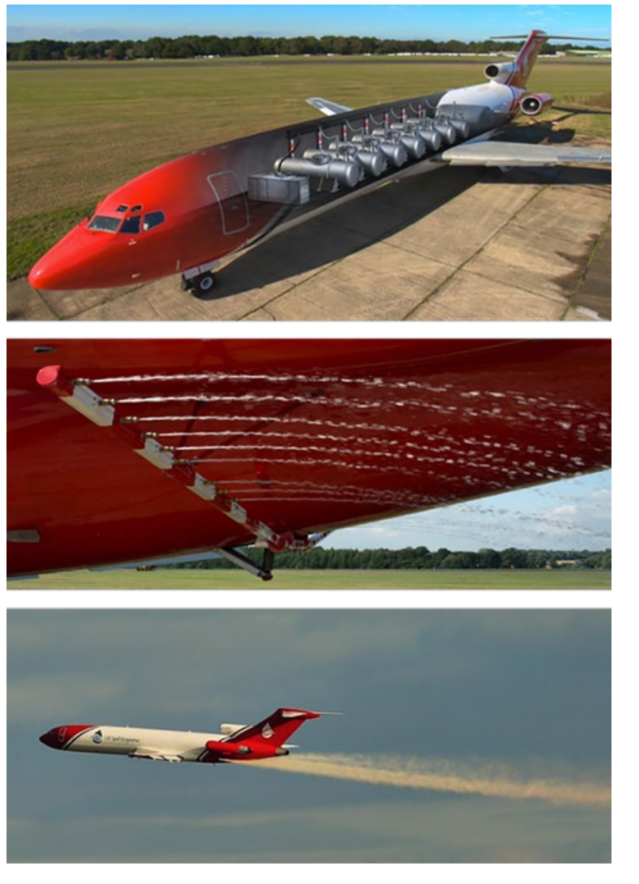


Figure 19. Dispersion system TERSUS (©OSRL)

MODULAR DEPLOYABLE ARM SPRAY FOR AIRCRAFT WITH LOADING RAMP

Specific packs have been designed for spraying dispersants when a high treatment rate is required.

Figure 20.a) application of false dispersant (water) by OSRL's Hercules aircraft equipped with ADDS pack and b) airborne Dispersant Delivery System (Biegert Aviation Inc.) (©Cedre).

EXTERNAL MODULAR AIRCRAFT ARM SPRAY; POD SPRAYING SYSTEMS

Modular POD spreading systems have been developed by OSRL to be fitted under the fuselage in the form of a detachable pod (i.e. in place of the baggage compartment), and represent an alternative to fixed systems. These self-contained systems (including tank, pump and spray booms) enable ordinary aircraft to be rapidly transformed into sprayers. The capacity of these systems is around 1.5 t of dispersant.

Figure 21. POD spraying aircraft (© Cedre).

SELF-CONTAINED AIRBORNE SPRAYING SYSTEMS

These systems are built to suit large transport airplanes which have rear cargo doors able to remain open during the flight. Containerized units comprise tank, power pack, pump and retractable spray arms and can be easily loaded into the cargo hold.

Figure 22. NIMBUS L-382 system by Ayles Fernie (© Ayles Fernie).

6.1.2 Helicopters

Helicopter spray systems are:

- either mounted **under the fuselage** (and made up of the same parts as the POD units fitted to aircraft). As in the case of aircraft, these systems can be originally designed for agricultural or chemical spraying, but which have been various chemical products diverted to apply dispersants. Each model is designed specifically for one type of helicopter. Helicopters with a payload capacity a payload capacity of 300 to 800 kg and a limited range, they can only be used in they can only be used in coastal areas, close to landing sites;

- or **heliborne via autonomous systems**. Helicopter-borne systems, known as buckets or heli-buckets, can be attached to most helicopters fitted with load hooks. A bucket system consists of a tank suspended beneath the helicopter, fitted with a stabilizing fin to prevent it from rotating during flight, and equipped with two multi-nozzle spreader bars. The product is delivered to the ramps by a centrifugal pump driven by a self-contained motor positioned beneath the tank. Spreading is triggered from the helicopter by remote control. The system can be released in the event of an emergency.

Figure 23. French Navy Super Frelon heavy-lift helicopter fitted with bucket system (© Cedre).

FIXED SPRAYING SYSTEMS FOR HELICOPTERS

These systems are mounted under the fuselage and are made up of the same parts as the units built-in fixed wing aircraft.

Figure 24. Fixed spraying systems for helicopter (©Dart Aerospace)

HELICOPTER SPRAY BUCKETS

They can be used with any helicopter having a cargo hook for under slung loads. Units are self-contained (tank, pump, power pack, spraying arms) and can be remotely controlled from the cockpit.

Figure 25. Dispersant bucket used during a Polmar-Terre/Mer exercise in Côtes d'Armor (France) (© French Navy)

6.2 Boat mounted spraying systems

Vessels are the most appropriate equipment for dispersing small-scale pollution or, in certain cases, particularly when they are already on site, for treating medium-scale pollution.

Their high carrying capacity and ability to remain on site for long periods make them complementary to aerial spraying equipment.

SPRAYING ARMS FOR SHIPS

Arms spray systems for ships can be:

- **Paravane-mounted**: paravane-mounted ramp consists of a mast, hose and dispersant spray line. In operation, the nozzle hose is routed along a line to the masthead.

Figure 26. Paravane-mounted ramp (© Elastec).

- **Ship-mounted**: ship-mounted ramp is typically positioned on either side of the foredeck so that the dispersant can be optimally applied. They can be mounted on the ship's freeboard, on the pump frame or in the hull. However, this type of equipment may prove difficult to use in case of heavy rolling.

Figure 27. a) single-jet ramp (© Jason Engineering AS), b) other example of a dispersant ramp (© Ayles Fernie).

Basic information on dispersants and their application

SINGLE-NOZZLE CANNON

These systems have been designed for deployment on all types of vessels, including "ships of opportunity" such as tugs, offshore supply vessels and workboats. Platforms and fixed installations such as wharves can also be fitted with them.

These devices, whether portable or fixed, are more compact than spray arms and easier to mount and operate.

The single-nozzle cannons can be mobile or fixed, integrated directly into the ship's hull.

Figure 28. a) mobile single-nozzle cannon (© Clean Caribbean & Americas), b) fixed system integrated directly into the ship's hull (© TotalEnergies).

BOOMS WITH DISPERSANT GANTRY

Barrier systems with dispersant gantries can be used to concentrate large strips of separate hydrocarbon slicks of varying thickness into a relatively uniform strip. This homogeneous strip is then passed under a gantry where dispersant is applied. These systems have been designed to limit dispersant over- and under-dosing.

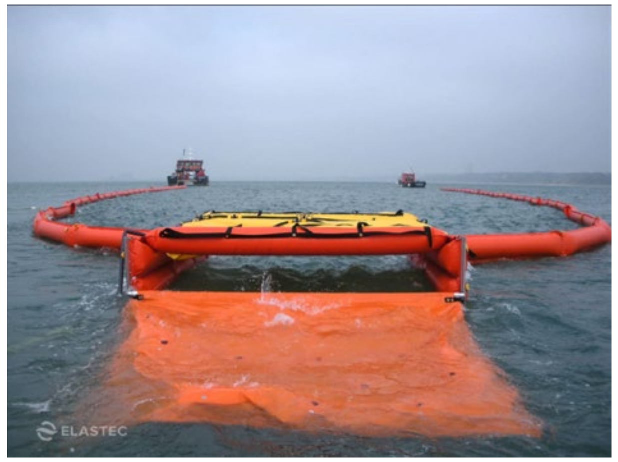


Figure 29. Dispersing barrier system (Neatsweep, Elastec) (©Elastec).

6.3 Benefits and limitations of the two main dispersant application systems

The following table lists the main **advantages and disadvantages** of air and sea systems.

Table 6. Benefits and limitations of the two main dispersant application systems.

System	Advantages	Limitations
Aerial	- **Speed**: able to get to the site in a very short time, offering a better chance of carrying out the treatment before the hydrocarbon ages; - High **prospecting rate**; - Ability to treat even in **poor sea conditions**; - Less need for **aerial guidance**.	- **Uneven spreading** and dispersant loss of up to 50% (since spraying is performed 10-30 meters above the water, part of the dispersant is lost without reaching its target); - Difficulty in **adjusting dispersant dosage** during the application process; - Limited helicopter **carrying capacity**; - Dependent on **weather conditions**; - Not favouring **mixing/agitation** of the water body.
Nautical	- Agitation created by the stem wave helps to **initiate dispersion** when sea conditions are too calm; - Treatment of **highly fragmented slicks** possible if they have aerial guidance to spot them; - **Dispersant dosage can be adapted**, either by modulating the ship's speed, or by using specific spraying equipment; - Potentially **greater dispersant-carrying capacity** than airborne equipment; - Ability to **remain on site** for long periods.	- Intervention time may be **longer**, reducing the chances of being able to carry out the treatment within the **window of dispersibility**; - **Modest prospecting rate** (in hectares treated per hour): due to limited treatment speed; - **Sensitivity to sea state**: as soon as sea state deteriorates, vessel movements are reduced; - Need for **aerial guidance**.

07

CHAPTER 07

Dosages of Dispersants and **Application Rates**

7. DOSAGES OF DISPERSANTS AND APPLICATION RATES

When applying dispersants, it is important to maintain an effective dosage throughout the operation, which can therefore be adapted to environmental conditions and the evolution of the situation. The number of dispersants to be applied to a certain quantity of oil, in order to achieve a desired level of dispersion, depends on the oil type, its weathering degree, its thickness, the environmental conditions (e.g. waves), and the dispersant itself.

In certain cases, as during the “Sea Empress” incident in 1995, the oil is easily dispersible and therefore a low dosage (oil/dispersant ratio or DOR) may be sufficient. In other incident less favourable (low dispersibility of the oil), it may be suitable to increase the dosage.

Practically, it is advisable to refer to the dose recommended by the manufacturer dosage which can be adjusted during the operations on the basis of certain average figures.

Figures for **concentrate dispersants** (or 3rd generation), are in the range of 20:1 for oils of up to 5 000 cSt. They may increase between 20:1 and 10:1 for treatment of oil between 5 000 and 10 000 cSt. Treatment of oils with viscosities of more than 10 000 cSt is considered ineffective. For fresh, light and easily dispersible oils with viscosity less than 500 cSt, a dosage lower than 20:1 may be sufficient to ensure dispersion efficiency.

Considering the application rate versus the oil thickness required, **application rates** can be calculated on the basis of generally accepted rules for the assessment of oil thickness (dark patches of oil are assumed to be approximately 0.1 mm thick and areas covered by a thin oil sheen are estimated to be between 0.001 and 0.01 mm). Regardless of the spraying device used, application rate is determined by the discharge rate of dispersant pump, speed of the vessel or aircraft and the width of the area covered by the spray (swath). The relation between these variables is the following:

$$\text{Application rate} = \frac{\text{Discharge rate}}{\text{Speed x Swath}}$$

Consequently, given the constant swath of the available spraying equipment, the required application rate for each particular slick area can be achieved by:

a) either selecting the appropriate discharge rate of the dispersant pump;

b) or selecting the appropriate speed of the vessel or aircraft.

Very often, an average treatment rate of 100 litres of concentrate dispersant per hectare, corresponding to oil thickness of 0.1 mm and a dose of 1:10 is used in approximate calculations for the use of dispersants.

08

CHAPTER 08

Logistic Requirements for the Efficient Use of Dispersants

8. LOGISTIC REQUIREMENTS FOR THE EFFICIENT USE OF DISPERSANTS

Regardless of the scale on which dispersants are applied, their use calls for well-organized logistic support. As oil is only expected to disperse chemically in the first few hours or days after being spilled at sea, at the time of the spill, the responder should be able to implement the dispersion application without loss of time. Therefore, all the logistics should be **pre-planned**.

This aspect may appear particularly important when dispersants are used for the treatment of massive spills relatively far offshore. Since mechanical recovery of oil also requires significant logistic support, logistical constraints may be a decisive factor in deciding whether to use one method or the other. In this context, the application of NEBA principles helps to guide the choice of the most appropriate technique. The availability of the necessary equipment, products and personnel will play a key role in taking decisions. However, other factors such as the size of the spill and its location, time required for mobilizing equipment and personnel and prevailing sea and weather conditions, will also strongly influence the decision on which method to choose.

To ensure maximum efficiency of the dispersant treatment operation, particular attention needs to be given to its logistic aspects:

- Treatment of oil with dispersants requires the use of **significant quantities of the product**. The dispersant quantity can be estimated at approximately 5 % of the volume of oil which is planned to be treated when concentrate dispersants are used. If conventional hydrocarbon-based products are used it can be up to almost the same volume of oil (100%) to be dispersed. This explains why nowadays conventional products are almost no longer used for the treatment;

- **Stockpiles** of dispersants existing in most of the countries are usually planned to be sufficient only for initial response. Pre-arrangements with manufacturers and/or distributors are therefore recommended to provide additional quantities of the product at an extremely short notice. International, regional, sub-regional and bilateral agreements with neighbouring countries should be considered in advance in view of mutualising national stockpiles available in the region or in remote countries. Particular attention should be given to custom pre-arrangement to ensure smooth transboundary movement. Countries affected by a spill requesting additional stockpiles and equipment can, in the framework of the Protocol Concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea, request the assistance of REMPEC to facilitate the coordination of the regional assistance;

- **Transportation** of dispersant from the sites of storage, production or from the airport of arrival (only airlifting the supplies from one country to another is fast enough to bring dispersants to affected country in time) to the spill site or base of operations, needs to be properly planned and precisely executed. If large quantities of dispersants are utilised, their transportation from the stores to the operations' base in road tankers or liquid containers is more efficient as compared to transportation in drums. High-capacity pumps should be used for reloading of spraying units;

Basic information on dispersants and their application

- **Maintenance** of spraying equipment as well as vessels or aircraft included in the operation should be planned. Supplies of the most important spare parts need to be available at the base;
- **Fuel** for vessels and aircraft needs to be available at the base and refuelling operations executed promptly in order not to delay spraying operations. Problems are often encountered when aerial spraying is used, since in most places the fuel for piston-engined aircraft is in short supply. If local aircrafts are used, necessary arrangements for fuel supply are made in advance through the contingency planning process;
- Generally speaking, **helicopters** can land or change the spraying systems, even without landing, almost anywhere. Landing sites for small aircraft can be improvised if proper airfields are not available. However, larger aircrafts need long runways and only appropriate airports can be considered as bases for the refuelling and reloading of dispersants;
- **Accommodation for crews** needs to be provided near the base. When larger vessels are used for spraying, this problem is eliminated since the crews are accommodated on board;
- **Appropriate communication links**, in particular those between spotter aircraft and spraying units, are essential;
- **Permanent contact** needs to be established with national aviation authorities to obtain clearance for planned operations without delay;
- If requesting aircraft through **international assistance** is considered, flight authorizations, compatibility of the infrastructure (e.g. runway specification), availability of specified fuel needs to be checked in advance, preferably when preparing the contingency plan;
- Take into account the need for **crew rotation** when planning spraying operations.

09

CHAPTER 09

Environmental Effects of Dispersants and Dispersed Oil

9. ENVIRONMENTAL EFFECTS OF DISPERSANTS AND DISPERSED OIL

Most scientific reports conclude that the toxicity of dispersant use lies not in the intrinsic product toxicity, but in the dispersion of the oil in the water column. Recent studies have actually shown that the oil dispersion increase bioavailability of hydrocarbons for marine organisms.

Environmental effects of dispersants' use are mainly related to:

- the **toxicity** of oil/dispersant mixtures;
- their influence on **microbial degradation** of spilled oil, and
- their effects on **marine organisms** (seabirds, mammals, pelagic and benthic populations).

9.1 Toxicity of oil and dispersed oil

TOXICITY OF OIL

Oils of different types contain a proportion of chemical compounds that are toxic to many marine organisms. Some of the more acutely toxic lower molecular weight compounds (benzene, toluene, ethyl benzene and xylenes, often referred to as BTEX compounds) are also volatile and water-soluble to some degree. Freshly spilled crude oils are much more acutely toxic than modern oil spill dispersants.

Higher molecular weight compounds that are present in low concentrations in many oils that often cause concern over toxicity are the **Polycyclic Aromatic Hydrocarbons** (PAHs). PAHs are known to be carcinogenic and can cause other effects by chronic exposure.

TOXICITY OF DISPERSED OIL

Dispersing spilled oil converts the oil from a surface slick to a plume or 'cloud' of very small oil droplets dispersed in the water column. These oil droplets might be ingested by filter feeding organisms, such as copepods, oysters, scallops and clams.

The widening of the oil surface area increases the rate at which partially water-soluble chemical compounds in the oil are transferred into the sea. The localised concentration of these potentially toxic **Water Accommodated Fraction** (WAF) compounds will rise before they are diluted. This is the justification for the argument that dispersants can never be a valid oil spill response because its use, if they are effective, will inevitably cause an increase in the dispersed oil concentration in the water column, leading to toxic effects on marine life. However, it is important to distinguish between:

(i) the increased **potential** for toxic effects to occur; and,

(ii) the possibility of **toxic effects actually occurring**.

Dispersed oil concentrations will certainly be higher if dispersants are used, than if they are not. This does not mean that the dispersed oil concentrations will be high enough, or persist for long enough, to cause actual toxic effects. Most spilled oils will naturally disperse to some degree in the initial stages of an oil spill, before the oil becomes emulsified. The successful use of dispersants will obviously increase the concentration of dispersed oil in the sea. However, this is a matter of degree rather than an absolute difference; some spilled oil is likely to naturally dissolve and/or disperse even if dispersants are not used.

By dispersing the oil in the water column the exposure of the organisms living in the upper layer of the water column increases. If the dilution of the plume of dispersed oil in the water column is rapid the exposure will be low: experience from both experimental field trials and dispersant offshore operations at real spills have shown that **dispersed oil will quickly be diluted into the sea**. The concentration of oil in water rapidly drops from a maximum of 30-50 ppm just below the spill short time after treatment, to concentrations under 1-10 ppm of oil in the top 10-20 meters after a few hours.

Because oil will disseminate in the environment by natural dispersion which is a process that proceeds quite rapidly in rough seas with low viscosity oils, exposure of some marine organisms to dispersed oil at some concentration will occur even when dispersants are not used.

Once in contact with cells, dispersants may in turn affect their functioning and metabolism by inducing alterations of membrane integrity and electrolytic imbalance with loss of cell osmotic permeability and cell lysis (Singer *et al.* 1991, 1996; National Research Council, 2005). EPA (2001) published a comparative study on crustaceans and fishes exposed to four dispersants, showing higher toxic effects of dispersed oil than oil and dispersant alone. Others confirmed dispersants be less toxic than the tested oils (Hemmer *et al.* 2011; Barron *et al.* 2013; Claireaux *et al.* 2013; McConville *et al.* 2018). Then, NASEM (2020) reported a data collection, highlighting that dispersed oil is not more toxic than untreated oil at concentrations below 100 mg oil/L, but above this value dispersants may increase oil toxicity. In the last, Fingas (2021) analyzed studies of ecotoxicity published between 2017 and 2021, reporting that chemically dispersed oil was more toxic than mechanically dispersed oil.

Table 7. Data from the Sea Empress incident.

During the "Sea Empress" incident, (Wales, 1996), which led to the largest dispersant treatment operation (440 tons of dispersant where applied on fresh crude at sea), oil concentrations were monitored in the upper water column as follows:	
Time after dispersant application	**Oil concentration in the upper water column (ppm)**
Just after treatment	10
2 days	1
1 week	0.5
1 month	0.2
3 months	Background level

Figure 30. The Sea Empress incident (UK) (© Cedre).

Various studies have been carried out to devise toxicity test methods which expose test organisms in conditions closer to their real environment. Toxicity tests performed with more realistic “spike-exposure” regimes show that the use of dispersants does not cause significant effects at dispersed oil concentrations of lower than 5-10 ppm with embryos and larvae. A level of 10-40 ppm-hours (concentration in ppm multiplied by exposure in hours) was found to produce no significant effects on higher marine life, such as older larvae, fish and shellfish.

However, recent studies (e.g. Discobiol), show that:

- lethal concentration on adults and juveniles are much higher than the concentration observed in real incidents;
- sub-lethal effects can be observed after the exposure time (bio-accumulation, metabolites in leaver, stress indicators…); however most of these observed effects are reversible in a relatively short delay: after 2 weeks of recovery the observed effects disappeared or reduced close to the background level.

Figure 31. Assessment of the impact of dispersed oil on fish and mussel – (Discobiol program) (© Cedre, © Laurent Mignaux).

Provided that dispersants are used to disperse oil in water where there is adequate depth and water exchange to cause adequate dilution, there is little risk of dispersed oil concentrations reaching levels for prolonged periods that could cause significant effects to most marine creatures.

Generally speaking, after incidents where large quantities of oil were dispersed at sea (e.g. “Sea Empress”), the environmental impact, when observed, has been much lower than expected, and the overall advantages resulting from the use of dispersants confirmed.

9.2 Microbial Degradation

Dispersion of oil, either mechanically or chemically, renders oil more available to microorganisms present in the sea water. The influence of dispersants on microbial degradation of oil is hence of prime importance.

Microorganisms capable to grow on petroleum hydrocarbons are present in all sea waters, and the rate of microbial degradation is directly related to the degree of oil dispersion. Paraffinic and high and medium aromatic fractions of oil are biodegradable, while for polyaromatic hydrocarbons (4, 5 cycles) and asphaltenes it has not been proven beyond doubt. There is no evidence of biodegradation of polar fractions, nitrogen-, sulphur- and oxygen-containing compounds and questions remain about the persistence of these compounds.

Dispersants increase the rate of oil biodegradation through:

- increasing surface to volume ratio of oil;
- increasing oil bioavailability (reduce the tendency of oil to form tar balls or mousse; stabilization of oil droplets in the water column instead of beaching or sedimenting).

However, dispersants may also reduce the rate of biodegradation by adding new bacterial substrate (the dispersant) that may be more attractive to microorganisms than oil or possibly increasing dispersed oil concentrations in the water column, which may have temporary toxic or inhibitory effects on the natural microbial populations.

As for toxicity, most of the knowledge of dispersed oil degradation is limited to results of laboratory or other small-scale studies. Some laboratory studies and all mesocosm studies have shown an increase in rates of oil biodegradation when dispersants are used.Temporary inhibition of biodegradation with dispersed oil was also recorded in laboratory tests. However, it appears to occur at higher dispersed oil concentrations than expected in the field. Data from pond and mesocosm studies strongly indicate that effective use of dispersants would increase the biodegradation rate of spilled oil. The question whether dispersants enhance the extent of biodegradation needs to be further studied, although available information suggests that refractory compounds would not be degraded despite the addition of dispersants.

9.3 Effects on marine organisms

The response of marine organisms evolving on the sea surface, such as seabirds, turtles and marine mammals, to exposure to oil depends on their sensitivity to the pollutant and the time of exposure. There are basically **four routes** of contact with oil:

1) **Absorption from water**: marine organisms may be exposed to naturally dispersed oil in the water column through uptake of bioavailable hydrocarbon compounds via their outer membranes and respiratory systems;

2) **Immediate contact**: these organisms might enter into direct contact with oil while they are swimming or rising to the surface to breathe. Their bodies may be coated with hydrocarbons, altering the waterproofing and insulating properties of their plumage or fur and leading to hypothermia or even death. Other extremely sensitive tissues, such as the eyes, can also be affected;

3) **Inhalation and aspiration**: organisms that breathe at the water's surface may be exposed to volatile organic compounds of oil and maybe to oil droplets that have been aerosolized from the surface slicks by the action of wind, mixing energy or rain. Wildlife like cetaceans can swallow water containing liquid oil, causing irritation to their respiratory tract; lung disease and pneumonia. These animals may also be exposed to oil droplets aerosolized by dispersants, which can be inhaled through their blowholes.

4) **Ingestion**: while feeding, marine organisms can be exposed to oil by directly ingesting water, sediment or a food source contaminated with hydrocarbon compounds. While some of these compounds can be eliminated by the digestive system due to their insolubility, other fractions that are more soluble in intestinal fluids can be absorbed and pass through the bloodstream. Indirect ingestion might also happen through grooming or preening.

Reduction of these effects by use of dispersant has not been studied extensively but it is expected that obtaining small oil droplets will promote the dissolution of soluble and semi-volatile compounds present in hydrocarbons, reducing the concentration of volatile substances suspended at the air/water interface. Potential impacts on fauna living on the water's surface should thus be reduced.

The effects of dispersant use on marine fauna are not fully understood, however, due to the lack of in situ studies and the difficulty of distinguishing the impacts of chemically dispersed hydrocarbons from those dispersed naturally by physical processes.

It is recognized that oil spills represent a greater risk of fouling for seabirds, turtles and fur-bearing mammals, as they spend more time on the water surface than cetaceans. In this sense, effective chemical dispersion represents a means of reducing the thickness and concentration of oil slicks, and therefore the potential toxicity and exposure of these organisms to the pollutant. Laboratory experiments have shown that chemically dispersed hydrocarbons alter the structure and the waterproofing of feathers in certain seabirds as well as their buoyancy. They also demonstrated that it was difficult to distinguish the magnitude of the effect of dispersed oil from that of non-dispersed oil.

It's clear that further studies are needed to accurately assess the impact of chemically dispersed hydrocarbons on marine fauna. Nevertheless, to limit the potential toxic effects of dispersant use, it is important to adopt a set of best practices when applying dispersants. These practices include, for example, the presence of wildlife observers during dispersant application who can confirm the absence of sensitive animals (e.g. cetaceans, fur-bearing mammals, seabirds, turtles) within a defined perimeter around the dispersal zone. Actions to discourage wildlife from entering the area can also be envisaged.

9.4 Impact on fisheries

The use of dispersants can have an impact on the fishing industry as fish or seafood can come into contact with and be contaminated by oil droplets in the water column. In certain circumstances, fishing areas may be temporarily closed to protect public health.

10

CHAPTER 10

Tools to Evaluate Response Environmental Benefit

10. TOOLS TO EVALUATE RESPONSE ENVIRONMENTAL BENEFIT

There are several techniques available to combat oil pollution, each with its own advantages and limitations. Thus, the decision to apply one or other of these techniques can be a difficult one for the response community, bearing in mind that each case of pollution is unique and that a lot of factors have to be considered. As the aim of the spill response is to minimize the overall ecological and socio-economic impact, several decision-making tools have been developed to help facilitate response option selection.

One of the first tool developed in the 2000s is called "NEBA" (Net Environmental Benefit Analysis). Based on Ecological Risk Assessments (ERA), NEBA is a process that compares the environmental (ecological, socio-economic, cultural) benefits of each of the possible response techniques, based on all the available data on the context of a spill. Such comparisons enable decision-makers to balance the trade-offs and to guide their strategies towards techniques and methods that are least damaging to the global environment.

When using dispersants, it is essential to use such decision-support tools, since this technique does not remove pollution from the environment, but rather transfers it to another environmental compartment (from the water surface to the water column) where it can be more easily diluted and biodegraded. The consequences involved in this transfer must therefore be scrupulously analysed in order to establish that this technique does not cause harmful effects to the environment than any other response technique.

As part of oil spill response plan development, it is recommended to evaluate certain spill scenarios according to NEBA, to determine, in advance, the possibilities in terms of response techniques. In this way, if the use of dispersants is the most appropriate technique, the dispersibility window is more likely to be respected in the event of an oil spill, and the efficiency of the dispersant optimized. This process must include:

- **evaluation of available data**: identify potential credible scenarios of oil spills (sources/location, type of oil, fate and trajectory modelling, etc.) as well as; in consultation with the local stakeholders; ecological, economic and social resources. From this inventory, determine which of these resources may be at risk (e.g. sensitive species, proximity to sensitive ecosystems and protected areas, weather, seasonal changes, fishing areas, desalination plants, etc.), taking into account their sensitivity and potential recovery;

- **prediction of outcomes**: review past spills to identify the main factors that led to the prediction and prevention of potential effects. For each threatened resource, the potential impact of the 'non-intervention' option is evaluated as a reference against which to estimate the effects of other response options;

- **balancing trade-offs**: compare the various ecological, socio-economic and cultural resources previously identified in the scenarios to determine which response techniques will be the most effective in minimizing impacts and guaranteeing protection of the global environment;

- **selection of the best options**: by taking into account the impact of non-dispersed versus dispersed oil, it is then recommended to draw up plans for the protection of priority resources. Response techniques that minimize the effects of the spill while promoting relatively rapid recovery of the environment are, following the previous steps, clearly identified.

In the last 20 years, other decision-making tools have been developed to improve the NEBA process, including:

- *Consensus Ecological Risk Assessment (CERA):* this tool is primarily based on the collaborative work of stakeholders on emergency plans and spill response plans. It's a time-consuming approach that is used more for emergency planning than as an adaptable decision-support tool in the event of an accident.

- *Spill Impact Mitigation Assessment (SIMA):* this approach brings together all stakeholders to prioritize the resources to be protected. It can be carried out relatively quickly and re-evaluated as the situation evolves following a spill.

- *Comparative Risk Assessment (CRA):* it is the latest tool to be developed and it includes fate/trajectory model as well as an effects model. This enables to assess the potential effects of the spill quantitatively, rather than relying on qualitative assessments as in the CRA/SIMA concepts. However, simulations of the models can take quite time to complete, which is not necessarily adapted to an actual spill context.

Responding to accidental oil spill requires quick reaction. In this way, effective pre-planning can considerably increase the success of the response by encouraging discussions between stakeholders and allowing a detailed analysis of the various resources to be protected as a priority. The adoption of best practices is then promoted.

In Part III of these Guidelines, the reader will find elements of practical guidance for conducting a NEBA process.

11

CHAPTER 11

General Recommandations for the Use of Dispersants in the Mediterranean Sea

11. GENERAL RECOMMANDATIONS FOR THE USE OF DISPERSANTS IN THE MEDITERRANEAN SEA

The decision to use dispersants as a means of responding to an oil spill must be motivated by the need to reduce the environmental and socio-economic impacts of a spill by preventing oil from reaching shorelines or sensitive ecological areas.

On the other hand, it is crucial to take into consideration the peculiarities of the Mediterranean that could aggravate the negative effects of using dispersants:

- it is a closed basin in which water circulation is rather limited, reducing the dilution of dispersed product;
- some bottom marine ecosystems (eg *Posidonia oceanica* meadows and coralligenous reefs), endemic to the Mediterranean and internationally protected, could be impacted by dispersed oil.

It must be based on a number of considerations that can be assessed using the NEBA/SIMA process and must answer the following questions:

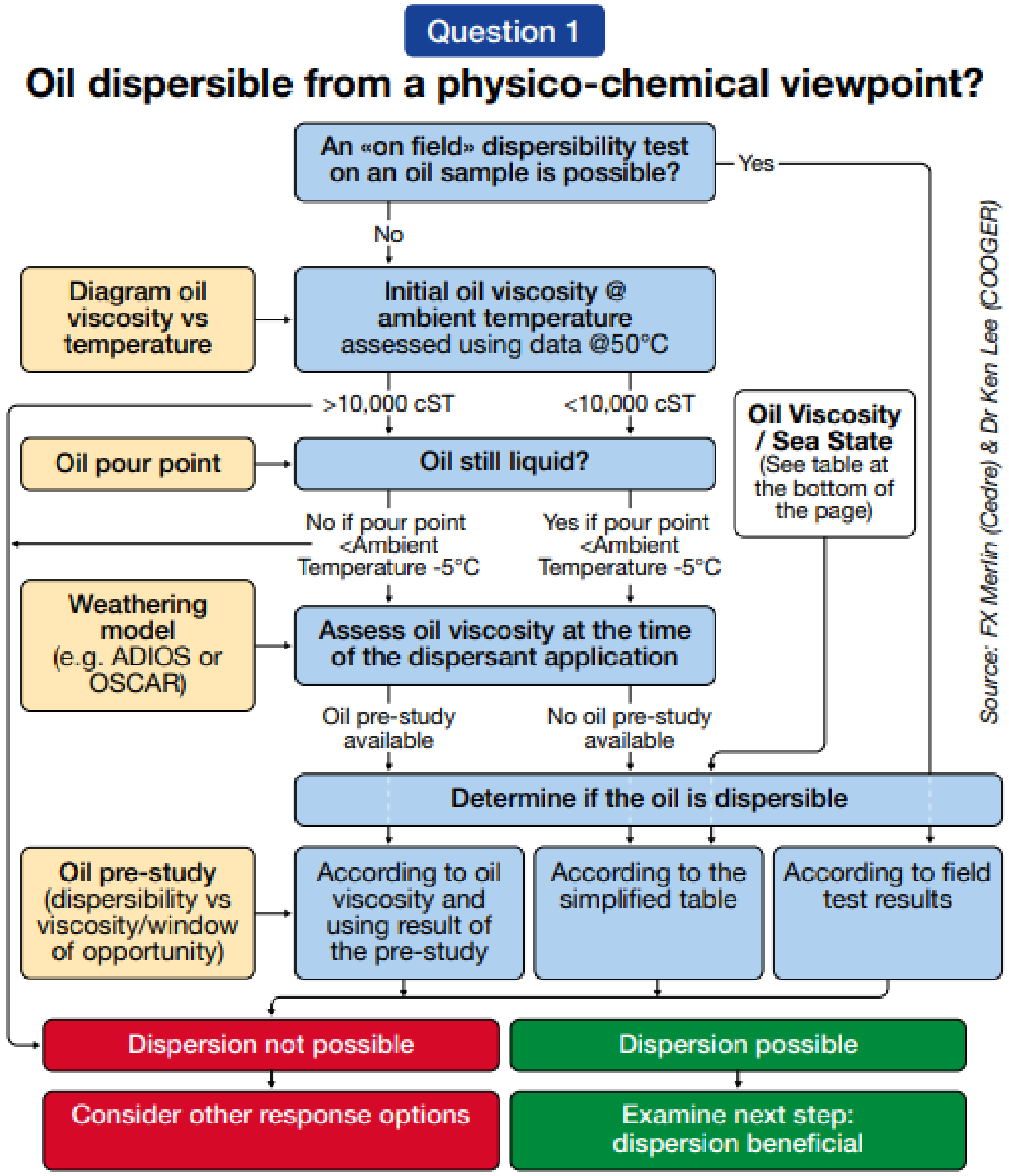
i. is dispersion physically and chemically **possible** under the prevailing conditions?

ii. is dispersion the most **beneficial** technique for the environment (ecologically and socio-economically)?

iii. is dispersion logistically **feasible**?

If these three conditions are met, then the use of dispersants can be considered. If one of these questions gives a negative answer it is necessary to consider other response options.

The following diagrams show the decision-making process for each of these questions, considering the use of concentrates dispersants, which must be adapted to the actual conditions of each spill.



Oil Viscosity / Sea State	<500 cST	500-5,000 cST	5,000-10,000 cST	>10,000 cST	>>10,000 cST
0-1	possible on limited spill with mixing energy	no	no	no	no
2-3	easy	possible	uncertain	no	no
>3	easy	easy	possible	uncertain	no

Figure 32 .First step in deciding whether to use dispersants (from Merlin (Cedre) & Lee (COOGER).

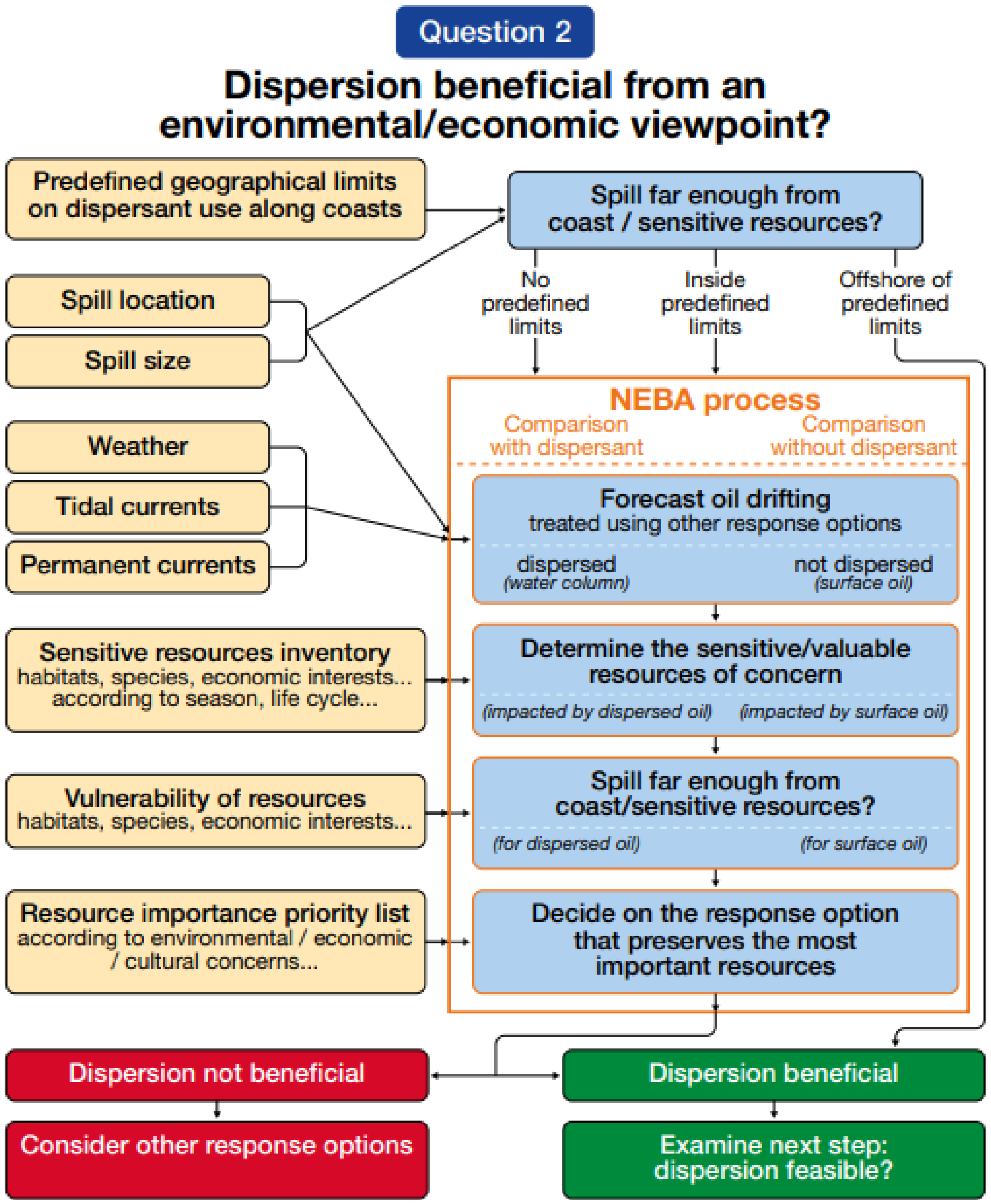


Figure 33. Second step in deciding whether to use dispersants (from Merlin (Cedre) & Lee (COOGER).

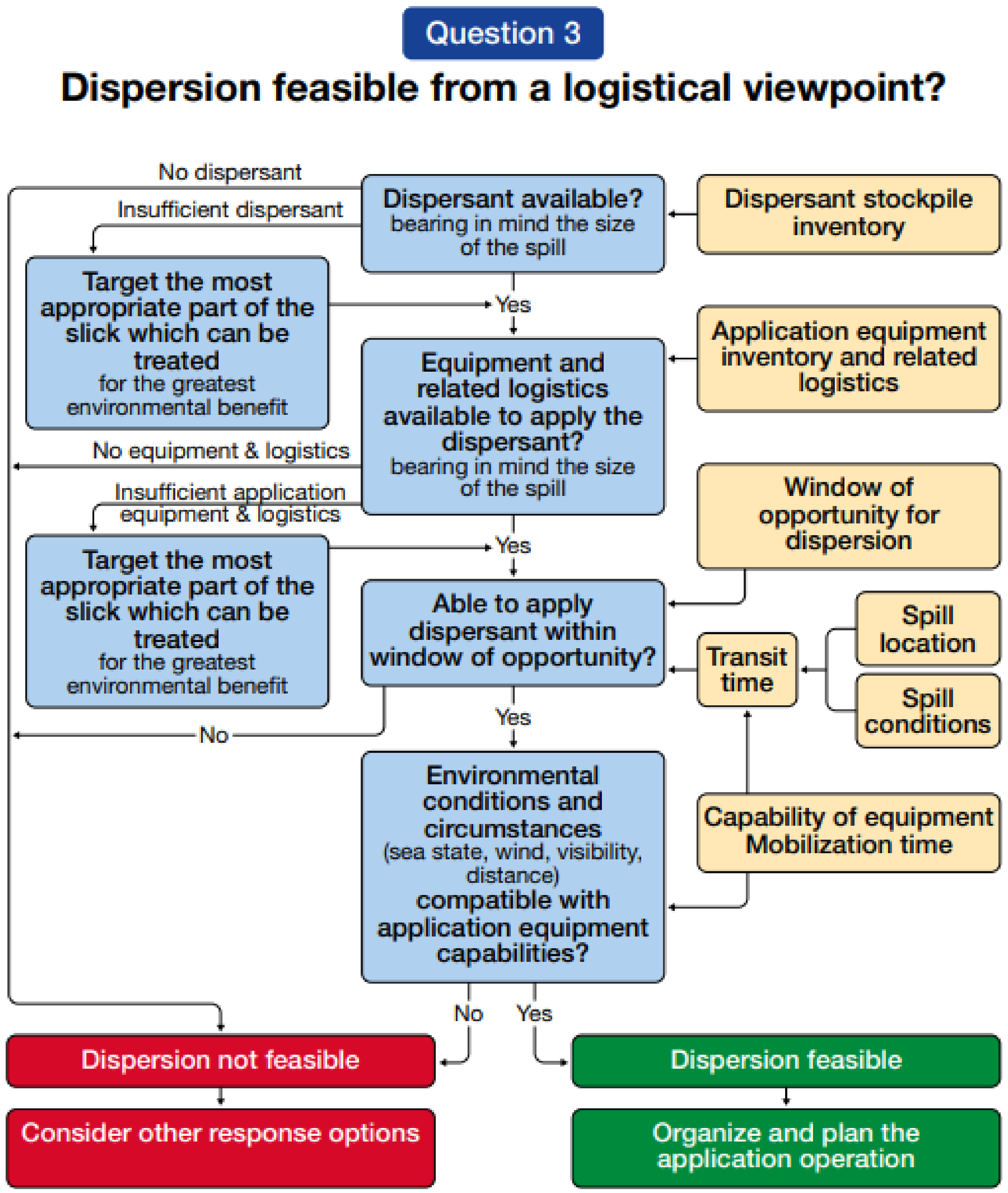


Figure 34. Final step in deciding whether to use dispersants (from Merlin (Cedre) & Lee (COOGER).

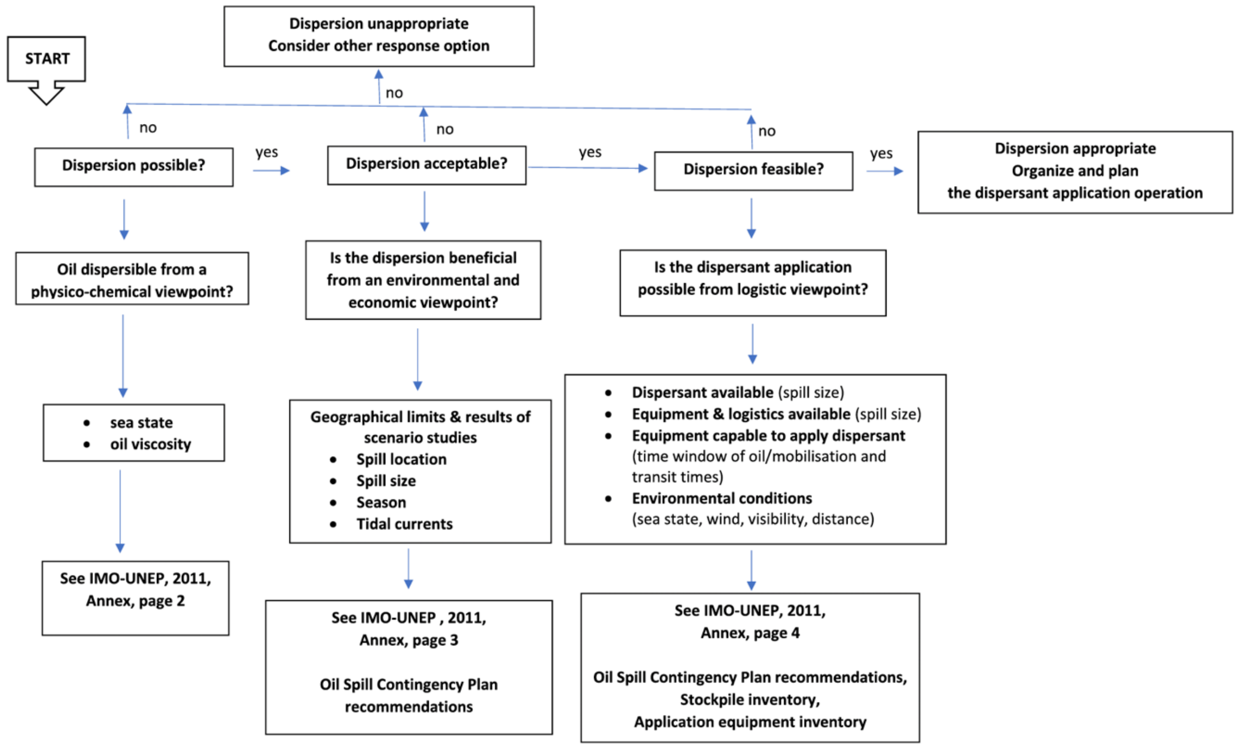


Figure 35. Decision making process

Once dispersants have been approved for use, their application requires the implementation of best practices to guarantee their effectiveness and their objective of minimizing the environmental impact of pollution. In particular :

- Apply dispersants as early as possible, to benefit of the hydrocarbon's dispersibility window ;
- Choose the right application system and adopt a methodical approach to processing to avoid wasting time and product;
- Protect operators with appropriate personal protective equipment ;
- Apply dispersants to the thick and medium-thick parts of the slick and not to the sheens ;
- Treat the slick by taking into account the prevailing conditions (e.g. apply dispersants against the wind) ;
- Avoid spraying too close to areas where marine mammals, turtles or birds may be present.

The feasibility of chemical dispersion depends on the availability of stockpiles, together with the equipment and operative capabilities. These logistic aspects, strictly peculiar for each country, are crucial to assess the applicability of dispersants and the window of opportunity for their use.

While recalling that each state bordering the Mediterranean has the sovereign right to prohibit in its territorial sea the use of dispersants to combat accidental marine pollution by hydrocarbons, here are some **general recommendations** on the use of dispersants in the Mediterranean Sea :

- **Bathymetry** and **distance from the coast** are important considerations when using dispersants. Dispersants should only be used in conditions where they can be sufficiently diluted (i.e. in water deeper than 50 meters and at a distance of around 2 kilometers from the coast to protect any water intakes), values depend also on intensity and direction of currents. However, if the protection of a sensitive area (ecological, cultural, economic) does not meet these conditions but requires the use of dispersants, an analysis will have to be carried out in relation to the benefits and risks represented by this decision;
- The Mediterranean region is vast and has many resources that need to be protected. To this end, **sensitivity atlases** are decision-making tools that could be worth developing, as they take into account the geomorphological, ecological and socio-economic features of the shoreline. They can be used to rank the sensitivity of the coastline and adapt response techniques in the event of oil pollution. Harmonization should also be provided for further attention to the countries bordering the same basin, based on the common environmental peculiarities, that affect the effectiveness of the dispersing action.
- As the Mediterranean Sea is home to great **biodiversity**, particular attention should be paid to the presence of sensitive, vulnerable or protected species when applying dispersants.. In particular, use of dispersants could determine adverse effects on protected benthic ecosystems, endemic in Mediterranean basin: *Posidonia oceanica* meadows and coralligenous reefs

An effective pre-planning in the use of dispersants is an essential process in ensuring the success of oil spill response operations. Pre-planning may involve the preparation of maps in which to divide sea stretches into areas where the use of dispersants is either **allowed**, **limited**, or **prohibited.** Wherever possible, it should provide an opportunity for **cooperation** between the various stakeholders to ensure the protection of the environment and public health.

Obviously, pre-planning should be carried out in cooperation with neighbouring Countries.

Pre-planning needs to take into consideration the zoning of the sea areas where the chemical dispersion is either allowed, limited, or prohibited, to guarantee environmental and economic benefits. This mapping requires the definition of geographical boundaries based on environmental and socio-economic components (i.e., shoreline, specific habitats, fish spawning areas, shellfish breeding areas, seasonal changes, etc.) and typical marine conditions (i.e., currents, tides, winds). In any case, the sea depth and the evaluation of distance from sensitive areas should be considered in mapping applicability of dispersants as well as in their own decision-making process, together with sea weather conditions and their forecasting. This is even more fundamental in the absence of the mapping process.

Bibliography

12. BIBLIOGRAPHY

Al Shami, A., Harik, G., Alameddine, I., Bruschi, D., Garcia, D.A., El-Fadel. M. (2017). Risk assessment of oil spills along the Mediterranean coast: A sensitivity analysis of the choice of hazard quantification, Science of the Total Environment. 234–245. Available on: https://www.sciencedirect.com/science/article/pii/S0048969716319830

Aprin, L., Heymes, F., Lauret, P., Slangen, P., & Le Floch, S. (2015). Experimental characterization of the influence of dispersant addition on rising oil droplets in water column. *Chemical Engineering Transactions*, *43*, 2287-2292.

Amundsen, T. (2022). The use and environmental impacts of dispersants for marine oil spill cleanup focusing on Corexit: a literature review.

Barron, M. G., Hemmer, M. J., & Jackson, C. R. (2013). Development of aquatic toxicity benchmarks for oil products using species sensitivity distributions. *Integrated environmental assessment and management*, *9*(4), 610-615.

Bonn Agreement (1991), Amended Chapter 20 of the Bonn Agreement Counter Pollution Manual (working paper), Bonn Agreement, Paris, France.

Boyd, J. N., Scholz, D., & Walker, A. H. (2001, March). Effects of oil and chemically dispersed oil in the environment. In *International Oil Spill Conference* (Vol. 2001, No. 2, pp. 1213-1216). American Petroleum Institute.

Cedre (Centre de documentation, de recherche et d'expérimentations sur les pollutions accidentelles des eaux) (1979). Traitement des hydrocarbures par épandage aérien de dispersant.

Cedre (1996). Lutte contre les pollutions accidentelles par hydrocarbures.

Cedre (2007a). SPREEX - State of the Art - Use of Dispersants. With the participation of Merlin F.X.

Cedre (2007b). Évaluation de système d'épandage aérien de dispersants - Essais à la base aéronavale de Cuers du 29 mai au 2 juin 2006. Avec la participation de De Nanteuil E., et Merlin F.

Cedre (2009). Journée technique - Évolution en France et développements récents à l'étranger.

Cedre (2014). Bulletin d'information du Cedre n°31.

Cedre (2015). Guide opérationnel: Traitement aux dispersants des nappes de pétrole en mer.

Claireaux, G., Théron, M., Prineau, M., Dussauze, M., Merlin, F. X., & Le Floch, S. (2013). Effects of oil exposure and dispersant use upon environmental adaptation performance and fitness in the European sea bass, Dicentrarchus labrax. *Aquatic Toxicology*, *130*, 160-170.

Coll, M., Piroddi, C., Steenbeek, J., Kaschner, K., Ben Rais Lasram, F., Aguzzi, J., ... & Voultsiadou, E. (2010). The biodiversity of the Mediterranean Sea: estimates, patterns, and threats. PloS one, 5(8), e11842.

Convention de Barcelone pour la protection de la Méditerranée | EUR-Lex, (s.d.). Available on : https://eur-lex.europa.eu/FR/legal-content/summary/barcelona-convention-for-the-protection-of-the-mediterranean.html

Convention sur la protection du milieu marin et du littoral de la Méditerranée (Convention de Barcelone), (1976). Available on: https://planbleu.org/wp-content/uploads/2022/03/Convention-de-Barcelone-1976-protection-du-milieu-marin-et-du-littoral-de-la-mediterranee.pdf.

Convention sur la protection du milieu marin et du littoral de la Méditerranée et ses protocoles, (2007). Available on : https://planbleu.org/sites/default/files/upload/files/Barcelona_convention_and_protocols_2007_fr%282%29.pdf

Ducrocq, V., Drobinski, P., Gualdi, S., & Raimbault, P. (2016). The water cycle in the Mediterranean. *The Mediterranean Region under Climate Change: A Scientific Update; Moatti, J., Thiébault, S., Eds*, 73-81.

Dussauze, M., Marguerie, J., Auffret, M., Merlin, F. X., & Le Floch, S. (2011). DISCOBIOL program: investigation of dispersant use in coastal and estuarine. In *International Oil Spill Conference* (Vol. 2011, No. 1, p. 173).

EMSA (2022). Inventory of national policies regarding the use of oil spill dispersants in the EU member states 2022. EMSA.

Energy Institute (2004). Operational guidelines on the use of oil spill dispersants at sea. Energy Institute.

Farahani, M. D., & Zheng, Y. (2022). The formulation, development and application of oil dispersants. *Journal of Marine Science and Engineering*, *10*(3), 425.

Fingas, M. (2021). A summary of dipsersants research : 2017 – 2021. 17p.

Fritt-Rasmussen, J., Linnebjerg, J. F., Nordam, T., Rigét, F. F., Kristensen, P., Skancke, J., ... & Gustavson, K. (2023). Effects of chemical dispersants on feathers from Arctic seabirds. *Marine Pollution Bulletin*, *188*, 114659.

G. Zodiatis, R. Lardner, D.R. Hayes, D. Soloviev, G. Georgiou. (2007). The successful application of the Mediterranean oil spill model in assisting eu decision makers during the oil pollution crisis of Lebanon in Summer 2006, Rapp Comm Int Mer Medit. Available on : https://ciesm.org/online/archives/abstracts/pdf/38/CIESM_Congress_2007_Istanbul_article_0214.pdf

Giakoumi, S., Sini, M., Gerovasileiou, V., Mazor, T., Beher, J., Possingham, H. P., ... & Katsanevakis, S. (2013). Ecoregion-based conservation planning in the Mediterranean: dealing with large-scale heterogeneity. PloS one, 8(10), e76449.

Giwa, A., Chalermthai, B., Shaikh, B., & Taher, H. (2023). Green dispersants for oil spill response: A comprehensive review of recent advances. *Marine Pollution Bulletin*, *193*, 115118.

Guidi, G., Sliskovic, M., Violante, A. C., & Vukic, L. (2016). Best available techniques (BATs) for oil spill response in the Mediterranean Sea: calm sea and presence of economic activities. *Environmental science and pollution research*, *23*, 1944-1953.

Hemmer, M. J., Barron, M. G., & Greene, R. M. (2011). Comparative toxicity of eight oil dispersants, Louisiana sweet crude oil (LSC), and chemically dispersed LSC to two aquatic test species. *Environmental Toxicology and Chemistry*, *30*(10), 2244-2252.

IMO (2024). Guidelines on the use of dispersants for combating oil pollution at sea, IMO, London, U.K.

IPIECA (2017). Dispersant storage, maintenance, transport and testing.

IPIECA (International Petroleum Industry Environmental Consideration Association) (2016). Dispersants: surface application. Good practices guidelines for incident management and emergency response personnel.

IPIECA. (2015). Dispersants: surface application. Good practice guidelines for incident management and emergency response personnel.

ITOPF (2011). Technical Information Paper - The use of chemical dispersants to treat oil spills. ITOPF, London.

ITOPF, Countries, Territories & Regions - Seas: Mediterranean Sea - ITOPF, (n.d.). Available on: https://www.itopf.org/knowledge-resources/countries-territories-regions/?tx_llcatalog_pi%5Bfilters%5D%5Bsea%5D=752&cHash=d09843d55c2f30a1bb98eb84dcc8d269

Kapsimalis, V. (2009). Geography of the Mediterranean Sea. Soil Protection in Sloping Mediterranean Agri-Environments: lectures and exercises.

Krair A, S.S, & Alkabu, H.A (2020) Oil spills and their effects upon the mediterranean, International Journal for Research in Applied Sciences and Biotechnology. Available on : https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3722865

Le Bihan, T., Giraud, W., & Le Floch, S. (Cedre) (2022). Subsea Dispersant Injection: How to Assess Oil Droplets Behavior in the Water Column from Pilot-Scale Experiments. In *EGU General Assembly Conference Abstracts* (pp. EGU22-7911).

Le Floch, S., Dussauze, M., Merlin, F. X., Claireaux, G., Theron, M., Le Maire, P., & Nicolas-Kopec, A. (2014). DISCOBIOL: assessment of the impact of dispersant use for oil spill response in coastal or estuarine areas. In *International Oil Spill Conference Proceedings* (Vol. 2014, No. 1, pp. 491-503). American Petroleum Institute.

Lewis, A., Merlin, F.X., Darling, P., Reed, M. (2006). Applicability of oil spill dispersants. Part 1 – Overview. EMSA.

McConville, M. M., Roberts, J. P., Boulais, M., Woodall, B., Butler, J. D., Redman, A. D., ... & Brander, S. M. (2018). The sensitivity of a deep-sea fish species (Anoplopoma fimbria) to oil-associated aromatic compounds, dispersant, and Alaskan North Slope crude oil. *Environmental toxicology and chemistry*, *37*(8), 2210-2221.

Manfra, L. A. Tornambè, J. Guyomarch, P. Le Guerrogue, L. Kerambrun, A. Rotini, F. Savorelli, F. Onorati, E. Magaletti. (2017). Dispersant approval procedures in France and Italy: A comparative ecotoxicity study, Ecotoxicology and Environmental Safety 143 180–185. Available on : https://doi.org/10.1016/j.ecoenv.2017.05.044.

Manfra, L.,Tornambè, A., Guyomarch, J.,Duboscq, K.,Faraponova, O.,Sebbio, C. (2020). Could a harmonized tiered approach assess dispersant toxicity in Italy and France?, Environ Sci Pollut Res 2730927–30932. Available on : https://doi.org/10.1007/s11356-019-06535-7.

Manfra, L. M. Mannozzi, . F. Onorati, (2022). Current Knowledge of approval procedures of dispersant use at sea: looking for potential harmonization from global to Mediterranean scale. Environmental Science and Pollution Research. Available on: *https://doi.org/10.1007/s11356-022-23462-2*

Manfra, L., Mannozzi, M., & Onorati, F. (2023). Current knowledge of approval procedures of dispersant use at sea: looking for potential harmonization from global to Mediterranean scale. *Environmental Science and Pollution Research*, *30*(7), 18380-18394.

Merlin, F. (1991). Cedre, Selecting dispersants and periodic checking of their quality, Cedre, Brest, France.

Merlin, F., Zhu, Z., Yang, M., Chen, B., Lee, K., Boufadel, M. C., ... & Zhang, B. (2021). Dispersants as marine oil spill treating agents: a review on mesoscale tests and field trials. *Environmental Systems Research*, *10*, 1-19.

Mukherjee, B., J. Turner and B. A. Wrenn (2011). Effect of oil composition on chemical dispersion of crude oil. Environ. Eng. Sci., 28: 497-506.

National Academies of Sciences, Division on Earth, Life Studies, Board on Environmental Studies, Ocean Studies Board, & Committee on the Evaluation of the Use of Chemical Dispersants in Oil Spill Response. (2020). *The use of dispersants in marine oil spill response*. National Academies Press.

National Academies of Sciences, Engineering, and Medicine. (2005). Oil Spill Dispersants: Efficacy and Effects. Washington, DC: The National Academies Press. https://doi.org/10.17226/11283

National Research Council (2005). Oil spill dispersant. Efficacy and effects. National Academic Press.

Natura 2000 Esterel (s.d.). Les habitats marins. Available on: https://esterel.n2000.fr/site-natura-2000-de-l-esterel/les-habitats-naturels-et-les-especes-vegetales/les-habitats-marins

NOWPAP MERRAC (2005). Guideline for the use of dispersant.

Organisation des Nations Unies pour l'alimentation et l'agriculture & Commission Générale des pêches pour la Méditerranée (2020). La situation des pêches en Mediterranée et en mer Noir, 2020. Available on: https://openknowledge.fao.org/server/api/core/bitstreams/3d28932d-a62b-404f-bab5-ab8d0cba14cf/content

Osborne, O. E., Willie, M. M., & O'Hara, P. D. (2022). The effects of oil spill dispersant use on marine birds: a review of scientific literature and identification of information gaps. *Environmental Reviews*, *31*(2), 243-255.

P. Nasr, E. Smith. (2006). Simulation of oil spills near environmentally sensitive areas in Egyptian coastal waters, Water & Environment J 20 11–18. Available on : https://doi.org/10.1111/j.1747-6593.2005.00013.x.

Pelletier, E. (2015). Revue des connaissances scientifiques sur la composition et le mode d'action des agents chimiques de traitement utilisés lors de déversements pétroliers ainsi que le devenir des mélanges hydrocarbures/agents de traitement en milieu aquatique. Étude GENV31, réalisée dans le cadre de l'évaluation environnementale stratégique globale sur les hydrocarbures.

Programme des Nations Unies pour l'Environnement/Plan d'Action pour la Méditerranée et Plan Bleu (2020). État de l'Environnement et du Développement en Méditerranée. Nairobi.

R.M. Abou Samra, M. El-Gammal, R. Eissa, Oceanographic factors of oil pollution dispersion offshore the Nile Delta (Egypt) using GIS, Environ Sci Pollut Res 28 (2021) 25830–25843. Available on : https://doi.org/10.1007/s11356-021-12570-0.

R.M. Abou Samra, R. Eissa, M. El-Gammal, Applying the environmental sensitivity index for the assessment of the prospective oil spills along the Nile Delta Coast, Egypt, Geocarto International 35 (2020) 589–601. https://doi.org/10.1080/10106049.2018.1533592.

Rades, C. V., & Tilesman, E. B. (Eds.). (2008). Advances in environmental research (Vol. 1). Nova Publishers.

REMPEC, Profils des pays, Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC) (s.d.). Available on : https://www.rempec.org/fr/resources/profil-des-pays

Silva, I. A., Almeida, F. C., Souza, T. C., Bezerra, K. G., Durval, I. J., Converti, A., & Sarubbo, L. A. (2022). Oil spills: impacts and perspectives of treatment technologies with focus on the use of green surfactants. *Environmental Monitoring and Assessment*, *194*(3), 143.

Singer, M. M., Smalheer, D. L., Tjeerdema, R. S., & Martin, M. (1991). Effects of spiked exposure to an oil dispersant on the early life stages of four marine species. *Environmental Toxicology and Chemistry: An International Journal*, *10*(10), 1367-1374.

Singer, M. M., George, S., Jacobson, S., Lee, I., Weetman, L. L., Tjeerdema, R. S., & Sowby, M. L. (1995). Acute toxicity of the oil dispersant Corexit 9554 to marine organisms. *Ecotoxicology and Environmental safety*, *32*(1), 81-86.

SPA/RAC (Specially Protected Areas Regional Activity Center) (s.d.). Biodiversity in the Mediterranean. Available on: https://www.rac-spa.org/fr/biodiversite

Swedmark, M., Granmo, Å., & Kollberg, S. (1973). Effects of oil dispersants and oil emulsions on marine animals. *Water Research*, *7*(11), 1649-1672.

Taupier-Letage, I. (2020). Le circuit 3D des masses d'eau en Méditerranée. CNRS. Available on : https://www.insu.cnrs.fr/fr/cnrsinfo/le-circuit-3d-des-masses-deau-en-mediterranee

Y. Shai. (2019). The Effect of Oil Pollution on Marine Microbial Populations in the Southeastern Mediterranean Sea, Master's Thesis, University of Haifa (Israel), available on : https://search.proquest.com/openview/0bdde1d239c78504580a939469772f56/1?pq-origsite=gscholar&cbl=2026366&diss=y

Ye, X., Zhu, Z., Merlin, F.X., Yang, M., Chen, B., Lee, K., & Zhang, B. (2021). Ecological impact analysis of dispersants and dispersed oil: An overview. *JEIL*, *5*, 120-133.

Zhu, Z., Merlin, F., Yang, M., Lee, K., Chen, B., Liu, B., ... & Zhang, B. (2022). Recent advances in chemical and biological degradation of spilled oil: a review of dispersants application in the marine environment. *Journal of Hazardous Materials*, *436*, 129260.

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