

USE OF DISPERSANTS TO TREAT OIL SPILLS

TECHNICAL INFORMATION PAPER

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Introduction

The principal aim of dispersant application is to break up an oil slick into numerous small droplets which become rapidly diluted into the water column and are subsequently degraded by naturally occurring micro-organisms. Used appropriately, dispersants can be an effective response to an oil spill and can minimise or prevent damage to important sensitive resources.

In common with other response techniques, the use of dispersants must be considered carefully, to take into account oil characteristics, sea and weather conditions, environmental sensitivities and national regulations on dispersant use. In some cases, significant environmental and economic benefits can be achieved through the use of dispersants, particularly when other at-sea response techniques are limited by weather conditions or the availability of resources.

This paper provides an overview of the use and limitations of dispersants on floating oil, as one of a range of options available for response to ship-source marine oil spills.

Mechanism of dispersion and dispersant composition

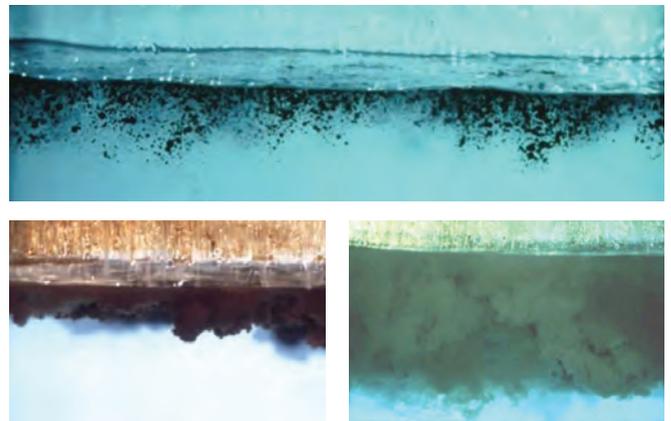
Following a spill of oil onto the sea surface, some of the oil in the resultant slick may disperse naturally into the water column. The extent to which this occurs depends on the type of oil spilt and the mixing energy of the sea. Oils with a lower viscosity are more amenable to natural dispersion than those with a higher viscosity. In general, crude oils will disperse to a greater extent than fuel oils.

Natural dispersion takes place when the mixing energy, provided by the waves and wind, is sufficient to overcome surface tension at the oil/water interface and break the oil slick into droplets of variable sizes (*Figure 1a*). The larger oil droplets will rapidly resurface and coalesce to reform an oil slick. The smaller droplets will remain suspended in the water column, due to wave motion and turbulence, and will be further diluted by subsurface currents.

The process of natural dispersion takes place in moderately rough seas, with breaking waves and winds above 5 m/s (10 knots). For example, severe storm conditions in Shetland, UK, during the grounding of the tanker BRAER in 1993, caused the majority of the 85,000 tonne cargo of Gulfaks crude oil, a very low viscosity oil, to be dispersed naturally, with minimal shoreline impact.

Dispersants are designed to enhance natural dispersion by reducing the surface tension at the oil/water interface, making it easier for wave motion to create many more small oil droplets (*Figures 1b and 1c*). Dispersants are a blend of surfactants (surface active agents) in a solvent. The solvent has two functions: to act as a 'thinner', reducing the viscosity of the surfactant, so that it can be sprayed, and to promote the penetration of the surfactant into the oil slick.

Each surfactant molecule contains an oleophilic part, (attracted to oil) and a hydrophilic part (attracted to water). When sprayed onto oil, the solvent transports and distributes

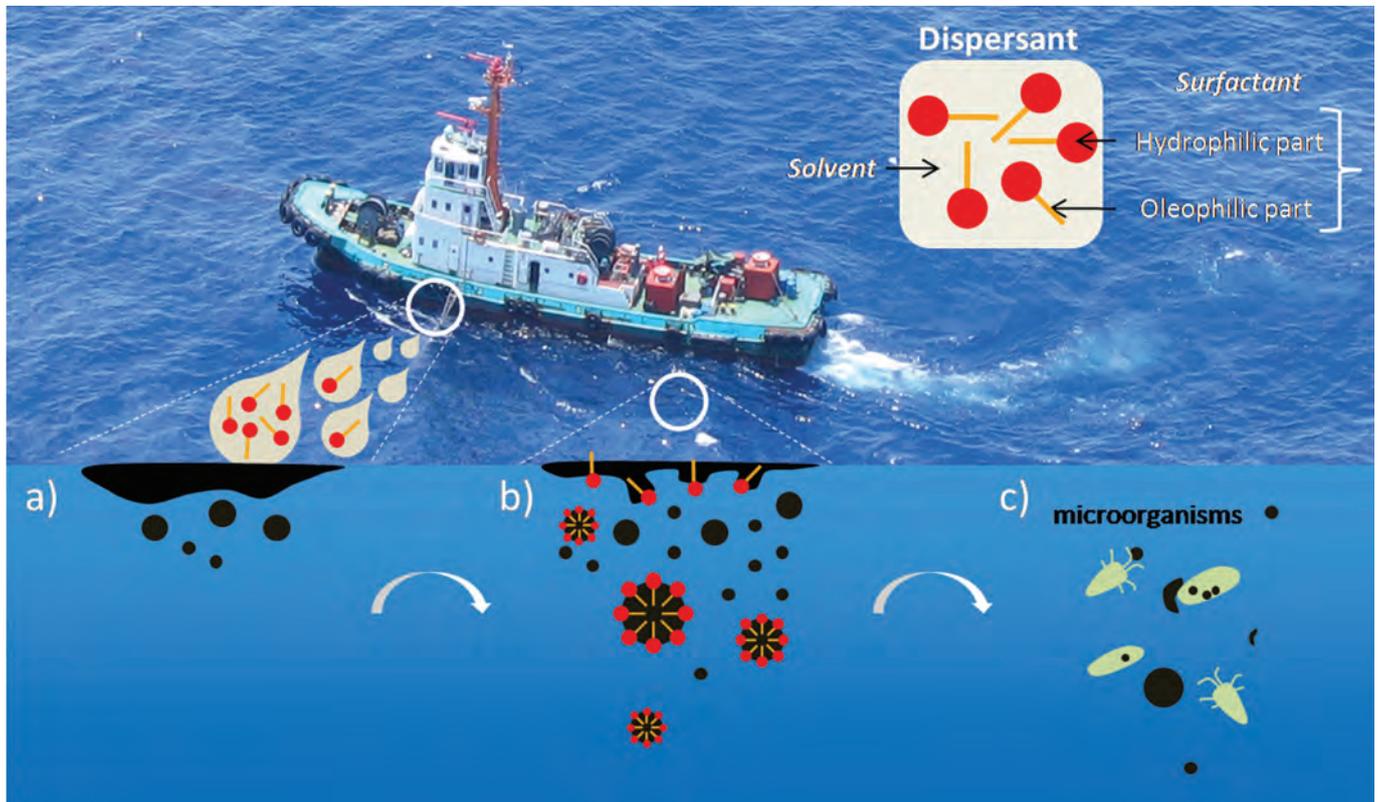


▲ *Figure 1: Successful dispersion in laboratory conditions. a) Oil without dispersant (natural dispersion), b) Oil with dispersant and c) Oil with dispersant a few seconds later, demonstrating rapid dilution. (Images courtesy of Delft Hydraulics Institute).*

the surfactant through the oil to the oil/water interface where the molecules re-arrange so that the oleophilic part is in the oil and the hydrophilic part is in the water. This reduces the surface tension of the oil/water interface, which, together with wave energy, results in droplets breaking away from the oil slick. Droplets that are sufficiently small to remain suspended in the water column produce a typical coffee-coloured plume seen to spread under the surface (*Figure 1c*).

To achieve an effective dispersion, oil droplet size must be in the range of $1\mu\text{m}^*$ to $70\mu\text{m}$, with the most stable size being less than $45\mu\text{m}$. The speed with which droplets in this size range rise towards the surface is balanced by the turbulence of the sea so that they remain in suspension and the oil and dispersant mixture dilutes rapidly within the top few metres of the water column. The presence of the surfactant molecules at the droplet surface, and the reduced probability of oil droplets coming into contact as they dilute and move apart, minimises the possibility of re-coalescence and reformation of surface slicks.

* μm = micrometres = 10⁻⁶ metres. $1\mu\text{m}$ = 0.001mm



▲ *Figure 2: The chemical dispersion process: a) Dispersant containing surfactants and solvent is sprayed onto the oil with the solvent carrying the surfactant into the oil; b) The surfactant molecules migrate to the oil/water interface and reduce surface tension, allowing small oil droplets to break away from the slick; c) The droplets disperse by turbulent mixing and are ultimately degraded by naturally occurring micro-organisms, such as bacteria and fungi. This latter stage may require days or weeks to achieve.*

Biodegradation by a range of marine micro-organisms can occur only at the droplet surface because the organisms are present in the water and not in the oil. The production of numerous smaller oil droplets increases the surface area of the oil and therefore the area available for biodegradation. For example, a droplet of 1mm diameter dispersed into 10,000 droplets, all of 45µm diameter, would result in a surface area that is 20 times larger than the surface area of the original droplet. In practice, dispersed droplets are not all the same size but are distributed such that there are very many more smaller droplets than larger ones, greatly increasing the opportunity for biodegradation.

Dispersant classification

Dispersants are classed according to their generation and their type. The first generation of products, introduced in the 1960's, were similar to industrial cleaners and degreasers, with high aquatic toxicity. They are no longer used in oil spill response.

Second generation dispersants, also called Type I dispersants, were designed specifically to treat oil spills at sea by spraying from vessels. They contain a hydrocarbon solvent with a low or no aromatic content and typically 15 to 25% surfactant. They are intended to be applied undiluted (neat), as pre-dilution with sea water renders them ineffective. They also require a high dose rate of between 1:1 and 1:3 (dispersant to oil). While having lower toxicity than the first generation dispersants, they are less effective and may be more toxic than third generation dispersants. In many countries, Type I dispersants are no longer used.

Third generation dispersants contain a blend of two or three surfactants with glycol and light petroleum distillate solvents. The most common surfactants used are non-ionic (fatty acid esters and ethoxylated fatty acid esters) and anionic (sodium alkyl sulphosuccinate). The concentration of surfactant within the solvent lies between 25% and 65% and tends to be higher than with Type I products.

Third generation dispersants can be divided into Type II and III dispersants. Both types are concentrate dispersants. However, Type II dispersants are generally diluted with sea water prior to use, typically at 10% dispersant, but require a high dosage of 2:1 to 1:5 (dispersant/water mix to oil) to be effective. This requirement for dilution limits their use to application from vessels. Type III dispersants are used neat and were developed primarily to allow efficient application from aircraft but may also be used from vessels. Dosage rates range between 1:5 and 1:50 (neat dispersant to oil), with the ideal practical ratio determined as a result of trials during an incident. Third generation, Type III dispersants are now the most commonly available dispersants.

Limitations of dispersants

Dispersant effectiveness is limited by certain physical and chemical parameters, the most important of which are the sea conditions and the oil properties. An awareness of these limitations is important to identify circumstances when dispersant use is appropriate.

Sea conditions

A minimum amount of wave energy is required for the successful use of dispersants at sea. Below this minimum, the dispersed oil droplets may re-surface and reform a slick. Furthermore, in severe sea conditions, the oil may be submerged by breaking waves, preventing direct contact between the dispersant and the oil, and dispersant efficacy will diminish. The results of field trials indicate that a wind speed between 4–12 m/s (8–25 knots, Beaufort Scale 3–6), is optimum.

Dispersants are manufactured primarily for use in seawater with a salinity of around 30–35 parts per thousand (ppt). Performance will decrease rapidly in brackish waters with a salinity below 5–10 ppt, especially when applying pre-diluted dispersant. Similarly, efficiency is also affected when salinity rises above 35 ppt. Efficacy is dramatically reduced in freshwater because the surfactants tend to migrate through the oil layer into the water column instead of stabilising at the oil/water interface. However, some dispersants have been specially formulated for use in freshwater. In a confined freshwater system, such as rivers and lakes, other factors need to be considered, such as whether there is sufficient depth or water exchange to achieve adequate dilution of the dispersed oil.

Oil properties

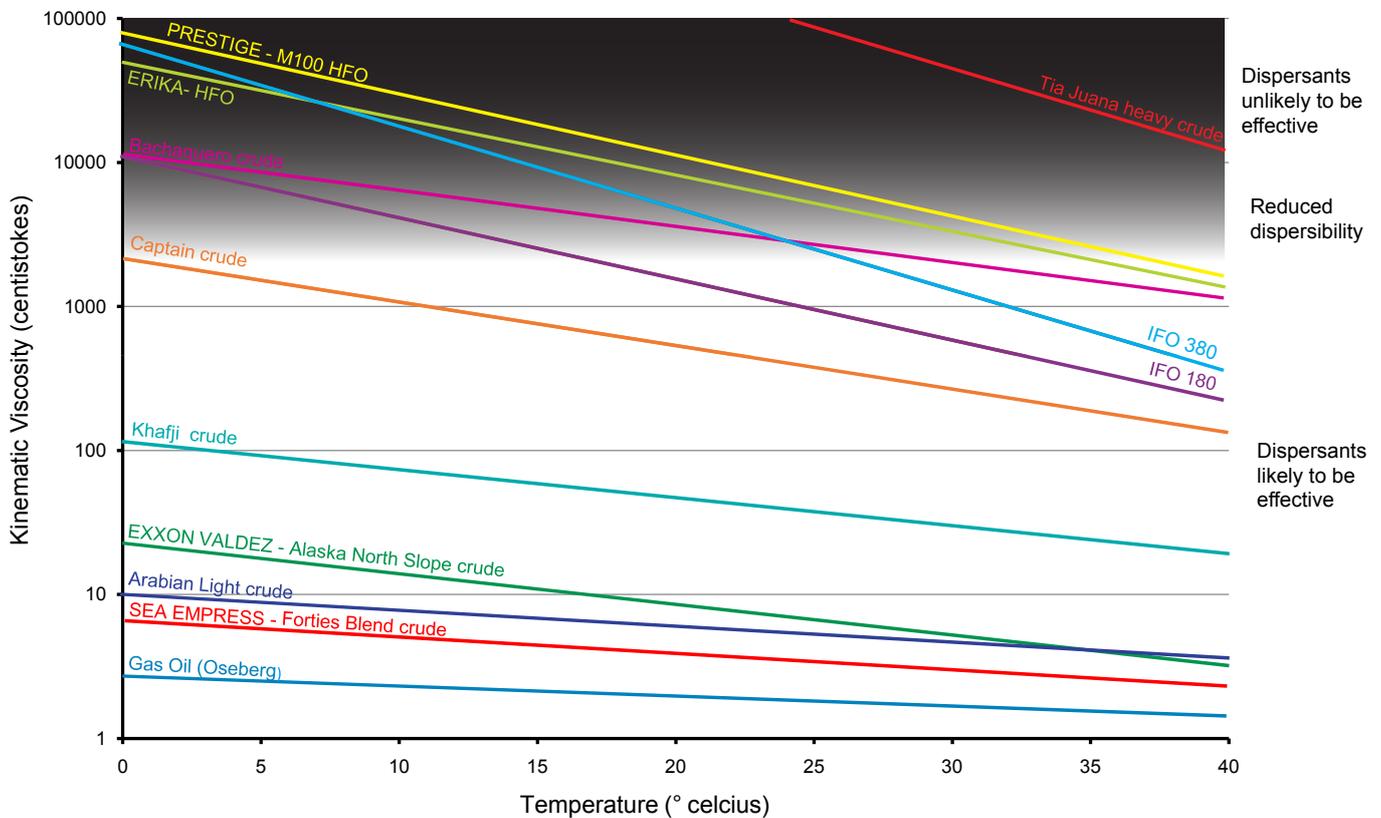
The characteristics of the oil and the manner in which these properties change by weathering at sea, are important when assessing whether the use of dispersants is likely to be successful. The viscosity and pour point of an oil are two properties that provide a good indication of how easily

the oil is likely to disperse.

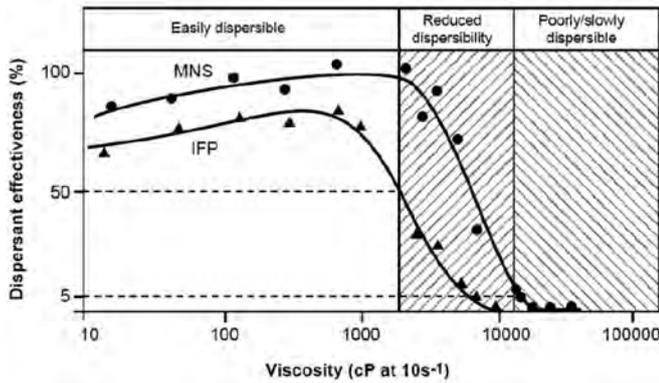
Dispersant effectiveness decreases as oil viscosity increases (Figures 3 and 4). Fresh, light-to-medium crude oils (group 2 or 3 oils, as described in the separate ITOF paper on the Fate of Marine Oil Spills) are generally considered to be readily dispersible at most sea temperatures. The upper limit for dispersion is likely to be reached with heavier oils (Group 4 oils). As a general guide, most dispersants are unlikely to be effective for oils with a viscosity above 5,000–10,000 centistokes (cSt) at the time that they are spilled. The viscosity of spilled oil will increase due to the effects of weathering, primarily evaporation and emulsification. As a consequence, oils that may be dispersible when fresh may not be dispersible subsequently. The changes in oil properties over time caused by weathering mean that the opportunity for the successful application of dispersants is limited. The time available or 'window of opportunity' usually ranges from a few hours to a few days depending on the type of oil involved and the ambient conditions.

Similarly, oils with a pour point that is higher than the ambient temperature are usually transported heated and if spilled will rapidly increase in viscosity as they cool, often becoming semi-solid. As a general rule, oils with a pour point close to, or higher than, the sea surface temperature will not be dispersible.

Oils with a high viscosity, including those with a high pour point, do not disperse easily, either naturally or after the application of dispersants because the mechanical resistance of the oil prevents small droplets from breaking away under



▲ Figure 3: Relationship between oil viscosity and sea temperature for 10 oils. The graph does not take account of increases in viscosity due to emulsification. Highly viscous oils, including the fuel oils spilled from ERIKA (France, 1999) and PRESTIGE (Spain, 2002), are generally not dispersible. Many crude oils, including those spilled from SEA EMPRESS (Wales, 1996) and EXXON VALDEZ (Alaska, 1989), are, in general, dispersible. Lighter products, such as gasoil, will generally readily disperse (and evaporate) without the use of dispersants.



▲ *Figure 4: Relationship between dispersant efficacy and oil viscosity for a range of oils and emulsions. Oils with a viscosity between 5,000–10,000 centiPoise become more difficult to disperse and above 10,000cP are generally not dispersible. The two trend lines result from the use of the differing MNS and IFP test protocols. (Centipoise = Centistokes x density) (Graph courtesy of SINTEF).*

the slick. Furthermore, dispersants are usually ineffective on these oils because they are not able to penetrate the oil before being washed off and lost into the water below, characterised by a white plume (*Figure 5*) that is noticeably in contrast with successful dispersion (*Figure 6*). Dispersant formulations are continually evolving to extend the viscosity range and improve their effectiveness on high viscosity oils. For example, dispersant gels are being developed to prolong contact with the oil to encourage solvent penetration.

Some oils are particularly prone to forming water-in-oil emulsions (especially those that have a relatively high asphaltene content (>0.5%) and a combined nickel/vanadium concentration greater than 15 parts per million (ppm)). However, if the emulsion is not stable, concentrate dispersants may be able to break it, releasing the water and allowing the relatively liquid oil produced to be dispersed by a second application of dispersant. If the emulsion has been successfully broken, patches of reflective pure oil should be observed.

Light products such as diesel, gasoline and kerosene do not



▲ *Figure 5: Ineffective treatment of a heavy fuel oil with dispersant is characterised by a white plume in the water. The oil remains unaffected.*

readily form emulsions but spread to form very thin films of oil or sheens on the water surface that evaporate or dissipate rapidly without the need to use dispersants. Irrespective of this, the use of dispersants on light products or on sheens derived from a crude or fuel oil is not advised because the dispersant droplets tend to ‘punch’ through the thin film into the underlying water and cause ‘herding’ of the oil. The dispersant in the water causes the oil film to draw back immediately, creating an area of clear water that should not be mistaken for dispersion (*Figure 7*). Dispersants formulated for use on mineral oils have been shown to have little or no effect on non-mineral oils, such as palm oil or rapeseed oil.

Dispersant choice

Dispersants are manufactured to different formulations, and their effectiveness varies with oil type. Laboratory tests may be carried out to rank the effectiveness of one dispersant relative to another for a particular oil and some countries require operators of oil production facilities and oil terminals, where the types of oils produced and handled are known, to undertake studies to identify the most effective dispersant for the oils involved. However, caution is advised when extrapolating the results from these studies to predict the amount of oil that will be dispersed at sea, as accurate replication of the conditions at sea is difficult in a laboratory environment. For planning purposes a dosage of 1:20, Type III concentrate dispersant to oil, is commonly used and spraying equipment is often pre-configured to achieve this. This dosage may sometimes be decreased for fresh oils and conversely, increased for viscous or emulsified oils where more than one application may be needed.

Conflicts with other response methods

In a large incident, coordination of all response actions is necessary to ensure dispersant use does not overlap or conflict with other response techniques. For example, oil dispersed into the water column cannot be contained by booms or recovered by skimmers. In addition, oil adheres to many sorbent materials, such as polypropylene, as a result of the relative surface tension of the oil. As the surface tension of oil is modified by dispersants, the effectiveness of



▲ *Figure 6: Dispersion starting after application to Forties Crude during the SEA EMPRESS spill. (Image courtesy of AEA Technology).*



▲ *Figure 7: Application of dispersant from vessel mounted spray arms onto sheen, causing herding of the oil, rather than dispersion.*

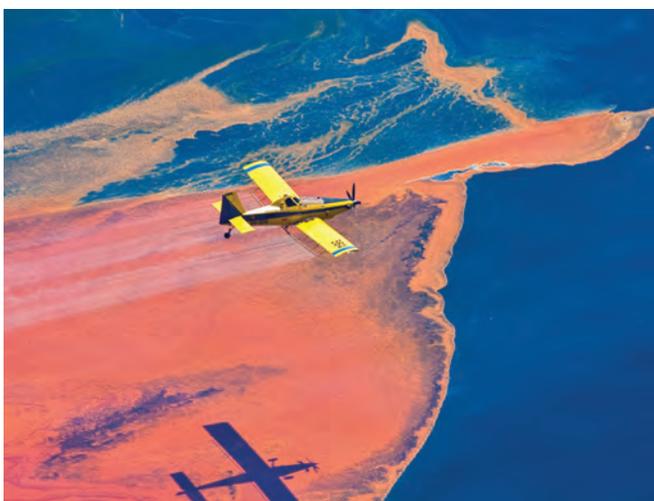
sorbent materials can be significantly reduced by the use of dispersants. Oleophilic skimmers will be similarly affected when used alongside dispersants.

Application methods

Dispersants can be applied from vessels or aircraft to oil spill on open water. Large multi-engine aircraft offer advantages of payload for application to major off-shore spills but, along with vessels, helicopters and light aircraft, may be suitable for treating smaller spills closer to the shore.

It is important that spray systems deliver dispersant droplets of the correct size. Droplets need to be large enough to overcome the effects of wind drift and evaporative loss but not so large that they punch through the oil rather than migrate to the oil/water interface. The optimum dispersant droplet size is between 600 and 800µm in diameter.

Dispersant sprayed onto water or sheen will be ineffective and a waste of costly resources. Consequently, the thickest part of the oil slick should be rapidly targeted, before weathering



▲ *Figure 9: An Air Tractor spraying from an under-wing spray boom onto crude oil spill from an offshore platform. (Image courtesy of Mark Hamilton Photography).*



▲ *Figure 8: Application of dispersant using fire monitors on a tug, showing uneven spread of dispersant and the effect of wind.*

of the oil or changes in the sea conditions render dispersants ineffective.

Vessel spraying

Dispersants sprayed from vessels are usually applied through a set of nozzles mounted on spray arms (*Figure 7*). Diesel or electric pumps transfer the dispersant from a storage tank to the spray arm, fitted with a set of nozzles calibrated to produce a uniform spray pattern of droplets along the length of the arm. Spray units can be portable or permanently installed on a vessel and systems are available to deliver the dispersant either undiluted or diluted with sea water.

Spray arms operate more effectively if mounted as far forward on the vessel as possible, to avoid the bow wave pushing the oil beyond the width of the spray pattern, or the spray swath. Mounting the spray arms on the bow allows the vessel to travel faster and, because freeboard is often greater at the bow, also allows the spray arms to be made longer. This optimises the encounter rate, i.e. the amount of oil that can be treated, with a limited dispersant payload. However, if the arms are too long they risk damage when



▲ *Figure 10: Application of dispersant from a multi-engine aircraft. Here, application in shallow waters was considered beneficial.*



▲ *Figure 11: A helicopter, with an under-slung spray system, approaching a fresh spill of fuel oil. To be effective, application from a lower altitude would be necessary. (Image courtesy of Indian Coastguard).*

the vessel rolls in swell.

Fire hoses or fire monitors (*Figure 8*) are sometimes used to apply concentrate dispersants diluted in the water stream. However, optimum dilution of the dispersant is difficult to achieve because of the very high flow rates and it is difficult to apply the dispersant as a uniform spray of droplets. The high pressure of the water jet also risks forcing the dispersant through the oil. Thus, fire monitors are likely to lead to wastage of dispersant and ineffective application unless specially modified for the purpose.

Vessels offer advantages for dispersant spraying because they are usually readily available, easy to load and can apply dispersant fairly accurately to specific areas of a slick. They have cost advantages over aircraft and may be able to carry larger payloads. Nevertheless, they also have severe limitations, particularly for larger spills, because of the low treatment rate and the difficulty of locating the heaviest concentrations of oil from the bridge of a vessel, although this latter problem can be partially overcome by directing the operation from a spotter aircraft.

Aerial spraying

The application of dispersants from aircraft offers the advantages of rapid response, high treatment rates and optimum dispersant use. In broad terms, three categories of fixed-wing aircraft are used: those designed for agricultural or pest control operations (*Figure 9*), which require minor modification for dispersant application, those that have been adapted specifically for the application of dispersant and cargo aircraft with modular tanks (*Figure 10*). Some helicopters have been adapted with fixed spray arms whilst others are able to carry under-slung bucket spray systems, usually without the need for major modifications (*Figure 11*). Helicopters can potentially reload dispersants from a vessel or offshore oil platform for operations offshore.

The ideal aircraft for a given incident will be determined primarily by the size and location of the spill, although local availability will be the crucial factor. Aircraft should be capable of operating safely at low altitudes (typically 15–30 metres for larger aircraft) and at relatively slow speeds (25–75 m/s) and should be highly manoeuvrable. Fuel consumption, payload, distance between the spill and the operating base, turn-around times and the ability to operate from short or improvised landing strips are all important considerations when selecting suitable aircraft.

Type III dispersants are most suitable for aerial spraying as the low dosage (typically 1:20 dispersant to oil) makes best use of the limited payload. Aircraft spraying systems consist of a pump that draws dispersant at a controlled rate from a tank into spray arms fitted to the aircraft. The dispersant is discharged either through pressure nozzles or from wind driven rotating units spaced at regular intervals along the spray arm, which are designed to produce dispersant droplets of the optimum size. Both types of discharge unit can be used on most light aircraft and helicopters but larger aircraft use pressure nozzles.

Shoreline application

Once bulk oil has been recovered from affected shorelines, dispersants are sometimes used as cleaning agents, to remove the remaining oil from hard surfaces such as rocks, sea walls and other man-made structures. They are generally applied from hand-operated backpack systems and brushed vigorously into the oil before flushing with seawater. The dispersed oil cannot be collected and, for this reason, where dispersant use on shorelines is approved, it is usually restricted to areas of low environmental concern but high amenity value. Shoreline cleaners, specifically formulated for the task, may also be used. However, these products work in a different way from dispersants as it is intended that the oil released should be collected. Degreasers are often carried on board ships to deal with engine room cleaning but most are more toxic than dispersant and should not be used as a dispersant at sea or as shoreline cleaners.

Application rate

To calculate the appropriate application rate, the ratio of dispersant to oil required for effective dispersion must be determined. This can range from 1:1 for Type I dispersants to 1:50 for Type III dispersants, depending on the application method, the type of dispersant, the oil type and the prevailing conditions. The application rate can be calculated in two steps, as follows:

1. Estimation of the volume of oil to be treated based on observations and assumptions concerning the average thickness and the area of the slick.
2. Calculation of the quantity of dispersant needed to achieve the required dosage (dispersant : oil ratio)

It has been found that although there are substantial variations in the thickness of the oil within a slick, most fresh crude oils spread within a few hours, so that overall the average thickness is 0.1mm (10^{-4} m). This thickness is often used as

the basis upon which to plan operations and gives the volume of oil in one hectare (10,000 square metres, 10^4m^2) as:

$$10^4\text{m} \times 10^4\text{m}^2 = 1\text{m}^3 \text{ or } 1,000 \text{ litres}$$

Further advice on estimating oil quantities is provided in the separate ITOPF paper on Aerial Observation of Oil.

For a dosage of 1:20, the quantity of dispersant required would be:

$$\text{Dispersant quantity} = 1000 \text{ litres of oil} / 20 = 50 \text{ litres.}$$

Therefore, the application rate would be 50 litres/hectare (4.5 imperial gallons/acre). The discharge rate can be calculated by multiplying the application rate (litre/ m^2) by the speed of the aircraft or vessel (m/s) and the spray swath (m).

For example, to achieve an application rate of 50 litres/hectare ($0.005 \text{ litre}/\text{m}^2$) from an aircraft travelling at a speed of 45 m/s (90 knots) with a swath of 15 metres, the discharge rate required would be:

$$\text{Discharge rate} = 0.005 \text{ litres}/\text{m}^2 \times 15 \text{ m} \times 45 \text{ m/s} = 3.37 \text{ litres/s (or about 200 litres/minute).}$$

Thus, to achieve a dose rate of 1:20 and disperse a slick of 0.1mm thickness, the discharge rate of the spray system pump would need to be 200 litres per minute. The same calculation can be made to determine the discharge rate for vessel application.

The significant variation in oil thickness within a slick means that, in practice, it is impossible to evaluate the optimum dosage precisely. The practical and most efficient solution is to target the thickest parts of the slick. Application rates of the order of 50 litres per hectare, as calculated above, have been found to be appropriate in many situations, but adjustment may be required to compensate for different types of oil and environmental conditions that may further affect the thickness of the slick. The application rate can be adjusted by changing the discharge rate of the pumps or the speed of the vessel or aircraft. In addition, estimates of the volume of dispersant required to treat a slick should take into account the accuracy with which the heaviest accumulations of oil can be targeted, with some allowance for overspray.

Logistics and control

Dispersant application is a specialised operation that requires trained operators and thorough preparation to ensure that all the logistics are in place. For operations to be most effective, it is desirable to use spotter aircraft to guide and co-ordinate spraying vessels and aircraft. The crew of the spotter aircraft should be able to identify the heavier concentrations of oil or the slicks posing the greatest threat. They will need to have good communication with the crews of spraying aircraft or vessels in order to guide them to the target, and with spraying aircraft, to identify the points at which spraying should start and stop in order to minimise overspray and wastage of dispersant. During the spraying operation itself, spotter aircraft can also be used to judge

the accuracy of the application and the effectiveness of the treatment. These functions are particularly important when directing large multi-engine spraying aircraft that can rapidly apply large volumes of dispersant. At the low altitude necessary for effective application, the crew will experience difficulties in distinguishing between oil, sheen and water, especially if the slick is fragmented.

To ensure safety, aircraft exclusion zones need to be in force during aerial spraying operations. Relief crews may be necessary, as flying over the sea at low altitude can be extremely demanding. Periodic checks of the aircraft are also recommended to ensure that the dispersant does not contaminate lubricants, particularly in the tail rotor of helicopters, or attack any exposed rubber components of aircraft flight control systems. It is advisable to wash down the aircraft frequently with fresh water to remove both dispersant and salt water spray.

Good organisation on the ground is needed to enable spraying operations to continue for the maximum available time during daylight hours. This may require routine maintenance of aircraft and spraying equipment to be carried out during hours of darkness. It is unlikely that a single payload will be sufficient to treat a slick, especially if the release is continuous, and additional supplies of dispersant need to be sourced and conveniently located in order to re-supply vessels or aircraft with minimum delay. Similarly, thought should be given to the provision of fuel, particularly for aircraft, and to the equipment necessary to load vessels or aircraft, such as high capacity pumps and road tankers.

For long-term storage of dispersants, plastic drums, tanks or 1m^3 Intermediate Bulk Containers (IBCs) (Figure 12) are preferable. Provided that they are not exposed to direct sunlight, dispersants stored unopened should last for many years. However, once opened, the dispersant should be tested periodically for its effectiveness. Recommendations from manufacturers include an annual visual inspection together with a check of the main physical characteristics such as density, viscosity and flash point of the product. If these physical parameters have changed significantly



▲ Figure 12: Use of 1m^3 Intermediate Bulk Containers (IBCs) allows straightforward storage and handling of dispersant. (Image courtesy USCG).

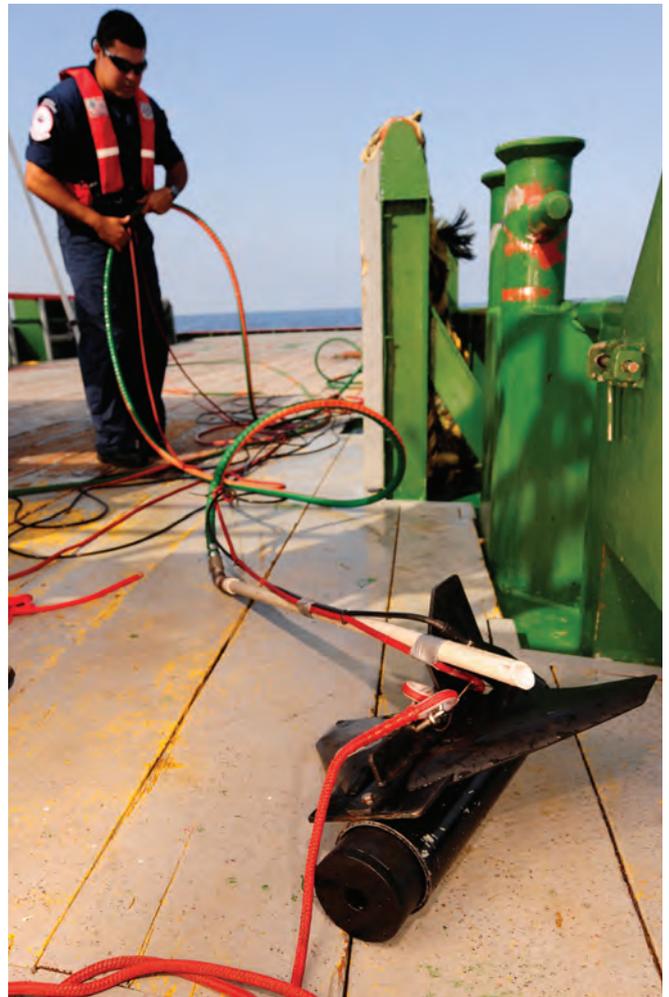
or the expiry date has passed, a laboratory dispersant effectiveness test should be conducted. Dispersants of different types, ages or brands should not be mixed in the same tank or storage container as this may alter the viscosity of the dispersant or cause some components to precipitate or coagulate. Dispersants should not be stored after they have been diluted with sea water. A temperature between -15°C and 30°C is optimum for storage of most dispersants and manufacturers recommend that temperature fluctuations are minimised during storage. In very cold air temperatures, some dispersants may become too viscous to pass through the spray nozzles.

Monitoring dispersant effectiveness

The effectiveness of chemical dispersion should be monitored continually and the response terminated as soon as the dispersant is no longer effective. Visual observation of effectiveness is key but may be impaired in poor weather conditions, in waters with a high sediment load, when dispersing pale-coloured oils, and in poor light. Clearly, spraying and visual monitoring at night is impractical.

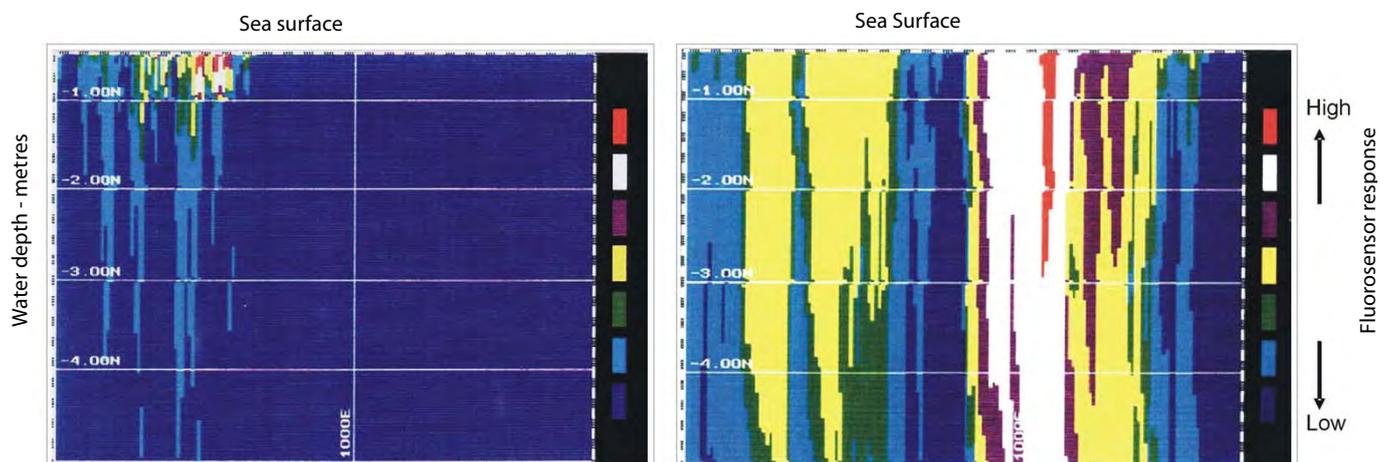
For the application of dispersants to be worthwhile, the oil needs to be dispersed relatively quickly after being spilt to reduce the risk of the oil reaching the shoreline and sensitive resources. A change in appearance should be visible from the air shortly after spraying. No change in the appearance of the oil, no reduction in the oil coverage, or if the dispersant runs off the oil to create a milky white plume in the water (Figure 5), all indicate the dispersant is not working. Equally, if the oil has spread over a wide area or has become widely fragmented, application of dispersant may not remove sufficient amounts of oil from the water surface to achieve a significant reduction in pollution damage.

Effectiveness can also be monitored using 'real-time' data on the concentration of dispersed oil in the water column with ultra-violet fluorometry (UVF). One or more fluorometers (Figure 13) are towed behind a sampling boat at depths of more than a metre under the slick to measure the variation



▲ Figure 13: Preparing a towed fluorimeter to measure dispersant effectiveness at sea. (Image courtesy USCG).

in oil concentrations. Dispersion is demonstrated by a significant increase in the concentration of oil detected by the sensor relative to the concentration measured prior to dispersant application (Figure 14). However, UVF cannot provide a quantitative measurement of the amount of oil dispersed into the water column and should be used in combination with visual observations to decide whether a worthwhile response can be achieved.



▲ Figure 14: Fluorometer response to oil from 0.5 to 5 metres water depth under an surface slick before (left) and a few minutes after dispersant application (right). Oil rapidly disperses and dilutes after treatment. (Illustrations courtesy of AEA Technology).



▲ *Figure 15: Dispersant use can help protect vulnerable sea birds by rapidly removing oil from the sea surface.*



▲ *Figure 16: Dispersant use in sensitive areas such as coral reefs is not advocated except in special circumstances and after careful consideration of the potential environmental consequences of its use.*

Environmental considerations

Dispersant use can be controversial, at times generating widespread debate in the media and public forums. Its use may be viewed as a way of minimising potential impacts on sensitive resources by preventing or reducing shoreline contamination, but is also sometimes seen as adding another pollutant to the environment. Despite improvements in dispersant formulations, the toxicity of the dispersant/oil mixture to marine fauna and flora is often the major environmental concern. In some countries, the ease with which dispersants biodegrade is a concern and studies are on-going. Approval processes for dispersant use in many countries are designed to take both effectiveness and toxicity into account. Products approved in one country may not be approved in another and, where available, the relevant national list should be consulted prior to their use.

After application of dispersant in open water, elevated oil concentrations are normally only observed in the upper layers of the water column (<10 metres) but are rapidly reduced by dilution, through water movement. Studies on crude oils have shown that immediately after dispersant application, oil concentrations in the range of 30 to 50 ppm can be expected in the water just below the slick, diminishing to 1 to 10 ppm in the uppermost 10 metres or so of the water column after a few hours. The exposure for marine organisms is thus 'acute' rather than 'chronic' and the limited exposure time reduces the likelihood of long-term adverse effects. However, spraying dispersants in shallow water is not advised, unless sufficient water exchange can ensure adequate dilution of the dispersed oil plume.

An estimation of the dilution potential is a useful basis for making the decision on whether or not dispersants should be used to protect certain resources without risking undue damage to others. Relevant factors to take into account when estimating peak concentrations and their duration include water depth, oil quantity per unit area, the distance between the application site and sensitive areas, as well as the direction and speed of currents.

By removing oil from the water surface, dispersants minimise the risk of sea birds becoming oiled (*Figure 15*) and contamination of sensitive shorelines such as salt marshes, mangroves and tourist beaches. However, oil removed from the surface is transferred to the water column and it is the risk of damage caused by dispersed oil that has to be balanced against the advantages of its removal from the surface. In the case of many free swimming fish species, their ability to detect and avoid oil in the water column will help to reduce their potential exposure. However, corals (*Figure 16*), sea grass and fish spawning areas may be highly sensitive to dispersed oil and the use of dispersants is not recommended if these resources could be affected. Similarly, the use of dispersants is not advocated in the vicinity of fish cages, shellfish beds or other shallow water fisheries due to the increased risk of tainting of stock. The use of dispersants close to industrial water intakes is not advisable due to the increased risk of oil entering water intakes.

The decision whether or not to use dispersants is seldom clear-cut and a balance has to be struck between the advantages and limitations of different response options (including reliance on natural processes), cost-effectiveness and conflicting priorities for protecting different resources from pollution damage. In many instances, a balanced assessment of the net environmental and economic benefits will be necessary, in consultation with national authorities, prior to application. The time available to use dispersants is likely to be limited both by the weathering of the oil and its movement towards sensitive resources. To avoid delays at the time of a spill, the decision on whether dispersants can be used and if so, the precise circumstances under which they may be used need to be agreed during the process of developing contingency arrangements for spill response.

Contingency planning

Factors to be considered during the contingency planning process include the types of oil likely to be involved in a spill, the effectiveness of the dispersant on these oils, the

sensitive resources in the area and the logistic support. Logistics relate mainly to the location and availability of dispersants, spraying equipment, vessels, aircraft, airstrips and refuelling capability, as well as to customs clearance for any international support that might be required in a major incident. Sensitivity maps are particularly useful to indicate when and where dispersants may or may not be used, as they can denote seasonal influences on sensitivity. For example, migratory birds will be present at certain times of the year and limitations on dispersant use in shallow waters may be overridden to allow application to reduce the risk of the birds encountering floating oil (Figure 17). Thought also needs to be given to sources of funding for maintenance of an effective dispersant response capability. The outcome of these discussions should be documented clearly in a contingency plan.

In many countries, national regulations require dispersant use to be approved by the competent national authority. For responders, an awareness of dispersant use policy is important as conflicts may arise and fines may be imposed if dispersants are used without prior consent or regard for national regulations. Some countries maintain a list of dispersants that have been approved for use on the basis of efficacy and toxicity testing. The competent authority may also grant pre-approvals to oil handling facilities or ports allowing them to use dispersants without further consultation, provided that certain criteria have been met.

Training and exercises are an essential part of planning for dispersant use, as indeed they are for all aspects of spill response. Operational crews should receive comprehensive training on dispersant application and safety. Practical exercises to mobilise resources and deploy spraying equipment should be held regularly.



▲ Figure 17: Sensitivity maps are often used in contingency plans to delineate where and when dispersants can be used. In the example, dispersant use is prohibited in the red area because of year-round commercial fishing, but is pre-approved seasonally for treating oil around a bird colony at Pelican Island (blue). Use in shallow water, close to the mainland may be allowed in special circumstances, for example to protect the mangroves or marsh which are both highly sensitive to stranded oil.

Key points

- Dispersants enhance the natural break-up of oil, removing it from the water surface into the water column as numerous small droplets to be rapidly diluted and ultimately biodegraded.
- Most dispersants are unable to disperse very viscous oils and stable emulsions.
- Spraying dispersant on oil sheen is an ineffective and ill advised use of resources.
- For most crude oils and some fuel oils spilt at sea, a brief opportunity exists in which dispersant use will be effective and a fast, well-planned response is essential.
- While vessels are suitable for dealing with small oil spills close to port, large, multi-engine aircraft offer a potentially more effective response for major spills offshore.
- In the open sea, observations show that concentrations of dispersed oil in the water column decrease within hours to levels below those likely to cause long-term adverse effects to marine organisms.
- Dispersants can rapidly and effectively minimise pollution damage to animals present at the surface, such as sea birds and to sensitive coastal resources, such as mangroves.
- Dispersant application should be avoided where the dispersed oil plume may cause damage to sensitive resources such as coral, shellfish beds or industrial water intakes.
- A well prepared and practised contingency plan, and a clear policy for agreed dispersant use, significantly increases the likelihood of an effective dispersant operation.

TECHNICAL INFORMATION PAPERS

- 1 Aerial Observation of Marine Oil Spills
- 2 Fate of Marine Oil Spills
- 3 Use of Booms in Oil Pollution Response
- 4 Use of Dispersants to Treat Oil Spills
- 5 Use of Skimmers in Oil Pollution Response
- 6 Recognition of Oil on Shorelines
- 7 Clean-up of Oil from Shorelines
- 8 Use of Sorbent Materials in Oil Spill Response
- 9 Disposal of Oil and Debris
- 10 Leadership, Command & Management of Oil Spills
- 11 Effects of Oil Pollution on Fisheries and Mariculture
- 12 Effects of Oil Pollution on Social and Economic Activities
- 13 Effects of Oil Pollution on the Environment
- 14 Sampling and Monitoring of Marine Oil Spills
- 15 Preparation and Submission of Claims from Oil Pollution
- 16 Contingency Planning for Marine Oil Spills
- 17 Response to Marine Chemical Incidents

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ITOPF Ltd

1 Oliver's Yard, 55 City Road, London EC1Y 1HQ, United Kingdom

Tel: +44 (0)20 7566 6999
Fax: +44 (0)20 7566 6950
24hr: +44 (0)20 7566 6998

E-mail: central@itopf.org
Web: www.itopf.org