Oil Spill Dispersants

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PREFACE

This document has been produced as an up-to-date guide on oil spill dispersants and is intended for a non-specialist reader with a particular interest on oil spill response. More scientific information, together with supporting references, is given in a recent literature review on the same subject (Lewis, 2001).

Oil spills can cause a lot of distress to affected communities. It is important that oil spill response actions are explained to everyone involved, including those likely to be worst affected by the oil spill. The use of oil spill dispersants can sometimes be controversial because of misunderstandings about the principle of dispersing oil and the lack of knowledge of the limitations of alternative response techniques. This document aims to inform and educate the general reader about dispersants.

SFT has recently prepared new regulations for the use of dispersants. These regulations require that oil spill response is carried out within the "Principles of Internal Control" - meaning that the companies that have operational control of the response also have the responsibility to provide adequate documentation. This document elucidate the documentation needed for use of dispersants in general, but with the focus on spill response in coastal water and sensitive areas.

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INTRODUCTION

Dispersing spilled oil into the sea by the use of oil spill dispersants can be an environmentally acceptable method of oil spill response. A "net environmental bene t" will be achieved if the damage that might be caused to marine life by dispersed oil is less than the damage that would have been caused if the oil had come ashore or drifted near to particularly oil-sensitive resources.

This justi cation for dispersant use cannot, however, be imported into every oil spill scenario. Dispersing spilled oil in some circumstances might have the potential to damage marine life that exists in the close vicinity of a dispersing oil slick. Dispersed oil droplets and the chemical components in oil that are transferred into the sea have the potential to exert toxic effects, but only if the oil is present at high enough concentration for prolonged periods. This will only occur if there is not suf cient dilution of the dispersed oil and oil components into the sea.

A great deal of research work has been carried out on dispersants over the last 30 years. Topics that have been studied include:

- The development of more effective dispersants.
- The capabilities of dispersants as a function of spilled oil properties and weathering time at sea.
- The ecological effects caused by dispersants and dispersed oil.

Any potential use of oil spill dispersants should be justi ed by a rigorous scienti c examination of the relevant facts. The concerns and fears of those people not normally concerned with oil spill matters need to be addressed because the sea and the coastline are a common heritage of everybody, not solely those involved in the oil production or shipping industries.

EFFECTS OF OIL SPILLS

When an oil spill has occurred, some sections of the general public and some environmental pressure groups might say that the only acceptable oil spill response strategy is the total removal of the oil and complete restoration of the environment to the pre-spill condition. Since this can never be achieved, these expectations can never be met and some people always consider that any oil spill response is only a partial success.

Dead seabird covered in sticky oil from the "John R - incident", Norway, 2001,

Spilled oil has the potential to cause ecological effects, yet crude oil has been seeping into the sea for thousands of years at some locations around the world. These natural oil seeps have not caused major damage and the ecology of these areas has adapted to persistent and chronic oil pollution. Accidental spills of oil can deposit very large volumes into the sea over a short period of time and in a comparatively localised area. This can cause temporary ecological damage, although natural recovery will eventually occur. The physical effects of the spilled oil, plus the less visible effects caused high concentrations of toxic components released from the oil, will affect the some marine resources in a localised area.

The dead and dying seabirds covered in thick, sticky oil have become the 'icon' of oil pollution in the last decades.

Shorelines affected by oil spills go through a predictable sequence of affects; dead and dying crabs, lobsters and shell sh will be washed ashore if crude oil or diesel fuel is spilled. On rocky shores, many limpets will become detached from the rocks and gulls will feast on them. The rocks will then start to be covered in lamentous green algae.

Nature will recover after even the worst oil spills; it may take up to 20 or 30 years or longer in particularly sensitive areas, but eventually almost all of the affected habitats will be as biodiverse and as productive as they were before the oil spill. In most cases it can take considerably less time. However, this may be too long for some people. A large oil spill can cause extensive disruption to the activities of many people in coastal communities. Feelings can run very high. Many people will feel that their local community has been ruined by the negligence or carelessness of outsiders. A shoreline heavily polluted with oiled seaweed

Dead and dying clams and shell sh washed on-shore due to toxic effect of light fuel oil freom the North Cape spill, RI, USA, 1996. No visual oil on-shore.

and dead and dying creatures is a distressing sight. It can take some time and a lot of effort to clean it up. The perception is that a catastrophe has occurred, despite the fact that oil spills are rarely the 'environmental disasters' that the press con dently predicts on each occasion. The local ecology and businesses are not the only 'casualties' caused by oil spills. The reputation of the oil and shipping industries will suffer when oil spills occur. Effective oil spill response must be reasoned and rational and carried out with urgency.

OIL SPILL RESPONSE

The objective of all oil spill response strategies should be to minimise the damage, both ecological and economic, that could be caused by an oil spill. The most obvious way to do this is to prevent the spilled oil from coming into contact with oil-sensitive resources. Most damage is done by spilled oil when it gets into shallow water or comes ashore. The objective of oil spill response actions at sea should be to prevent oil from reaching the shoreline or particularly sensitive resources at sea, such as sh spawning grounds. The response actions can include:

- Using booms to contain the oil near the spill source
- Using sorbents to soak up the oil near the spill source.
- Using booms and skimmers to contain and recover the oil at sea, before the oil drifts too close to the shore.
- Using booms to protect a shoreline resource and divert the spilled oil away from it.
- Using oil spill dispersants to disperse the oil into the water column before it approaches an oil-sensitive site.

All of these techniques have certain capabilities, but all suffer from limitations and some of these are major limitations.

Booms to contain oil at sea will not be successful in rough weather; the oil will leak out of the boom.

Mechanical recovery off-shore, NOFO-oil-on-water exercise

Sorbents can be used on small oil spills in calm conditions, but need to be recovered and disposed of.

Using booms and skimmers to contain and recover oil at sea is only suitable for small oil spills in relatively calm conditions. Booming operations from ships to recover larger amounts of oil at sea are dif cult. The ship deploying the boom cannot 'sweep' the sea surface at relative velocity of more than about one knot. The area of sea surface that is swept can be increased by using pairs of ships with a boom between them in various con gurations, but very large numbers of ships would be needed to recover large oil spills.

Some small areas of shoreline resources can be protected by protective booming, but it is not feasible to use huge lengths of boom, even if they are readily available and can be deployed in time. Oil spill dispersants do have real capabilities and limitations (and these will be described later), but more than any other oil spill response technique there are misconceptions about their use and this can cause their use to be controversial.

Near-shore recovery of Heavy Fuel Oil during the "Green Ålesund-incident", Norway, 2000

PRINCIPLES OF USING DISPERSANTS

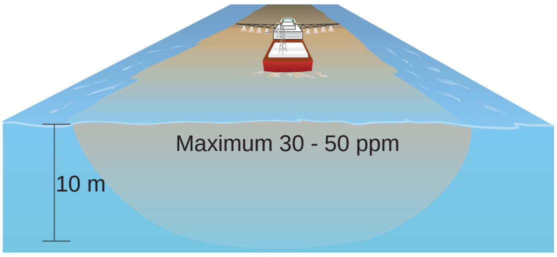
Before describing dispersants in detail, it is important to have an understanding of the basic principles of dispersant use.

- The purpose of using oil spill dispersants is to remove the spilled oil from the surface of the sea and transfer it into the water column where it is rapidly diluted to below harmful concentrations and is then degraded.
- Spraying oil spill dispersants onto spilled oil while it is still at sea may be the most effective, rapid and maneuverable mean of removing oil from the sea surface, particularly when mechanical recovery can only proceed slowly or is not possible.
- The use of oil spill dispersants reduces the damage caused by oating oil to some resources, for example sea birds, and minimises the damage that could be done to sensitive shorelines by dispersing the oil before it drifts ashore.
- The use of oil spill dispersants has the potential to present a small risk of temporary and local exposure to dispersed oil for some marine organisms.
- Oil spill dispersants are not capable of dispersing all oils in all conditions.

Any decision to use dispersants involves a judgement that dispersant use will reduce the overall impact of a particular spill, compared to not using dispersants. This requires a balancing of the advantages and disadvantages of dispersant use and a comparison with the consequences of other available response methods. This process is known as "**Net Environmental Bene t Analysis"** (NEBA) and it is important that it should consider all relevant environmental conditions and implications for resources needed.

HOW DISPERSANTS WORK

Natural dispersion of an oil slick occurs when waves cause all or part of the oil slick to be broken up. When a breaking wave (at > 5 m/s wind speed) passes through an oil slick at sea, the oil slick is temporarily broken into a wide range of small and larger oil droplets . Most of the oil droplets are large (0.1 - several mm in diameter), and rise quickly back to the sea surface where they coalesce and reform a thin oil film when the wave has passed, while the very smallest oil droplets will become dispersed into the water column. The addition of dispersants is intended to accelerate this natural process and rapidly convert a much larger proportion of the oil slick into very small oil droplets. Figure below illustrates the mechanism that occurs when dispersants are sprayed on to an oil spill at sea.



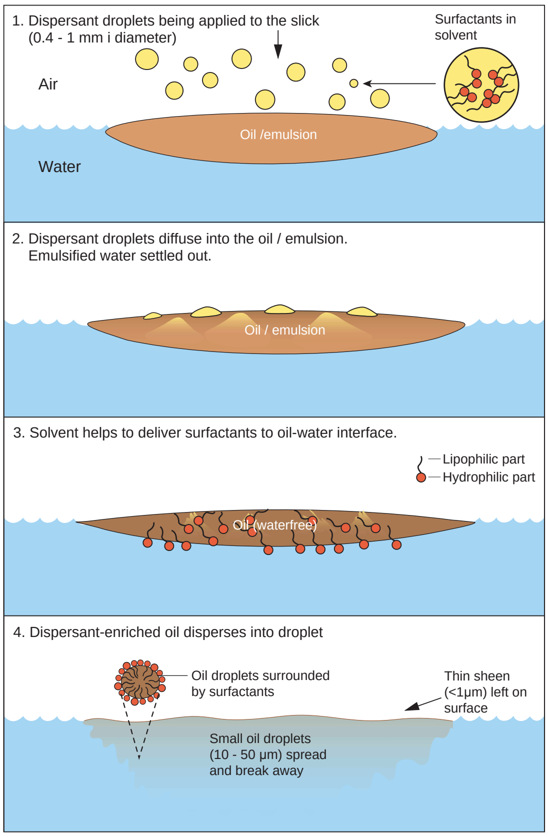
Schematic picture of dilution and spreading of dispersed oil in the water masses after treatment with dispersant

When the dispersant droplets containing the surfactants hit the oil surface, the surfactants (the active ingredients) diffuse into the spilled oil or emulsion. The emulsion-breaking properties of the surfactants can cause the water droplets in the emulsion to coalesce into larger water oil droplets that eventually will separate from the oil phase.

The surfactants in the dispersant will gradually arrange or orientate themselves at the interface between oil and water. The resistance to mixing (technically known as interfacial tension) between the oil and water is dramatically lowered, making it easy very small oil droplets (typically 10-50 µm diameter) to be formed, even under low turbulence conditions. Small oil droplets like these will have a very low rise velocity, and will drift " passively" in the water column with near neutral buoyancy.

Experience from experimental field trials and dispersant operations at real spills have shown that dispersed oil will be rapidly diluted into the sea. Oil in water concentrations drop rapidly from a maximum of 30 - 50 ppm just below the surface shortly after treatment to concentrations of < 1 ppm total oil in the top 10-15 meters after few hours (see figure below)

The formation of these small oil droplets enhances the biological degradation of the oil in the marine environment by increasing the oil surface area available to micro-organisms capable of biodegrading the oil. The dispersants themselves does not lead to increased biological activity.
It is important to emphasise that the dispersants remove the oil from the surface, but do not make it sink to the bottom.



Mechanism when applying dispersant (modified after Fiocco, 1995).

WHAT DISPERSANTS CAN AND CANNOT DO

Dispersants are effective on the majority of crude oils, particularly if they are used as soon as possible after the oil has been spilled, but they have some limitations. The changes in oil composition and physical properties, caused by the loss of more volatile components from the oil by evaporation and the formation of emulsion (collectively known as oil "weathering"), may decrease the effectiveness of dispersants with time. These changes depends highly on oil composition and the prevailing temperature, wind speed and sea conditions.

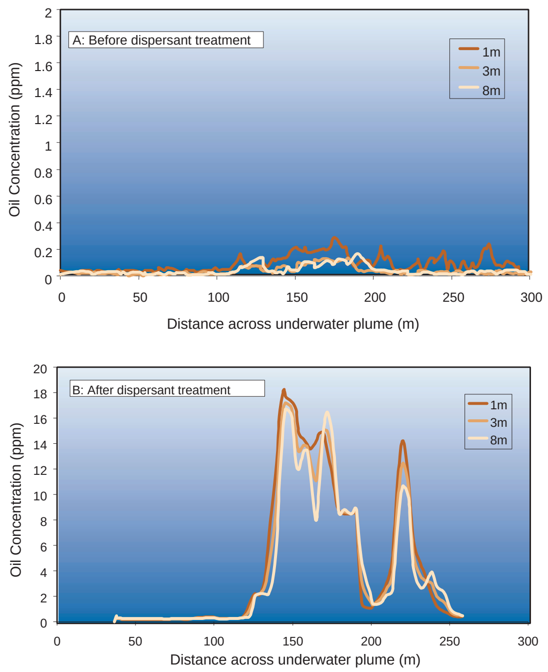
Since the 1980s, several well-documented eld tests have been conducted in several countries, including Canada, France, Norway, USA and the UK. UVF (Ultra Violet Fluorometry) has been used to measure the dispersed oil concentrations in the water beneath and around test slicks sprayed with dispersant. These comprehensive measurements, combined with surface sampling and extensive use of remote sensing from aircraft, have allowed a quantitative estimate to be made of the amount of oil dispersed with time. These eld trials have conclusively demonstrated that dispersants can be very effective, that is, they have been successful in rapidly removing the majority of the volume of some crude oils from the sea surface, even when the crude oils have been on the sea for several days.

Dispersants have been successfully used at real oil spills on many occasions. The action of dispersants is often visible as the formation of a light-brown or a grey plume or 'cloud', of dispersed oil in the water column (see gure below). Such observations are best made from aircraft. Dispersant treated oil will rapidly disperse, leaving only a thin lm of oil sheen on the surface.

While it can be fairly easy to observe dispersants working on some occasions, the viewing conditions can make it more dif cult on others. In poor visibility, it may not be possible to clearly observe dispersed oil in the water. Qualitative evidence of the dispersion of oil can be obtained by visual observation, while a quantitative estimate of dispersant effectiveness at a real oil spill is much more dif cult. It is also extremely dif cult to make comprehensive measurements of sub-surface oil concentrations under very large oil slicks. The effects of natural dispersion and dispersant spraying can be distinguished by measuring the oil concentrations a different depths. Dispersants cause higher dispersed oil concentrations at greater depths. UVF measurements showing a homogenous "plume" with a signi cant increase in dispersed oil concentration at depths of 1 to 8 metres below the dispersant treated oil is a good indicator that the dispersant is working (see gure below).

Dispersant field trials in the North Sea. Statfjord crude oil, weathered at sea for 3 hours.
A) just prior dispersant treatment.
B) 15 min after treatment (oil has started to dispersed into water clumn, a grey plume is created)

However, dispersants do not work well in all circumstances. The speci c physical and chemical interactions controlling dispersant effectiveness are complex. Many of the factors are inter-related and it is dif cult to separate them completely, but the evidence from eld and laboratory tests shows that the oil properties, the weathering degree, type of dispersant, application strategy and the sea-state conditions are important.



Concentration profiles (by in-situ UVF measurements) of dispersed oil in the water column at 1,3 and 8 m A) just prior dispersant treatment. B) 15 min after treatment

Spilled oil properties

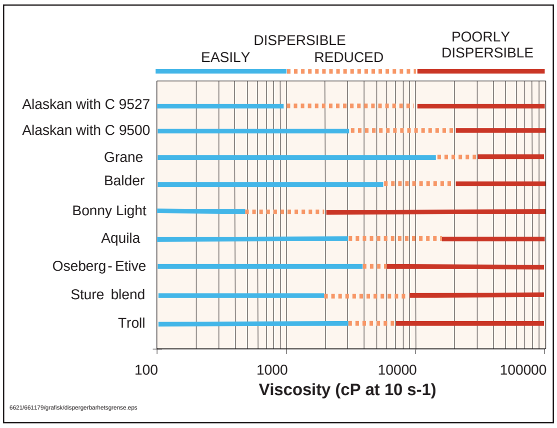
Most crude oils can be dispersed, provided that they are sprayed with dispersant soon after they have been spilt. Low to medium viscosity crude oils (with a viscosity of less than 1,000 centiPoise, cP, at the prevailing sea temperature) can be easily dispersed. Crude oils with a pour point 10-15° C above sea temperature cannot be dispersed because they may solidify at sea.

Modern oil spill dispersants are generally effective up to an oil viscosity of 5,000 cP or more, and their performance will drop above a certain viscosity. Crude oils with a viscosity of more than 10,000 cP are, in many cases, dif- cult no longer dispersible. However, oil composition appears to be almost as important as viscosity and pour-point of these are only two of several factors that affect dispersant performance; the amount of energy from the waves, dispersant type and dispersant treatment rate are also very important factors.. Dispersion of the lighter grades of residual bunker fuel oils (also known as Intermediate Fuel Oils -IFOs), such as IFO-30 and IFO-80 is possible. Some medium fuel oils (MFO, IFO-180 or No. 5 Fuel oil) may also be dispersible , especially in summer waters and rougher seas, but their individual rheology properties at the prevailing sea temperatures seem to be very important. Even some very heavy fuel oils (HFO, Bunker C, No. 6 Fuel Oil) might be dispersible in summer conditions , but are unlikely to be dispersible in colder waters (e.g. in North Sea winter time). Recent studies have shown that many residual fuel oils are dispersible up to viscosities around 20,000-30,000 cP. Very heavy industrial fuel oils (also known as LAPIO oils), such as that spilled at the Erika incident, cannot be dispersed because they have far too high viscosities. They also tend to oat as very thick patches on the sea, too thick to be sprayed with dispersants. The maximum permitted pour point HFO speci cations is +30 C. Not all fuel oils have such a high pour point, but those that do would be solid at sea temperatures below 15-20oC and will therefore not be dispersible.

Oil weathering at sea

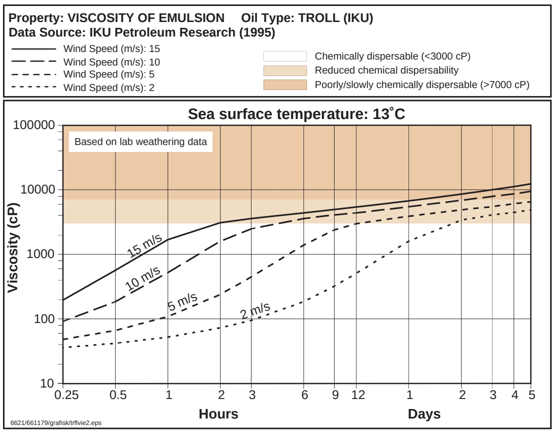
The physical properties and composition of spilled oil changes as the more volatile oil components are lost by evaporation and as the oil incorporates water droplets to form a water-in-oil emulsion. Asphaltene components precipitate from the oil to form a stabilising coating around the water droplets and the emulsion becomes more stable with time. The exing and compression of the emulsi ed oil, caused by wave action, reduces the average size of the water droplets within the oil. All of these processes cause an increase in the viscosity and stability of the emulsi ed oil and cause dispersants to become less effective with time. The rate at which these processes occur depends on oil composition and the prevailing temperature, wind speed and wave conditions.

The reduction in dispersant effectiveness is partly due to the increase in viscosity, but is also due to the stability of the emulsion. Some recently developed dispersants have the capability to ‘break’ the emulsion (cause it to revert back to oil and water phases), particularly when the emulsion is freshly formed and not yet thoroughly stabilized. A double treatment of dispersant; the rst stage at a low treatment rate to ‘break’ the emulsion, followed after some time by second treatment at a higher rate to disperse the oil, has been found to be effective. As emulsi ed



Examples of different viscosity limits for dispersibility of different oil types.

oil undergoes further weathering, the emulsion becomes more stable and dispersants become less effective. A methodology for “mapping” of the dispersant ef ciency as a function of the speci c emulsion viscosity has to be established to obtain a documented foundation for the calculation of the probable “time window” for ef cient dispersant application. Such studies have revealed that the emulsion viscosity limits for dispersibility might vary substantially between the different oils (see gure above). By combining the information from the dispersibility studies, with the weathering prediction using e.g. the SINTEF Oil Weathering Model, the operation window for the opportunity of using dispersant for the different oils can be established (see gure top right).



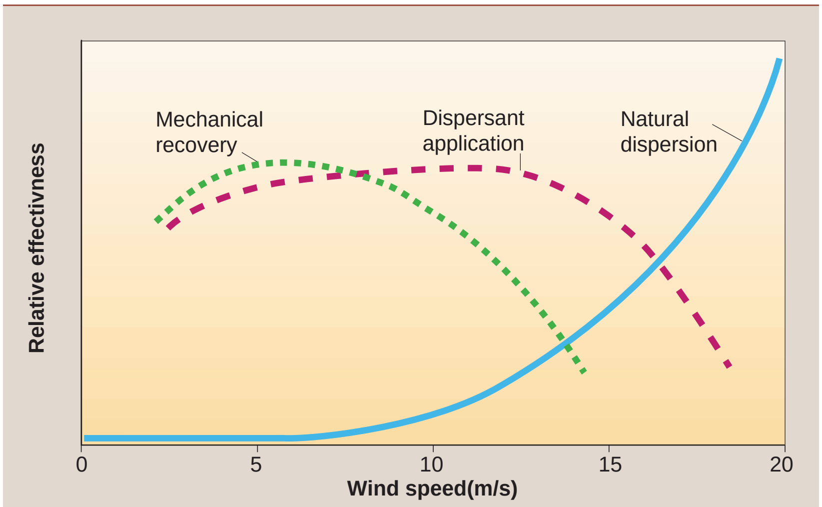
Caculation of “time-window” for effective use of dispersants on Troll Crude (North Sea) under various wind-/sea-state conditions

Dispersant type, application method and treatment rate

Although many dispersants may be capable of meeting the minimum level of performance speci ed in different national approval procedures, not all dispersants are the same. It is particularly important to recognise the very large difference in performance between the older, ‘conventional’ or ‘hydrocarbon-base’ dispersants and the much more effective ‘concentrate’ dispersants available today. ‘Hydrocarbon-base’ dispersants are much less effective than ‘concentrate’ dispersants, even when used at ten times the treatment rate. Even amongst the most recently developed dispersants, there are signi cant differences in capability. Some dispersants are better at dispersing some oils than other dispersants. Speci c testing will reveal the best dispersant for a particular oil and weathering state.

The performance of a dispersant will depend on the prevailing sea conditions. Dispersants work well on easily disperible oils at low sea-state with noe breaking waves (< 5 m/s wind), however, the dispersion prosess may go more rapid in rougher seas.. Dispersant can therefore be sprayed in very calm conditions if rougher seas are expected to occur within a few hours. The dispersant will stay with the oil and will cause rapid dispersion when suf- cient wave action occurs. There is also an upper limit of sea conditions (> 15 - 20 m/s wind) when dispersant spraying is not practical because the spilled oil will be constantly submerged by waves The gure below compares the relative effectiveness decreases caused by weathering for mechanical recovery and the use of dispersants.

Dispersant needs to be applied as evenly and as accurately as possible to spilled oil. The recommended treatment rate for modern dispersants is 1 part dispersant to 10 to 30 parts of spilled oil. Lower treatment rates have been shown to be effective with light, freshly spilled crude oils. It is always dif cult to achieve exactly the recommended treatment rate because oil slicks have large variations in localised oil layer thickness. Undiluted spraying from ships or aircraft is the preferred method of using dispersants, although seawater-dilution can be used from vessels if the appropriate equipment is available.



Schematic picture of relative efficiency as a function of weather condition

THE 'PROS' AND 'CONS' OF DISPERSANT USE

The use of oil spill dispersants can be controversial. To many people, dispersants can be a very useful oil spill response method; a rapid and effective means of minimising the damage that might be caused by an oil spill. Other people feel that the use of dispersants is adding to the problems caused by the oil pollution.

The objections to dispersant use range from a general feeling that it cannot be correct to add chemicals to an already polluted environment to speci c concerns about the effect of dispersed oil on especially sensitive marine environments. Some environmental pressure groups are against dispersant use because they perceive it as a way of 'hiding' the problem of oil pollution rather than 'solving' it.
Explaining the purpose, capabilities and potential bene ts of dispersant use can be dif cult when seemingly contradictory views are being put forward by 'experts' from various sources. Some of the concerns about dispersants are genuine, but in the highly-charged atmosphere following a large oil spill these genuine concerns can be manipulated by those trying to nd someone to blame for the disaster, or others who may be pursuing their own agenda. The debate over dispersant use can be considered as a series of statements and counter-arguments that have been made at various times over the past 30 years of dispersant use.

Some statements and counter arguments connected to use of dispersants

Criticism	Counter-argument
The best method of protecting the environment is to immediately pick up all the spilled oil from the sea. The use of dispersants is the wrong approach to oil spill response.	Mechanical containment and recovery with the use of booms and skimmers is a very useful oil spill response strategy for small oil spills in calm weather, but suffers from some major limitations.
Dispersants push the oil into the environment, rather than removing it from the environment, and this must be a bad strategy.	Dispersants do transfer oil from the sea surface into the water column. If this is done in conditions that allow rapid dilution of dispersed oil to very low concentrations, the risk of ecological harm is small, compared to letting the oil impact the shoreline or other sensitive sites.
Dispersants are only used to hide the oil pollution, to remove it from view, but the oil does is not 'neutralised' and will cause unseen harm.	The aim of transferring oil from the sea surface into the water column is not to hide it and the potential consequences of dispersing oil must be estimated. The aim of using any oil spill response method - including dispersants - is to minimise the damage (economic and ecological) that would be caused by an oil spill.
Addition of toxic chemicals to an already polluted environment will poison the marine life.	Dispersants are less toxic than the oil they are used to disperse.
Dispersants are an unreliable method because they do not always work. Mechanical recovery should be used instead.	Dispersants do have limitations. They may not disperse high viscosity oils in cold waters or disperse heavily weathered oils. Mechanical recovery methods have limitations caused by the weather and by oil characteristics.

THE DISPERSANT DEBATE

The debate about the use of oil spill dispersants has been in progress for over 30 years. During this time there have been several signi cant events that have formed opinions. The rst major use of detergents (true oil spill dispersants had not been invented at that time) was at the Torrey Canyon oil spill in 1967.

CASE STUDY 1

The *Torrey Canyon* oil spill - first use of detergents on a massive scale

The Torrey Canyon was bound for Milford Haven in Wales on a voyage from the Persian Gulf. The ship was carrying 117,000 tonnes of Kuwait crude oil when she grounded on the Seven Stones (15 miles west of Land's End) on the 18th March 1967. Approximately 30,000 tonnes of oil escaped in the rst 60 hours.. A large oil slick, about 18 to 20 miles long, started to drift along the English Channel. Within 12 hours the Royal Navy started spraying the oil at sea with detergents. Within three days a total of approximately 75 tonnes of detergents had been sprayed onto the spilled oil at sea.

Six days after the grounding, another 18,000 tonnes of oil was released and was blown directly onto the Cornish coast. On Sunday 26th March, the Torrey Canyon broke her back and another 40,000 - 50,000 tonnes of oil was released into the sea. This drifted southwards, towards France. The Royal Air Force bombed the ship in an attempt to burn off the remaining oil. This was not successful. Nearly 3,500 tonnes of detergent was sprayed onto the oil at sea in an attempt to disperse it. The shorelines of Cornwall, Guernsey and Brittany were contaminated with large amounts of emulsi ed oil. The attempts to clean the shoreline in the UK used massive amounts of the same detergents that had been sprayed at sea. Approximately 10,000 tonnes of detergents were used

to treat the estimated 14,000 tonnes of oil that came ashore in Cornwall.

Effects

A study of the effects of the oil pollution from the Torrey Canyon found that the oil at sea had caused a large loss of sea birds, but few other effects. The intertidal areas were the worst affected; rocks were denuded of limpets and algae was killed in extensive areas. From a comparison of the shoreline areas where detergents had been used with other areas that were subject to only oil, it rapidly became apparent that the greatest amount of ecological damage had been caused by the detergents. Limpets that were apparently unaffected by the oil (they recovered from being covered in oil and they grazed on oiled rocks) were killed by detergent spraying. Subsequent studies over many years con rmed that the type of detergents used at the Torrey Canyon incident had had a far more damaging effects than the oil.

After the *Torrey Canyon*

To some people, the Torrey Canyon experience was (and still is, in some people's minds) positive proof that the use of detergents was not an appropriate oil spill response method. The opinion that "the cure was worse than the disease" was voiced.

The UK authorities took a different view. They considered that dispersing the oil was a valid oil spill response strategy. However, the detergents used at the Torrey Canyon were far too toxic, not effective enough, had not been applied in the most effective way and there was a lack of guidance and regulation on how to use these chemicals to best effect. Each of these topics was tackled in a series of developments within a few years after 1967.

Equipment designed for application of dispersant concentrates from boat.

Toxicity

Subsequent investigations confirmed that it was the high level of toxicity of the detergents that was the primary cause of the ecological damage. The toxic effects on marine life were mainly due to the very high proportion of aromatic compounds in the solvents. When solvents containing a very low level of aromatic compounds were substituted for the original solvents, a much lower toxicity was evident.

Modern oil spill dispersants are less toxic than the spilled oil.

Effectiveness

The recommended treatment rate of the detergents used at the Torrey Canyon was to use approximately 1 part of detergent on 2 or 3 parts of oil, although accurate estimation of this was not possible. In the mid 1970's the UK authorities introduced a new efficacy test requirement with a minimum level of performance that had to be achieved before a product could be licensed for sale or use in UK waters. Over the last 30 years there have been many improvements in dispersant formulations.

A modern dispersant is more effective than the early oil spill dispersants when used at only one-tenth of the treatment rate.

Application techniques

Inshore and offshore dispersant spraying systems were developed for the UK Government. These spray kits enable an even spray of dispersant to be accurately applied over a wide area onto spilled oil from boats and ships.

Dispersant spraying systems from aircraft (both fixed-wing and helicopters) and improved spraying systems for ships were developed and improved throughout the 1980s and 1990s in various countries including Norway.

Approved dispersants

The UK government introduced regulations that required any dispersant to pass stringent tests of performance and toxicity before it was permitted for sale or use in UK waters.

Many other countries formulated similar regulations. These have been refined and improved over the years and the Norwegian government has recently issued new regulations regarding oil spill dispersants.

Regulations and guidelines for dispersant use

The UK government developed regulations that required specific permission from MAFF (Ministry of Agriculture, Fisheries and Food) for dispersant use in shallow water (defined as within one nautical mile of the 20 metre water depth contour).

The Norwegian develpoed Heli-bucket, Response 3000, filling dispersant from supply vessel.

Other countries subsequently developed similar regulations. The recent Norwegian regulations (2002) require that speci c considerations are made regarding the environmental consequences of dispersant use as part of speci c scenario-based contingency plans.

By the mid-1970s, the principle of using dispersants as a major oil spill response strategy was accepted by the UK and in some other countries throughout the world.

Oil spills on the 1970s, 80s and 90s

Oil spills of various sizes and causes continued to happen (see example on next page). Most oil spills are small.

The amount of damage - ecological or economic - caused by an oil spill is not directly related to the amount of oil spilled, but is more related to the properties of the oil and to the sensitivity of the resources affected. A relatively small spill of a very persistent oil in a particularly sensitive habitat (for example, a salt marsh), or at a particular time of year when some particularly sensitive resource is present (for example, the nesting season of some sea bird species), may cause far more damage than an oil spill of greater volume.

The ecological effects of spilled oil

The effects of spilled oil on marine and shoreline creatures are caused by:

- the sticky and adhesive nature of spilled oil leading to physical contamination and smothering;
- and by the chemical components of the oil causing toxic effects (acute or chronic) and accumulation of oil components in tissues leading to 'tainting' of sh esh.

Physical oiling

Spilled oil on the surface of deep water has little effect on the majority of creatures in the sea. The exceptions are sea birds; these can be badly effected by spilled oil at sea. When sea birds come into contact with the oil they become coated in oil and their feathers lose their insulating properties. As a result they will die of exposure or may be unable to feed. Most damage caused by oil spills occurs when the oil moves into shallow water and contaminates the shoreline. The main threat posed to inter-tidal and shoreline creatures by spilled oils is physical smothering. The animals that are initially most at risk are those that could come into contact with a contaminated sea surface or oil stranded in inter-tidal areas. These include marine mammals and reptiles, wading birds and small crustacea and invertebrates.

Spilled oil physically smothering Havert-puppies, at the Froan islands of Norway

Some oil spills during 1970 - 2000

Year	Incident	Tonnes oil spilled	Effects and response
1977	Eko sk Bravo blow-out	22,000	Effects were considered to be slight; the oil was released far offshore, dispersants were used on a small scale at sea, but no oil came ashore.
1978	Amoco Cadiz	223,000	Considerable ecological damage and distress and economic loss to the local population. The ship was very close inshore and there was no chance to use at sea recovery methods. An aggressive shoreline clean-up operation was mounted.
1983	Iranian Norwuz platform	300,000	Response was not possible in the war zone, nor was it possible to carry out an ecological assessment.
1989	Exxon Valdez	37,000	Permission to use dispersants was sought, but not granted by State authorities. Extensive shoreline oiling occurred and a very costly shoreline clean-up operation was conducted.
1991	Gulf War spills	910,000	No response possible because of continuing con ict. Subsequent ecological assessment conducted, but with inconclusive results.
1993	Braer	84,700	Dispersants used, but all the oil was naturally dispersed by very rough seas.
1996	Sea Empress	72,000	Dispersants used on a large scale at sea.
1999	Erika	14,000	Very heavy oil. At-sea recovery only managed to recover a very small fraction of the oil and there was extensive contamination of the shoreline

Toxic effects of oil

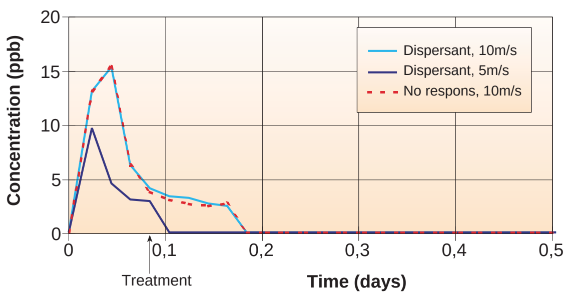
In addition to the more obvious effects of physical oiling, it also became apparent that some compounds in crude oil or refined products can cause toxic effects to marine life. Some of these chemical compounds are partially water-soluble and are slowly released from the oil into the water column. These compounds are collectively known as WAF (Water Accommodated Fraction).

Refining of crude oils concentrates the potentially toxic compounds into different oil products; diesel fuel oil is particularly toxic to marine life, while HFO (Heavy Fuel Oil) is less acutely toxic than crude oils (unless it contains particularly toxic 'cutter stock'). Toxic effects may be:

- acute (develop rapidly and of short duration)
- chronic (long-lasting and persistent)
- lethal (causes death)
- sub-lethal (do not cause death, but impair some functions)

The severity of toxic effects depends on exposure of an organism to the oil, either as dispersed oil droplets or as WAF.

- Very high levels of exposure to some chemical compounds in crude oil can be lethal to some species. Some of the most acutely toxic oil compounds (known as the BTEX compounds - benzene, toluene, ethylbenzene and xylenes) are also the most volatile and will evaporate quickly. No significant increase of these volatile components will occur when dispersant is used. This is illustrated on the concentration calculation by the model-system OSCAR (see figure) and has also been verified by full-scale dispersant field exponents.
- Dispersing crude oil into small droplets can increase the rate of transfer the slightly water-soluble oil compounds (e.g. substituted naphthalenes) into the water column. These compounds are not as volatile as the BTEX compounds and therefore persist for longer.
- Adult fish detect oil compounds in the water and swim away to avoid it. Fish exposed to dispersed oil may incorporate oil compounds into their flesh and this results in 'tainting' of fish flesh, making it unsuitable for human consumption. Fish lose 'taint' by depuration (transferring oil components back out through their gills) when in clean water.
- Juvenile fish and larvae will be more susceptible to toxic effects because their biological systems are rapidly developing. The larvae drift in the upper layers of the water, where dispersed oil initially resides, and they have no means of avoiding the oil. Fish rapidly metabolise hydrocarbons from oil. Exposure to PAHs (Polycyclic Aromatic Hydrocarbons) in oil can be detected by body chemistry changes. PAHs are potent carcinogens to humans and some marine creatures.



Calculated concentration profile of BTEX-components below an oil spill, at 5 and 10 m/s wind, respectively, and where the dispersant has been added after 2 hours in one of the scenarios.

Toxic effects caused by dispersed oil

Dispersing spilled oil converts the oil from a surface slick to a plume or 'cloud' of dispersed very small oil droplets in the water column. These oil droplets might be ingested by filter-feeding organisms, such as copepods, oysters, scallops and clams. The figure below shows the physical effects of mechanically dispersed oil on the copepod Calanus finmarchicus, where epifluorescense images reveals that oil are adsorbed both on the surface of the organisms and that the copepodes actively lters and ingests oil droplets from the water.

It is important to distinguish between the increased potential for toxic effects to occur and the inevitability 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.

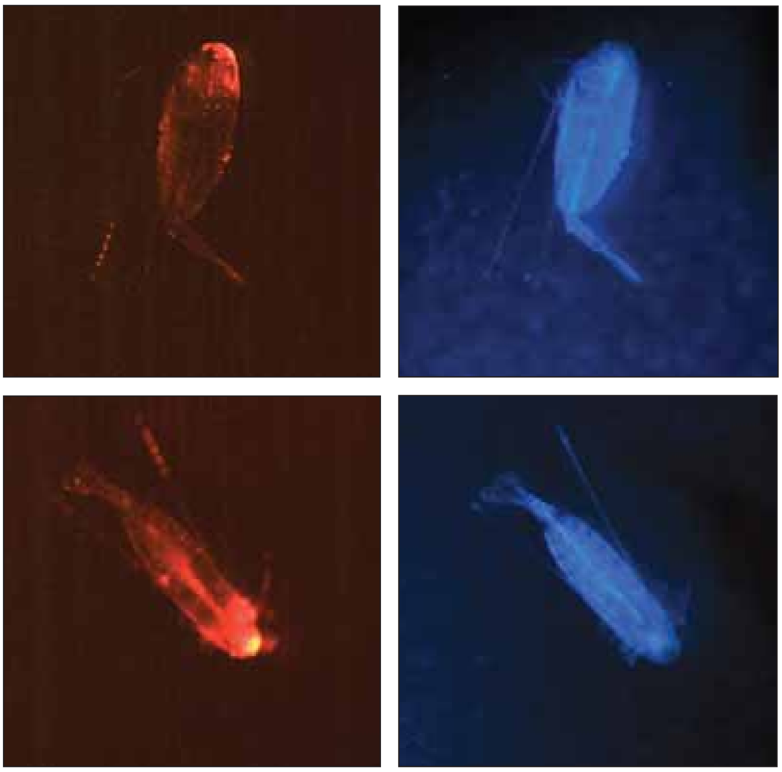
Most spilled oils will naturally disperse to some degree in the initial stages of an oil spill, before the oil becomes emulsi ed. The successful use of dispersants will obviously increase the concentration of dispersed oil in the sea. However, this is a matter of degree rather than an absolute difference; some spilled oil is likely to naturally disperse even if dispersants are not used (e.g. in the Braer and the North Cape incidents)

The "fish versus bird" debate

The argument that much lower toxicity and much more effective dispersants produced after the Torrey Canyon, combined with restrictions in their use as regulated in the UK, would avoid potential problems with dispersant use has not universally accepted. It became generally accepted that modern dispersants are of low toxicity, but their use would enhance the toxicity of the spilled oil. This became known as the " sh versus birds" debate and the main reasoning was:

"Dispersing the oil will save the sea birds, but will poison the creatures in the sea."

Like many aspects of the dispersant debate, the basic premise is an over-simpli cation of the facts. Although it is very likely that the use of dispersants will offer a degree of protection to sea birds from oiling, it is not inevitable that signi cant harm will be caused to marine creatures by dispersant use.



Two different grabbed epicluorescense images showing the physical effects of mechanically dispersed oil on the copepod Calanus nmarchicus., where images reveals that oil are adsorbed both on the surface of the organisms and that the copepodes actively lters and ingests oil droplets from the water (a seen through an oil-speci c lter in the images to right)

The " sh versus birds" debate is divisive and sets members of communities that have been affected by oil spills against each other. It is also too simplistic and wrong in several respects; oil spills may affect marine life, whether or not dispersants are used, and the risks to sh of using dispersants are generally very small and can be further minimised by careful dispersant use.

Impact of oil spills on fisheries

Fish farms can be pro-tected from some of the pollution by booming

The fear that long-term damage to commercial fisheries may result from the dispersion of spilled oil is a recurrent theme in the dispersant debate. The possibility that the short-term 'solution' of using dispersants to get rid of the more visible aspects of oil pollution, but that this may ultimately lead to a much more damage to fisheries is a genuine concern that must be addressed.

Oil spills affect fisheries even if dispersants are not used. Experience from major oil spills has shown that the possibility of long-term effects on wild fish stocks is remote. Adult fish swim away from spilled oil; they can detect or 'smell' the oil in the water and avoid it. Laboratory studies have shown that fish eggs and larvae are more likely to be affected than adult fish. However, fish produce vast numbers of eggs and larvae and these undergo very high mortality rates from processes other than oil spills. The area, or volume, of sea in which elevated concentrations of dispersed oil or oil compounds will persist is very small compared to the size of fisheries.

This means that, in almost all circumstances, the local fish population will be quickly replaced from other areas of the sea not affected by the oil spill. However, an oil spill can cause loss of confidence in the fish for sale, <u>whether or not dispersants are used</u>. The public may be unwilling to purchase marine products from the affected area, irrespective of whether the seafood is actually tainted. Farmed fish and shellfish are more at risk from an oil spill than wild fish. The natural tendency of adult fish to avoid spilled oil will be prevented in fish that are in cages. Oiling of fish cages and other equipment may cause prolonged contamination of the fish or shellfish.

Exposure and toxicity

The concerns about the potential for toxic effects caused by dispersed oil, or toxic compounds liberated from dispersed oil, have generated many laboratory toxicity studies on the toxicity of oil and dispersants. The results from these toxicity studies have been selectively quoted by both sides in the dispersant debate to 'prove' particular views.

As described earlier, toxic effects can be acute or chronic, lethal or sub-lethal. The toxic effects produced by a particular substance depend on the <u>exposure</u> an organism has to the substance. Exposure, in a toxicological sense, is a combination of:

- Concentration of oil (as dispersed droplets or water-soluble components) to which the organism is exposed.
- Duration of time for which the exposure persists

Toxicity testing and predicting effects at sea

In standard 96 hour LC50 toxicity test procedures, the test organisms are exposed to progressively higher concentrations of oil, dispersant or oil and dispersant for 4 days (96 hours). The concentration required to kill 50% of the test organisms is then calculated; hence the LC50 description (**L**ethal **C**oncentration required to kill **50**% of test animals). The results from 96 hour LC50 testing are useful indications of relative toxicity LC50 results do not give an indication of what might happen at sea because the exposure is for 4 days and the concentrations required to kill the test organisms is much higher than those in the sea.

Early work concentrated on determining the toxicity of dispersants using standard 96 hour LC50 methods. The next toxicity test strategy was to compare the effects of non-dispersed oil with dispersed oil. The results from these

CASE STUDY 2

The *Braer* oil spill - an example of natural dispersion of oil

In the morning of 5th January 1993 the tanker Braer, en route from Norway to Canada and laden with 84,700 tonnes of Gullfaks crude oil, lost all power 15 km south of Shetland. By midday she was aground in very rough seas with wind speeds of Beaufort Force 10 and 11 and started to leak oil. Just over 100 tonnes of dispersant was sprayed on the oil on the next day (January 6th) from six DC-3 aircraft. The weather then deteriorated and no further signi cant dispersant spraying was possible until January 9th when a further 20 tonnes of dispersant was sprayed. Large oil releases were observed on the morning of January 9th, with a massive release on the afternoon of January 11th when the ship broke into three sections. By January 24th the wreck had been totally broken up and it was judged that all the 84,700 tonnes of crude oil and several hundred tonnes of Heavy Fuel Oil had been released. Gullfaks crude oil does not readily form stable water-in-oil emulsions. The extremely rough seas caused all of the oil to be naturally dispersed into the water column. It was estimated that the dispersant may have dispersed only 2 - 3% of the total volume of oil released - nature dispersed the rest.

The concentration of dispersed oil in water around the wreck was very high; values as high as 50 ppm (20,000 times background level) were measured for several days as the oil escaped. Ten days after the incident, the oil concentration was measured to be 5 ppm. The water containing the dispersed oil drifted northwards and the oil concentration fell as dilution occurred, eventually falling to background levels 60 -70 days after the incident. Some oil became entrained in sediments to the south of the Shetlands.

The waters around Shetland are rich shing grounds and sea sheries are a central feature of Shetland's economy. Shell sh and salmon farming are large contributors to wealth and employment. The potential impact of the Braer oil spill was very high. Precautionary shing bans were

put in place and a long series of studies were undertaken. The ban on shing for all species of wild sh was lifted in April 1993. The bans on the taking of shell sh persisted for longer. The salmon farms had been badly affected, mainly by the loss of the reputation for pure products. Some tainting of the salmon esh was found, but this declined with time and there was no further recontamination from oil that might have been trapped in sediments. However, it was decided to destroy all the salmon so that a fresh start could be made with the con dence of consumers restored.

Effects

An extensive series of studies were carried out after the Braer oil spill by ESGOSS (the Ecological Steering Group on the Oil Spill in Shetland) (Scottish Of ce 1994). They concluded that:

"The impact of the oil spill on the environment and ecology of South Shetland had been minimal. Adverse impacts did occur but were both localised and minimal. The resilience of ecosystems and species populations has already been powerfully demonstrated and provides con dence and reassurance for the future."

Subsequent studies have shown no effects from the spill, although shing for nethrops (Norwegian lobster) is still restricted near oiled sediment areas.

tests quite often conclude that dispersing oil makes it more capable of causing toxic effects because the oil (and the partially water-soluble chemical compounds from the oil) become much more available to the test organisms.

The potential for causing toxic effects to marine life is greater if dispersants are used, than if they are not. However, the dispersed oil concentrations needed to cause effects in the tests, and the time of exposure required to cause these effects, are normally much higher and more prolonged than occurs at sea when dispersants are used.

Even within a standardised toxicity test methodology there are many variables:

Test organism
The oil concentration and period of exposure required to cause effects depends on the test organism used. Amphipods (very small shrimp-like creatures) are particularly sensitive to dispersed oil. Other marine creatures are much less sensitive.

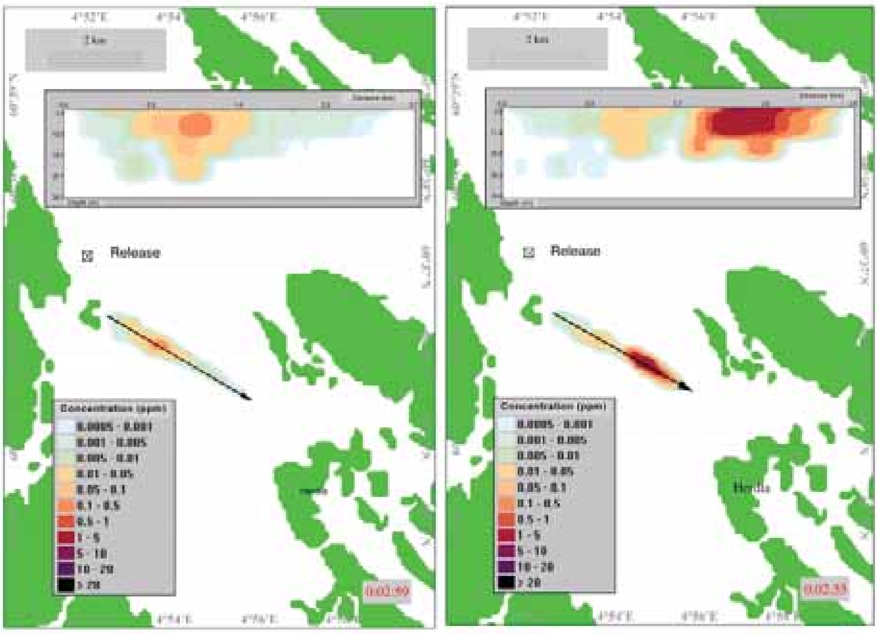
Observed effect
Sub-lethal effects, rather than lethality, have often been used as toxic effect indicators. Even lower degrees of exposure will cause no observable effects and the NOEC (No Observable Effects Concentration) can be determined for a particular period of exposure.

Interpreting toxicity data can be dif cult. The results cannot be directly 'translated' into effects that could be caused at sea without taking into account the exposure levels that will occur at sea.

Realistic exposure levels

Experience from both experimental eld trials and dispersant operations at real spills have shown that dispersed oil will quickly be diluted into the sea. The oil in water con centration rapidly drops from a maximum of 30-50 ppm just below the spill short time after treatment, to concentrations of <1-10 ppm total oil in the top 10-20 meters after few hours.

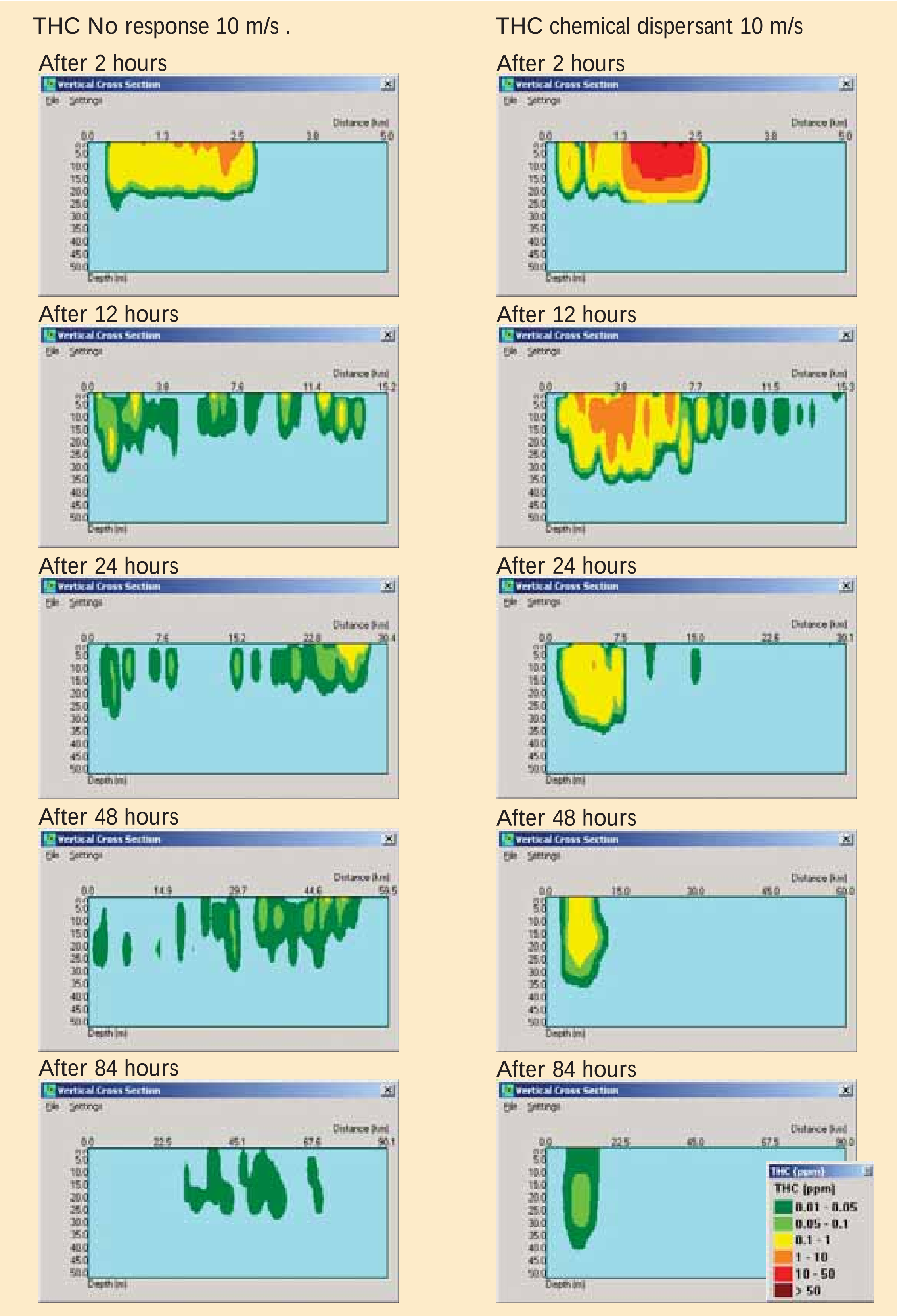
The Figure above depict the modeled total oil concentration (THC) in the water column 3 hours after a simulated spill of 100 m3 oil from the Sture terminal in Norway. The vertical section at the top of the gure gives the concentration pro le along the axis of the arrow. With no response, the maximum concentrations are in the range 0.1 to 0.5 ppm. The application of dispersants 90 minutes after the release increases the peak THC-concentrations in the area of application to 10-20 ppm locally. The vertical section shows that this concentration is mixed down to about 12 m, as compared to about 6 - 8 m in the case of natural dispersion.



Simulated total hydrocarbon concentrations (THC) in the water column 3 hours after release of 100 m North Sea crude at 5 m/s wind from the Sture terminal.

Left): No response

Right): After dispersant application from helicopter



Development and dilution of oil plume in water column after dispersant treatment versus a non-treated slick. OSCAR-simulation of a release of 100 m3 crude oil at 10 m/s wind speed. Dispersant application from one vessel start 1 hour after release.

The figures on the previous page is taken from a simulation of a 100 m3 crude oil spill from a production platform in the North Sea at 10 m/s wind, showing the development and dilution of oil plume in water column over a period of 2 days after dispersant treatment versus a non-treated slick . Dispersant application from one vessel starts 1 hour after release.

A great deal of work has been carried out to devise toxicity test methods that use exposure regimes for test organisms that more closely resemble the real conditions.

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.

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.

Biodegradation of dispersed oil

It has been known for a long time that spilled oil will be biodegraded quite rapidly if conditions are suitable. The naturally occurring micro-organisms responsible for the biodegradation of spilled oil require oxygen and nutrients in proportion to the amount of available oil.

Biodegradation of surface oil slicks is slow because much of the oil is not available to the micro-organisms - it is within the bulk of the oil, even though the slick might be quite thin. Oil dispersed into the upper layers of the water column as a locally low concentration of very small oil droplets maximises all the opportunities for rapid biodegradation. The surface area of oil exposed to the water is high compared to its volume because of the small droplet size. The local concentration of oil is low compared to the water and this provides the opportunity for a high concentration of oil-degrading micro-organisms to survive without being limited by the available nutrients. Different oil components biodegrade at different rates at sea; some of the simpler chemical compounds biodegrade quite rapidly, but some of the more complicated oil components biodegrade at a very slow rate, if at all. The components of dispersant are, in themselves, very biodegradable.

Biodegradable oil compounds and dispersants are converted into biomass and eventually to carbon dioxide and water.

A small proportion of the oil - the larger and heavier molecules - cannot be biodegraded by micro-organisms. It is not toxic and it cannot be processed by marine life - it is biologically inert. This portion of the spilled oil will be present in the marine environment for a very long time.. It will be dispersed in a very large volume of sea water and may eventually settle to the sea bed over a huge area and will eventually become incorporated into sea-bed sediments.

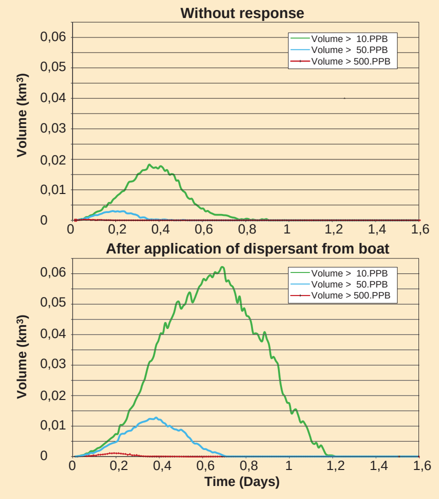
PLANNED USE OF DISPERSANTS

All the evidence that has been gathered during over 30 years of research indicates that there is generally only a small risk to marine life when dispersing spilled oil.

This is not to say that there is no risk, or that the risk should be ignored. It cannot (and should not) be denied that dispersed oil has the **potential** to cause toxic effects to marine life, but only if dispersants are used where there is inadequate dilution.

Quantifying the risk of using dispersants

The risk of using dispersants must be quanti ed to enable rational judgements to be made about dispersant use.



Volume (km3) of WAF-concentrations above 10, 50 and 500 ppb, respectively, from a spill with 100 m3 Balder crude oil (10 m/s wind) using the OSCAR model system.

The use of toxicity test results can be combined with computer modelling techniques to produce a quantitative assessment of the likely effects of dispersing oil. The modelling can generate 3-dimensional representations of the dispersed oil and WAF concentration pro les (or concentration pro les of individual chemical compounds from the oil) that will be produced by using dispersants. Furthermore, the models can calculate the differences in water volume to be exposed to water-soluble WAF (BTX) concentrations above the indicated limits for acute toxicity with and without use of dispersants (see gures).

Predicting the the ultimate fate of dispersed oil is uncertain and some questions remain unanswered:

- How rapidly does the potential for toxic effects caused by dispersed oil or WAF decrease as the oil is biodegraded ?
- Under what conditions will dispersed oil interact with suspended sediment ?

These topics are the subject of current and future research.

NEBA (Net Environmental Benefit Analysis)

The purpose of any oil spill response method should be to reduce the amount of damage done by an oil spill. The damage might be to ecological resources, such as sea birds and sensitive habitats, or economic damage to resources, such as sheries or tourism. The concept of NEBA is that, in some circumstances, it might be reasonable to sustain some damage to a particular resource as the result of oil spill response, provided that the response prevents a greater degree of damage occurring to another resource. NEBA considers the overall damage that might be caused by an oil spill and does not concentrate on one particular aspect.

Comparing the outcomes of different response methods

An oil spill response method might seem capable of reducing both the ecological and economic elements of damage caused by an oil spill; recovering small volumes of spilled oil at sea will eventually prevent oiling of sea birds and it will prevent shoreline contamination. However, mechanical recovery of large volumes of spilled oil at sea can be a slow and only partially successful process. During the time that oil remains on the sea, sea birds will continue to be oiled and the oil that is not recovered will impact the shoreline.

Recent NEBA and response analyses of various spill scenarios indicate that there could be a strong motivation to use dispersants instead of mechanical recovery. By spraying dispersants from aircraft or helicopter it is possible to treat spilled oil quite quickly. The oil will be dispersed, the oiling of sea birds will rapidly cease and the oil will not drift ashore. There would be the possibility of achieving a much higher degree of success - as measured by the reduction in sea bird deaths and the reduced amount of oil on the shore - by using dispersants than by using mechanical recovery. However, there is the risk that the dispersed oil may cause some additional effects to marine life that inhabits the water column or sediment if the water is shallow.

The NEBA process should be used to assess the probable outcome of different response actions, relative to no response, so that the best overall outcome is achieved. This can then be justified as the best response method.

CASE STUDY 3

The *Sea Empress* oil spill - the use of oil spill dispersants

Shortly after eight o'clock on the evening of 15th February 1996, the oil tanker Sea Empress, laden with 131,000 tonnes of Forties blend crude oil, ran aground in the entrance to Milford Haven in Pembrokeshire, one of Britain's largest and busiest natural harbours. In the days that followed, while the vessel was brought under control in a salvage operation beset with problems, some 72,000 tonnes of Forties light crude oil and 480 tonnes of heavy fuel oil spilled into the sea, polluting around 200km of coastline recognised internationally for its wildlife and beauty. From the 16th until the 21st of February a fleet of six DC-3 dispersant-spraying aircraft sprayed oil at sea with a total of 446 tonnes of dispersant. No dispersant spraying took place after 21st February because any remaining surface oil was in patches too small to treat effectively, or was emulsified and weathered to an extent where it was no longer amenable to the use of dispersants.

Effects

The Sea Empress oil spill caused the deaths of many thousands of sea birds, but the populations of these species were not seriously affected and there was no evidence of any affects on seabird breeding success. The population of the most affected sea bird, the common scoter, was recovering within two years. Large numbers of marine organisms were killed either as freshly spilled oil came ashore (for example, limpets and barnacles) or when raised levels of hydrocarbons in the water column affected bivalve molluscs and other sediment-dwelling species. Populations of amphipods (small crustaceans) disappeared from some areas and were severely depleted from others. Recovery of these populations was slow. There appeared to have been no impacts on mammals. Although tissue concentrations of oil components increased temporarily in some fish species, most fish were only affected to a small degree, if at all, and very few died. The fishing bans that were imposed caused hardship for the 700 fishermen in the £20 million a year local fishing industry until compensation claims and payments were sorted out. Within two years the fishing stocks appeared to be back to normal.

It appears that although a very large amount of oil was spilled in a particularly sensitive area, the impact was far less severe than many people had expected. This was due to a combination of factors - in particular, the time of year, the type of oil, weather conditions at the time of the spill, the clean up response and the natural resilience of many marine species.

Although the rapid, large scale use of dispersants at sea probably increased exposure to oil of animals on the sea bed - and to have contributed to the strandings of bivalve molluscs and other species and the decrease of amphipod populations in some areas - on balance it is likely that it was of benefit by reducing the overall impact of the spill. It was estimated that approximately one-half to two-thirds of 37,000 tonnes of the spilled oil that was estimated to have been dispersed was caused to do so by the use of dispersants. The 20,000 to 25,000 tonnes of oil that was dispersed in this manner had the capability of being converted into up to 100,000 tonnes of emulsified oil. Some of this would certainly have impacted the coastline, caused ecological damage and would have had to have been removed in a very costly clean up procedure. The use of dispersants certainly reduced the cost of the response and - on balance - reduced the overall environmental impact.

CONCLUSIONS

There is a great deal of scienti c evidence to show that the use of dispersants can be an effective oil spill response method. There is little likelihood of dispersant use causing negative effects unless they are used in shallow water or very close to particularly sensitive species. Even in cases when dispersants might cause negative effects, the positive bene t obtained by their use might outweigh this to produce a Net Environmental Bene t. Nevertheless, any use of dispersants must be carefully planned and explained to all those who might be affected by an oil spill.

Some of the fears and concerns expressed about dispersant use are genuinely held, have their basis in fact and are rooted in an understandable concern for the marine environment. It is important that these concerns are addressed and that they are addressed openly and truthfully so that the real purpose of using dispersants is clear to everyone. This can be dif cult as some of the arguments are complex and not obvious; how can it be sensible to force oil into the sea when common-sense apparently says that picking it up is, by far, the best option ? Questions will be asked during and after oil spill response and it is much better if the discussion can take place in the calmer and less recriminating atmosphere, during oil spill contingency planning.

Putting dispersant use in the context of other options

People who are not directly involved in oil spill response rarely appreciate the immense practical dif culties in responding to oil spills. The failure to achieve a total solution with no environmental damage caused is seen as only as a partial success - a degree of failure by the responders is assumed. The reality is that achieving anything at all, in the face of prevailing conditions, may evade even the most dedicated and well-equipped responders. Dealing with the variations of weather and the sea can be unpredictable, even during routine procedures. Conducting an emergency response to an oil spill incident, in which rough weather or sea conditions is a contributory factor, is doubly dif cult. It should be made clear to people that all oil spill response techniques have limitations

Concerns over dispersed oil

Dispersed oil does not cease to exist, even if it is no longer visible on the sea surface. The purpose of using dispersants is to rapidly transfer oil from the sea surface into the sea, but this should not just be for the purpose of just making it disappear from sight. Concerns over dispersed oil should be addressed by pointing out that:

- The initially high concentrations of dispersed oil and partially water-soluble oil components will be very rapidly diluted to concentrations below those that cause negative effects on a wide variety of marine life.
- A lot of the spilled oil that is dispersed will eventually be biodegraded over a period of weeks and months; it will therefore not persist inde nitely in the marine environment.
- Any oil that cannot be biodegraded will be of very low toxicity (the components are not bio-available, otherwise they would have been biodegraded) and will eventually join the seabed sediment, diluted with other detritus over a huge area, but at extremely low local concentrations.

Identifying the real unknowns and the real potential risks

The fear that insidious or 'invisible' effects may be occurring, or that the consequences of dispersing oil may only become apparent long after dispersants have been used, is not an unreasonable concern. Fears that sh stocks, already under stress from over- shing and other forms of pollution, might be further adversely affected by dispersed oil in a possibly unknown way is also a reasonable concern - up to a point.

A great deal of work has been done in trying to identify the possible risks of dispersing oil and, to date, the risks appear to be very small in most circumstances. While this should not be a cause for complacency, there is little point in devoting vast resources in trying to identify a risk that may not exist. The information that exists needs to be carefully interpreted.

There are real bene ts and real risks in using dispersants. In many cases, the potential benee ts can often be large and the potential risks can be very small. To deny that a balanced assessment needs to be made would be missing the point of using dispersants - the rationale of using dispersants will be questioned on the basis of the particular oil spill that has occurred. It is therefore important to be able to point out the bene ts and the risks - and quantify them - for the relevant oil spill and to explain the overall bene t of using dispersants, compared to other response options.

Reassuring people that possible concerns have already been considered

Large oil spills are rare events. When an oil spill occurs at a particular location it will seem to the local community that they are among the few to have this misfortune fall upon them. They may feel like 'victims' of the events. It is therefore very important that the oil spill response strategy is clearly explained to them (and others, such as the media) and that it is carried out with a due sense of urgency, but not with panic which will only add to the sense of crisis.

Impromptu 'experts' from organisations such as environmental pressure groups may view a major oil spill as a fund raising opportunity. They have every right to do so. However, there have been occasions when these organisations have added to the already large problems by adding confusion and dissension. This is especially true of dispersant use. In some cases, this is due to genuine ignorance on their part. In other cases, a more political agenda may be the root cause of the objections. For these reasons, it is important that a rationally justi able explanation of dispersant use is given as soon as possible.

SUGGESTIONS FOR FURTHER READING

This document has been produced as an up-to-date guide on oil spill dispersants and is intended for a non-specialist reader. More scienti c information, together with supporting references, is given in a literature review conducted on the same subject:

- Lewis, A. , 2001: Potential Ecological Effects of Chemically Dispersed Oils - A Literature Review on the Potential Ecological Effects of Chemically Dispersed Oils. SINTEF Report No, SFT 66FO1179

Several other guidelines on the use of oil spill dispersants are available from several organisations, including:

- IMO / UNEP Guidelines on Oil Spill Dispersant Application, including Environmental Considerations; 1995 edition, International Maritime Organisation, London, UK.
- IPIECA (International Petroleum Industry Environmental Conservation Association). Report Series Volume Five. Dispersants and their Role in Oil Spill Response. 2001 Edition. IPIECA. London, UK.
- ExxonMobil Research & Engineering Company (2000), ExxonMobil Dispersant Guidelines, Fairfax, NJ.
- Daling, P.S., A. Lewis, 2001: " Oil Spill Dispersants. Guidelines on the planning and effective use of oil spill dispersant to minimise the effect of oil spilsl". SINTEF report: STF6601018. 113pp.

In addition, new regulations concerning dispersant use have recently been prepared and published by the Norwegian authorities. The national regulations in France, the USA, the UK and many other countries of the world have been revised or reviewed in the last few years or are currently undergoing revision.

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