

Viewpoint

The use of chemical dispersants to combat oil spills at sea: a review of practice and research needs in Europe.

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Abstract

In order to better understand the practice of dispersant use, a review has been undertaken of marine oil spills over a 10 year period (1995 – 2005), looking in particular at variations between different regions and oil-types. This viewpoint presents and analyses the review data and examines a range of dispersant use policies. The paper also discusses the need for a reasoned approach to dispersant use and introduces past cases and studies to highlight lessons learned over the past ten years, focussing on dispersant effectiveness and monitoring; toxicity and environmental effects; the use of dispersants in low salinity waters; response planning and future research needs.

Keywords Dispersant, Oil, Spill, Policy, Europe

Introduction

When used judiciously and in the right circumstances, the application of chemical dispersants can be an effective means of accelerating the dispersion of oil from the sea surface into the water column. This in turn helps to accelerate dilution and biodegradation of the oil (Swannell and Daniel, 1999), and can reduce the environmental and economic impact of spilled oil. However, prior to the use of dispersants, consideration must be given to the impact of the dispersed oil on sub-surface resources, such as fish stocks and coral. In addition, it is essential that the limitations of dispersants are recognised so that they are used effectively.

Within the European Union, a recent inventory of national practices and policies relating to the use of dispersants as an oil spill response tool, which was undertaken by the European Maritime Safety Agency (EMSA), has revealed a divergence of opinion amongst EU Member States (EMSA, 2005). In most States, the use of dispersant is secondary to mechanical containment and recovery, and in several states the use of dispersants is either not allowed or is highly restricted, particularly in the Baltic States. In other countries where dispersant use is permitted, in practice, they have not been used for a decade or more. The reasons for this shall be discussed later in this paper. Only one country, the UK, lists dispersant use as its preferred option. This is partly due to weather conditions that preclude the use of containment and recovery response options for much of the year. In order to generate a debate regarding dispersant use and its consideration as an effective response option in more Member States, EMSA held a workshop on the Use of Oil Spill Dispersants in European Waters in Brussels in December 2005¹. The aims of this workshop were to facilitate a common understanding of the use of chemical dispersants in European waters and to consider the implications of their use, the testing and approval procedures, as well as to provide the Member States with a mechanism for decision-making according to each country's individual circumstances. A subsidiary aim was to identify gaps in knowledge and to encourage EU member states and regional bodies to promote additional studies if needed.

One of the outcomes of the workshop was the agreement of a number of conclusions and recommendations. The need to standardise dispersant test methods, develop a framework of European guidelines, and to encourage the inclusion of pre-defined areas and criteria for dispersant use in National Contingency Plans, were identified as being of highest priority. The workshop also concluded that there was a need for more information regarding Russian oils transported through EU waters and the effectiveness of dispersants on those oils.

The Helsinki Commission² has also been exploring the merit of using dispersants in the Baltic Sea. During a workshop held in 2005 as part of a project entitled "Analysis of new opportunities for usage of dispersants in the Baltic Sea", the following knowledge gaps were identified:

¹ <http://www.emsa.eu.int/end187d010.html>

² HELCOM or Baltic Marine Environment Protection Commission, the Governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area", or Helsinki Convention.

- Properties and behaviour of oils transported in the Baltic Sea
- Efficiency of dispersants in the Baltic Sea with regard to salinity, temperature and the most common oil types
- Sensitivity of wildlife to dispersed oil
- Guidelines for Net Environmental Benefit Analysis (NEBA) and sensitivity assessment
- Checklists for dispersant application
- Testing and approval of dispersants.

There are a number of common threads and concerns within these European initiatives which need to be addressed. This paper aims to collate and present data for dispersant use on marine oil spills world-wide over the past ten years, including statistics on the oil types, the countries/regions involved and their policies on dispersant use. It was also envisaged that a study could be made on the effectiveness of dispersant use in recent cases. This has been partially accomplished subject to the minimal availability of data in this field. We will introduce a number of case studies in order to highlight lessons learnt and to emphasise the need for a reasoned approach and pragmatic policy-making in relation to the use of dispersants at sea.

Dispersant use statistics

A review of ITOPF's database of past oil spills has found that, of the 258 marine incidents that ITOPF were involved with between 1995 and 2005, 46 (18%) involved the use of chemical dispersants at sea.

Figure 1 compares the use of dispersants in different international regions for the 46 cases considered, and shows that over half took place in southeast Asian waters. This is compared with the fact that southeast Asia experienced about a third of all the spills attended by ITOPF during that period. It is probable that this reflects the region's spill response policies, as some of the countries in the region are known to use dispersant in preference to other response methods, such as containment and recovery. These data indicate that southeast Asian and Middle Eastern countries are more inclined to use dispersants than Europe and the Americas.

Figure 2 compares the types of oil involved in the spills attended by ITOPF over the last decade, and shows that a large proportion (39%) of the spills treated with dispersant were spills

of heavy fuel oil (IFO 380 and above). This is despite the general acceptance by oil spill response specialists that dispersants are less effective on heavier oils. Past studies, trials and observations from actual spills have shown time and again that weathered heavy fuel oils are often too viscous for dispersants to penetrate and be effective. Nevertheless, they have been used significantly on such oils over the past ten years. In certain scenarios, such as when the fuel oil is fresh and the sea temperature is high, dispersants may be effective, particularly if the country involved has a policy to use dispersants and arrangements are in place to respond quickly. In many cases, however, it is simply the political need to be seen doing something that drives dispersant use on oil spills irrespective of the circumstances.

Dispersant use and policies

Focussing on Europe; of the 77 incidents attended by ITOPF in Europe during the period under review, 6 involved the use of dispersants at sea (8%): one in France, one in Cyprus, two in Greece and two in the UK (Figure 3). Two of the six incidents were spills of heavy fuel oil. It is interesting to note that Europe is less inclined to spray dispersant than other regions of the world. This is despite having a wealth of expertise available on the subject, significant volumes of passing tankers carrying crude oils, and weather conditions that frequently preclude containment and recovery at sea. It is therefore worth looking into the dispersant use policies of Europe to understand why dispersants are so rarely used. In fact, in most of the cases over the last decade, dispersant spraying has not been an option due to conditions specific to those spills, such as an inappropriate oil-type, a location too close to the shore, rapid stranding of oil (i.e. before an on-sea response could be organised), or insufficient oil to warrant dispersant application. This, therefore, suggests that it has been the conditions of the spill that have prevented the use of dispersant rather than restrictive policies or the unavailability of resources.

Policies for the use of dispersants vary greatly across the EU (Figure 4) and range from absolute prohibition of dispersant spraying, to a preference of dispersant use over containment and recovery where conditions are suitable.

Most European countries that allow the use of dispersants, whether as a primary or secondary response option, have set certain restrictions on spraying based on the distance from shore and/or the water depth. Threshold depths have been derived from the individual countries' conclusions from studies on the mixing and dilution of dispersed oil at various depths. Minimum permitted depths for dispersant spraying range from 10 metres in France to 60

metres in Malta. This difference in permitted depths may be due to varying climate and topography across Europe, leading to variable dilution, and are chosen largely from consideration of potential for adequate dilution and preferred distance from shore. For example, coastlines on the Atlantic Sea tend to be much more exposed and have good water exchange when compared with those on the Mediterranean or Baltic Sea. Therefore, these exposed areas are less likely to be affected by high concentrations of dispersed oil. The range of depth thresholds is also likely to be due to differences in decision-making. For example, in principle, France allows dispersant application at shallower depths than other EU countries, but French policy requires case-specific assessments that include a technical assessment of oil type, weathering effects and environmental conditions as factors to be taken into account in the decision whether or not to use dispersants.

It is interesting to compare European policy with other regions. The USA, for example, (which experienced a similar proportion of cases where dispersants were used as Europe) also works on threshold distances from shore and minimum depths. Many States in the USA have pre-approved the use of dispersants outside three nautical miles from shore and/or in depths greater than 10 metres. Again, any decision to spray would be based on an incident-specific assessment. The USA may allow greater flexibility for responders following the outcome of regional workshops that are currently in progress to assess the risks and benefits of using dispersant in waters less than three nautical miles offshore (NRC, 2005). In contrast, in southeast Asia, the region where dispersants have been used the most in recent times, there have been occasions when dispersant has been used without due consideration of oil type, weathering effects, or water exchange.

Dispersants are generally not used by countries with coastlines bordering the Baltic Sea due to the sensitive ecological conditions and low water exchange. Current HELCOM guidance states that response to oil spills should be by mechanical means as far as possible. However, there is a growing interest in investigating circumstances in which dispersants may offer a net environmental benefit, especially with the anticipated increase in oil moving through the region and the inability to use containment and recovery during periods of ice cover. In recognition of this, in 2001, HELCOM amended their policy stating that “chemical agents may only be used in exceptional cases”, to a requirement for using chemical agents with optimised efficiency and an acceptable effect on the marine environment. The recommendation also stressed that “use in

shallow waters should only be authorised in exceptional cases and restricted to minor spills³”. The growing interest in the use of dispersants in shallow, low-salinity waters has prompted calls for more research and, whilst dispersant use in the Baltic is still very limited, this may change depending on new scientific knowledge as it becomes available.

A notable change in policy has also been seen recently in Norway. Following the introduction of new regulations in 2002, the Norwegian response policy effectively changed from mechanical recovery only to an acceptance that dispersant application may be permitted if it gives the best environmental results, as judged by Net Environmental Benefit Analysis (NEBA) (Vik, 2003). This significant change is largely due to a reduction in toxicity of commercially-available dispersants, an increased understanding of the effects of dispersant and dispersed oil as well as an acceptance of the limitation of alternative techniques, such as containment and recovery.

Knowledge gained from actual spills and studies (ranging from small-scale laboratory testing to studies in the field) has led to a better understanding of the criteria that determine the effectiveness of dispersants and the fate of dispersed oil. Indeed, it seems that lessons learnt from past experiences could be used more widely to enhance dispersant use policies and preparedness for oil spill response.

Dispersant effectiveness

As previously mentioned, laboratory and meso-scale testing is useful to gain an idea of the effectiveness of one dispersant relative to other dispersants. However these tests do not indicate how a particular dispersant will perform under the specific conditions of a real incident at sea.

Studies have shown that some oils are more amenable to dispersion than others, for example during the UK 2003 sea trials (Lewis, 2004) the IFO 180 that was used in the trial dispersed much more readily than the IFO 380. As a general rule of thumb, oils with high viscosities and pour points tend to be much less dispersible as delivery of the surfactant to the oil/water interface becomes more difficult. As weathering will increase the viscosity of the oil, it therefore follows that the longer the oil is left to weather, the less likely it is to disperse

³ HELCOM 2001

effectively. Other properties of oil, such as asphaltene and wax content, also affect the behaviour of oil spilled at sea and the manner in which it will weather, emulsify and disperse (Strøm-Kristiansen *et al*, 1997). Knowledge of oil properties and how they change with weathering is therefore important in determining whether or not dispersants should be used during a real incident.

Sea state and weather conditions play an important role in the dispersion of oils at sea. Laboratory, wave tank studies and sea trials have shown that better dispersion is obtained with greater mixing energy (Lewis 2006 and Mullin & Trudel 2006). It is often reported (NRC, 2005) that wind speeds of at least 5m/s are needed to generate sufficient wave energy for good dispersion and that dispersants are ineffective in calm conditions. However, recent studies suggest that the application of dispersant in calm conditions may be effective provided that it is applied within 24 hours of a spill and the wave energy is predicted to increase within a reasonable timescale (Nedwed *et al*, 2006). On the other hand, in very rough and windy conditions it is difficult to accurately target the oil, which may be over-washed by waves thereby inhibiting the interaction between the dispersant and oil. Any dispersant that does hit the oil is likely to be washed or blown off into the sea before it has a chance to penetrate to the oil-water interface and to have any effect.

The incident involving the NATUNA SEA in the Singapore Straits in 2000 serves as a good example of the importance of having information on the oil properties and weather conditions at the time of an incident. When some 7,000 tonnes of Nile Blend crude oil were spilled from the vessel as a result of the grounding, dispersant was applied to thick oil patches around the stricken vessel. No previous testing had been carried out to assess dispersant effectiveness on this little known crude oil but visual observations showed that the oil was semi-solid as early as the first day after the spillage. When the properties of the oil were evaluated in more detail, it was found that the sea temperature was 3°C below the pour point of the oil and the viscosity was estimated to be greater than 50,000mPa and beyond the envelope of effective dispersion. The situation was further exacerbated by calm weather conditions where there was little wave energy to promote effective dispersion. In-situ fluorometry was used to monitor the effectiveness of dispersion and the results verified the visual observations and predictions based on the oil properties, supporting the conclusion that the oil was not amenable to chemical dispersion.

This is in contrast to a recent incident in adjacent waters in which fresh IFO380 leaking from a container vessel's fuel tanks was successfully treated with dispersant because the oil was relatively light, and the warm waters helped to keep it sufficiently fluid to allow penetration of the surfactants.

With the large variety of different crude oils and fuel oils that are carried on tankers transiting European waters, information from laboratory testing, sea trials and real incidents can be useful to enable decisions to be made rapidly and with greater confidence. Where the properties of the oil are known in advance, such as during exploration and production or storage activities, testing of the oil under different conditions to optimise dispersant effectiveness should enhance decision making. For example, Norwegian pollution control authorities require testing to determine the characteristics and dispersibility for most of the oils in production in the North Sea and Norwegian Sea (SINTEF 2005). This includes determination of the window of opportunity⁴ for effective dispersion of a particular oil. However, while testing in advance may be of use on a local scale, it would be impossible to test every single crude and refined oil produced worldwide, and under all possible conditions. In many spills therefore the properties of the oil and its amenity to dispersant treatment are unknown, and so in-situ dispersant spray trials early on in a spill can be used to determine whether the oil in question will disperse under conditions specific to that spill. To avoid delaying oil spill response, or losing the window of opportunity, the resources and logistics necessary for in-situ trials should be readily available and documented within contingency plans. The results of such trials should enable a quick and easy decision on whether or not to carry out a full-scale dispersant response.

Monitoring effectiveness

Following a decision to apply dispersants, it is essential to continuously monitor the sea state and weather conditions, as well as the movement and behaviour of the oil. On 29 August 2000, the bulk carrier NORDLAND grounded in strong winds off Kythira Island, Greece. An estimated 110 tonnes of IFO180 was spilled, which drifted towards the shore of a nearby village, contaminating a few kilometres of coastline and a small fishing harbour. Attempts were made to contain the oil remaining at sea with booms, however poor weather conditions prevented successful deployment. Dispersants were applied over three days to the floating oil via a small portable spraying unit. Visual observations indicated that the dispersant had

⁴ A period of time before weathering of the oil alters its properties to such an extent as to preclude effective dispersion.

dispersed some of the oil. However, after the second day of spraying, the oil became too fragmented for the technique to have any benefit, and the decision was made to cease spraying.

It is extremely difficult to quantify the effectiveness of dispersants and to estimate the amount of oil actually dispersed into the water column but it is often possible to say qualitatively that either the dispersant did or did not work. Visual monitoring can be undertaken from vessels or, ideally, from spotter planes, which can also ensure that the heaviest concentrations of oil are being targeted. Observers should look out for a visible reduction in oil coverage as well as a change in the appearance of the oil, often seen as a coffee-coloured plume within the water column in good viewing conditions. A milky white plume surrounding unchanged oil, as seen during the NATUNA SEA incident (see Figure 5), indicates that the dispersant has not penetrated the oil layer and therefore has had no significant effect.

A submerged flow-through system using ultraviolet fluorescence spectrometry (UVF) to monitor oil concentrations in the sea has been used in several studies, and, notably, during the SEA EMPRESS incident, to indicate effective dispersion. Although UVF will not determine exactly how much oil is dispersed, by measuring the oil concentration before and after dispersant application, it can indicate qualitatively whether or not dispersed oil in the water column has increased significantly, and therefore whether or not the application was successful.

In general, the policy in the USA requires the deployment of trained SMART (Special Monitoring of Applied Response Technologies)⁵ teams to determine qualitatively whether dispersant application is effective. In the case of the M/V RED SEAGULL, visual observations made by the SMART team following the application of dispersant to Arabian Light and Arabian Medium crude oil that was spilt showed that treated oil was readily dispersed. It is interesting to highlight that this spill occurred in a “pre-approval zone”, which enabled rational and rapid dispersant decision-making and response, and ensured application of dispersant within the window of opportunity for successful dispersion.

⁵ http://response.restoration.noaa.gov/book_shelf/648_SMART.pdf

Dispersant toxicity and environmental effects

Improvements in dispersant formulation mean that it is the toxicity of the dispersed oil that is of concern rather than that of the dispersant itself. For lighter oils, natural dispersion (caused by breaking waves) can be significant even in the absence of dispersants. Studies have shown that both naturally and chemically dispersed oils are unlikely to have acute toxic effects on the marine environment provided that there is sufficient dilution to rapidly reduce hydrocarbon concentrations.

As an example, following the SEA EMPRESS incident off the coast of South Wales it was estimated from the results of in-situ monitoring and modelling that about 90% of the oil dissipated at sea as a result of a combination of natural processes (essentially evaporation and natural dispersion) and chemical dispersion, although it was not possible to separate the precise contribution of each process. The majority of the spraying took place in deep water away from the coast but some dispersant was also sprayed on fresh oil within 1km of the shoreline and where the water depth was less than 20 metres deep. This was done on an ebb tide to prevent dispersed oil from entering the highly sensitive Haven Estuary. Fortunately, at the time of the incident, shellfish such as crawfish, spider crabs and many fish would still have been in their winter feeding grounds away from the spill-affected area and there were no reports of mortalities of commercially exploited crustaceans or fish (including salmon and sea trout) as a result of the oil spill. Rather, to the contrary, the temporary ban on fishing during the period of elevated hydrocarbon concentrations in the water column resulted in an abundant harvest for commercial stocks in the following year.

In support of this finding, landings of crustaceans (mainly crabs and lobsters) in South Wales averaged 756 tonnes (range 711 to 844 tonnes) during the years 1993-1995; landings fell to 343 tonnes during 1996 whilst fishing was restricted, and then rose to 1,106 tonnes in 1997 and 962 tonnes in 1998 (SWSFC, 2006). For molluscs (including cockles, mussels, winkles, oysters, scallops and whelks, but dominated by cockles from the Burry Inlet) the landings averaged 6,323 tonnes (range 4,149-8023 tonnes) during the years 1993-1995. The landings were 6,077 tonnes in 1996 and rose to 8,487 tonnes in 1997 and were 5,958 tonnes in 1998 (SWSFC, 2006). In neither case was there any apparent reduction in landings as a result of the oil spill and subsequent dispersant operation.

Despite the immediate benefit of the fishing ban to commercial fish stocks, a study to examine whether dispersed oil may have affected the breeding and recruitment of some species of fish, shellfish and crustaceans (e.g. bass, edible crabs, lobsters and whelks) in the year following the spill were undertaken by the Sea Empress Environmental Evaluation Committee (SEEEC)⁶. The studies undertaken on bass showed that fish spawning in 1996 was more abundant on the south side of the Bristol Channel, which was unaffected by dispersed oil, than in the South Wales nurseries, and was particularly scarce within the Haven estuary. Also, juvenile bass in the affected area were less likely to have attained the critical 60 mm overall length for survival through the first winter when compared with those from nursery areas in North Devon and Cornwall. In 1997, however, there was no indication that juvenile bass were less abundant in any South Wales nursery, including the Haven estuary (Lancaster *et al.* 1998). The late recruitment of juvenile bass in 1996 was attributed to lower water temperatures in February and March, when compared with the same period in 1997 and 1998, and was not restricted to South Wales (Reynolds *et al.*, 2003).

The herring stock within the Haven estuary was also of particular interest as it represented a discrete stock. It was not possible to establish the success of spawning in 1996, but the presence of adult fish in spawning condition in 1997 suggested that there was no long-term effect (SEEEC, 1998). Data from the routine surveys conducted using the continuous plankton recorder in the Bristol Channel and adjacent offshore areas indicated that the SEA EMPRESS oil spill had no dramatic effects on the plankton of the southern Irish Sea between February and October 1996. All of the common taxa showed normal levels of abundance. Some species suggested in the literature to be susceptible to the effects of oil pollution showed no marked changes, and no striking differences were noted in the phytoplankton and zooplankton communities as a whole. This was despite the large quantity of oil which entered the water column as a result of both natural and chemical dispersion (Batten *et al.*, 1998).

Studies of the seabed showed little impact resulting from the spill except for marked reductions in the abundance of amphipods (particularly *Ampelisca* spp., *Harpinia* spp., and Isaeidae) in some areas to the north of the grounding site (Levell *et al.*, 1997; Rutt *et al.*, 1998). In a previous survey conducted in October 1993, these taxa were distributed almost exclusively on

⁶ Sea Empress Environmental Evaluation Committee: an independent committee appointed by the UK Government after the SEA EMPRESS incident. The committee brought together teams of experts and commissioned about 80 scientific studies on the effects of the incident.

the lower and middle parts of the Haven estuary, and were absent from the majority of the same sites in October 1996. As the amphipods were situated within the Haven estuary, where dispersants were not used, it seems most likely that they were affected by naturally dispersed oil, driven into the water column by the turbulent conditions within the entrance to the Haven. Recovery of the amphipod fauna was evident in all reaches of the Haven estuary by 1998; a pattern that generally continued during a later survey in 2000 (Nikitik and Robinson, 2003).

It is possible to conclude therefore that despite the large amount of chemical dispersion that occurred in this case, there were no discernible effects on the biodiversity of the marine environment in Haven estuary that could have been attributed to the use of dispersants.

The 1984 TROPICS study in Panama (Baca *et al*, 2006) was undertaken to compare the effects of floating oil and chemically dispersed oil on mangroves, sea-grasses and coral in sheltered shallow sea areas. The short and long-term effects on the three habitats were monitored over some 20 years. This study concluded that the dispersed oil initially caused mortality to invertebrate fauna, sea-grass beds and corals at both sites. Dispersed oil initially reduced the major categories of coral organisms by 30%, however within 10 years coral coverage had fully recovered to pre-spill levels, equalling those at the non-oiled control site. Floating oil did not impact the coral in the long-term, but it did have a significant effect on the mangroves, with 46% mortality of adult mangroves and evidence of erosion of the sediment in the affected area. 20 years after the initial oiling, it was observed that sediments were still releasing a visible sheen and that adult trees were still dying, although new trees were slowly replacing those killed by the oil. While oil contamination remains at the floating oil site, it is no longer detectable at the dispersed oil site and there have been no significant long-term effects on the mangrove population. Although this study focussed on habitats found mainly outside European waters, it not only illustrates the value of conducting a Net Environmental Benefit Assessment (NEBA)⁷ by prioritising sites, but also highlights the need to consider the longer-term effects of floating and dispersed oil on various resources when making decisions on response options.

Toxic effects of oil spills and dispersant use is understandably of great concern to the public and media in the vicinity of an incident. In Japan in 1997, a spill of 500 tonnes of light crude oil was reported by the local media as “Japan’s worst ever spill”, and the impacts were greatly

⁷ IPEICA, 2000. Choosing Spill Response Options to Minimise Damage: Net Environmental Benefit Analysis

exaggerated. The adverse media coverage combined with the spraying of dispersant during response, resulted in a strong negative reaction from the public and from fishery associations throughout Tokyo Bay with allegations that oil and dispersants in the water and sediments had destroyed both the fishery and its reputation. However, the dispersants used were government-approved and they were applied well away from the important fishing grounds in Tokyo Bay and where the dilution capacity of the bay would have been more than enough to quickly reduce the concentration of dispersed oil to below harmful levels. Consequently, it was unlikely that the dispersants would have had such a severe impact on the fisheries in Tokyo Bay. Nevertheless, to allay concern, a sampling programme of water and sediment was undertaken. The Japanese Ministry of Environment published their monitoring results, stating that it could not detect oil or “chemicals used in connection with the grounding”, and that results were comparable to baseline levels and/or within water quality threshold levels for the country. This case highlights the need to ensure positive information is presented to the public, so that undue fears might be reduced.

Use of dispersants in low salinity waters

Much debate centres on the use of dispersants in areas where their effectiveness and impact are less easy to predict; for example, shallow seas, areas of low water exchange, areas of unique ecological value and water bodies of low salinity, e.g. the Baltic Sea.

Apart from consideration of the environmental benefits of dispersing oil into fresh or brackish water, there is an issue as to whether or not dispersants will work at all. The major commercially available dispersants have been formulated for use in normal marine salinities of 30‰ or higher and it has been shown that their effectiveness generally decreases at lower salinities (Blondina, *et al.* 1999; Chandrasekar *et al.* 2006). The effectiveness of a dispersant is a function of how much of the surfactant is available to reach the oil-water interface and reduce the interfacial tension. As salinity decreases, the surfactant becomes more soluble and thus, less is available to interact with the oil.

Sterling *et al.* (2004) discovered only a limited influence of salinity on dispersant effectiveness when the oil and dispersant were pre-mixed, with no significant changes with respect to droplet size or subsequent coalescence kinetics under these conditions. Pre-mixing is, however, not an option in a real response. Therefore, research has been conducted into reducing the surfactant solubility by increasing the salt content of the dispersant formulation by the addition of

calcium chloride (Georges-Ares et al. 2001) with a resultant improved effectiveness in brackish and fresh water. Currently, there are no statutory product approval schemes in Europe that assess product efficiency or toxicity under conditions of low salinity. For example, in the United Kingdom, both the efficacy test (Morris and Martinelli, 1983) and the toxicity assessment (Kirby *et al*, 1996) that are used to approve oil spill treatment products are carried out under full marine salinity conditions. Such test protocols could, however, be adapted to address the physical conditions representative of the Baltic Sea area.

Any decision regarding the use of dispersants in low salinity waters must take account of local conditions. In the Baltic Sea, low salinity is only one factor and low mixing energy, limited potential for dilution, low water exchange and ice cover (in the north during winter months; see Granskog *et al.*, 2006) are all important factors to consider. The soft-bottom macrobenthic communities in the Baltic are characterised by low diversity and highly variable abundance, factors driven by the unique nature of the sea and the low number of species adapted to this brackish environment (Laine, 2003). Toxicity is closely related to the solubility and bioavailability of toxic oil components (e.g. polycyclic aromatic hydrocarbons – PAH), and some of these may become more soluble in low saline conditions. The increased solubility holds true for oil components whether dispersants are used or not, but is enhanced by the use of dispersants (Ramachandran *et al.* 2006) almost certainly as a result of decreased droplet size which is also known to increase toxicity (Norton and Franklin, 1980). Ramachandran *et al.* (2006) demonstrated that a biomarker of PAH exposure, ethoxyresorufin-o-deethylase (EROD), was increased in fish at lower salinities and enhanced by the use of dispersant.

In summary, the use of dispersants in low salinity areas remains an issue of contention where the debate is partially hampered by a relative lack of scientific evidence on the associated efficiency and impacts. The Baltic Sea is a unique environment and, whilst there are very sound reasons why the use of dispersants should be approached with caution there may also be scenarios when correctly formulated dispersants could be of net environmental benefit. In particular, whilst large-scale application of dispersants may not be desirable due to the reduced opportunities for dilution of the dispersed oil, tactical use of limited quantities may help to protect particularly vulnerable natural resources, e.g. rafting birds.

Response planning

Contingency planning and pre-approvals need to adequately address the application of dispersants in order to promote a rapid response. Delays can result in reduced dispersant effectiveness due to the continuous weathering or fragmentation of spilled oil. The establishment of pre-approval areas for dispersant application or the inclusion of locations where dispersants are allowed or prohibited on sensitivity maps allow for more rapid decision-making, as it removes the need for lengthy authorisation processes during the incident itself.

Consideration of issues such as the location and quantity of resources is important to ensure that oil spill response equipment is readily available and adequate for an effective response. The logistics of getting the required equipment to the spill site is also an important matter for contingency planning. In 2005, following a spill of crude oil off the north coast of Egypt, a C-130 aircraft equipped with an Aerial Dispersant Delivery System (ADDS pack) were mobilised from UK to Cairo with 10,000 litres of dispersant on board. However, for unspecified security reasons, the aircrew were prevented from flying to the spill site. Fortunately, most of the oil dissipated naturally and dispersants were not required. However, this incident highlights the need for thorough contingency planning for oil spill response options, including detailed consideration of logistics and customs arrangements for rapid transportation and receipt of equipment from other countries.

Good communication and co-operation are also important in response planning. The International Convention on Oil Pollution Preparedness, Response and Co-operation 1990 (OPRC 90) encourages co-operation both nationally and internationally and also between government and industry. Investing time and resources in preparing and implementing local, national and international agreements is likely to facilitate an effective response and significantly reduce the damage that an oil spill may have on sensitive resources.

A bilateral agreement between Argentina and Uruguay was put to the test in 1997, when the tanker SAN JORGE grounded off the coast of Uruguay, near Punta del Este and spilled an estimated 2,000 tonnes of crude oil into the River Plate. In an attempt to protect sensitive shorelines, including a southern fur seal colony on a small island nature reserve, the oil was treated with dispersant both from aircraft and vessels. Under the bilateral agreement the Prefectura Naval Argentina provided a dispersant spraying aircraft and crew and applied dispersant to the floating oil offshore over a period of 9 days. The effectiveness of the

dispersants was confirmed by visual observation. The co-operation that existed between the two countries ensured that assistance could be provided quickly, effectively reducing the potential impact of the oil on these sensitive resources and benefiting both countries.

The Bonn Agreement⁸ between the North Sea coastal states is another example of a co-operative arrangement for pollution response. During recent spills in Europe, Bonn Agreement countries worked together to assess the likelihood of dispersants being an effective response. In the case of the ERIKA and PRESTIGE incidents that occurred off the coast of France and Spain in 1999 and 2002 respectively, testing of the very heavy fuel oil cargo that spilt with chemical dispersants by experts in France quickly showed that dispersants would not be effective. This enabled valuable resources to be directed to other areas with greater benefit. Similarly, during the TRICOLOR incident in the English Channel (in which IFO 380 was spilt and threatened the coastlines of Belgium France, UK and the Netherlands), the UK government planned a trial with dispersants using their aircraft to test if they would be effective on the fuel oil. However, the oil was too fragmented to achieve an effective response and efforts were focused instead on mechanical containment and recovery.

When planning to use dispersants, it is important to remember that they only enhance the natural dispersion of oil. Provided that the oil is amenable to dispersion and the energy is sufficient, dispersed oil will be present in varying degrees in the water column even before any chemical dispersants are applied. Therefore, the decision becomes not one of deciding whether or not any oil should enter the water column, but the degree to which enhancing the concentration will affect sensitive resources and prioritising accordingly. A balanced approach to response planning is needed, which compares and prioritises the benefits of using dispersants to protect different resources and adequately prepares for their use in the right circumstances (ITOPF 2005, IPEICA 2000, IMO/UNEP 1995).

Research Needs

Although considerable research has been carried out to determine the optimum working parameters for the use of dispersants on oil under various conditions, there remains a need to develop technology that can enhance the operational use of dispersants. For example, whilst

⁸ The 1983 Bonn agreement for cooperation in dealing with pollution of the North Sea by oil and other harmful substances between Belgium, Denmark, European Community, France, Germany, the Netherlands, Norway Sweden and the United Kingdom

laboratory and meso-scale testing of dispersants have been invaluable to guide the use of dispersants in the field, extrapolation of these test results to a real spill situation must be done with caution. Consequently, a better understanding of the relationship between the different testing regimes and the natural environment may enable more reliable predictions to be made during real incidents. This might require further research into the function of dispersants on a molecular level. A better understanding of the most appropriate platforms for application of dispersant (particularly for smaller spills) may also be beneficial, starting with a review on past research on droplet sizes and rates of application. In addition, investigation of the mechanism of how dispersant is delivered and how droplets migrate to the oil-water interface may lead to improved application techniques.

The quest for a method to quantify the amount of oil dispersed during the response to a real incident remains unfulfilled. Laser fluorometry has been used to show qualitatively an increase in dispersion relative to natural dispersion but falls short of providing real-time information on the amount of oil actually being removed from the water's surface during dispersant application.

The fate of dispersed oil in different environments is of particular interest to those responsible for monitoring or assessing the longer term effects of oil in the environment. Opinion as to whether dispersants prevent oil from adhering to sediment (due to the presence of a surfactant), or whether sediment and oil interaction is encouraged by increasing the concentration of oil droplets in the water column, appears still to be divided, and will probably depend on circumstances specific to the incident. Nevertheless, further research on the fate of dispersed oil in the environment and particularly in areas of high turbidity, would be worthwhile.

The volume of maritime traffic in the Baltic Sea area and the Gulf of Finland is high and set to increase still further. A number of significant oil spills have already occurred in the region, such as the 'ANTONIO GRAMSCI' in 1979 (and 1987), the 'GLOBE ASIMI' in 1981 and the 'BALTIC CARRIER' in 2001 (HELCOM, 2004). It has been suggested that the increase in oil transportation will raise the risk of a large oil spill involving over 10,000 tonnes of oil by 35% for the whole of the Baltic Sea, and by 100% for the Gulf of Finland (HELCOM, 2001).

The incident in which the 'RUNNER 4' sank off the coast in the Gulf of Finland in 2006 illustrated the difficulties experienced when attempting to respond to oil spills in ice conditions. A combination of the increased risk of an oil spill in the Baltic Sea and the Gulf of Finland, and recognition of the limitations of conventional response methods when responding to oil spills in ice conditions, has prompted interest in exploring the possibility of using dispersants in this region. Information on the effectiveness of dispersants in low salinity environments, especially in the presence of sediment, calm seas and low temperatures will assist in identifying scenarios where dispersant use may be of benefit. To prepare for the possibility of an oil spill during exploration and production in Sakhalin, the oil industry has been investing in research to determine whether dispersants can be applied effectively in ice conditions and in calm seas⁹. Developments in this area are likely to prove useful for contingency planning in countries where the similar conditions apply.

In considering a global issue such as research needs for dispersant use, it is logical to promote international co-operation between interested parties so that studies need not be duplicated and that findings may be shared. In the USA, the CRRC¹⁰ has organised a series of meetings on dispersants, with the aim of bringing together interested international parties to share past studies and co-ordinate future research and development needs.

Conclusion

A review of the use of dispersants on oil spills that occurred over the 10 year period between 1995 and 2005 has shown that there were relatively few occasions when dispersants were used in response to incidents in European waters. This appears to be chiefly due to inappropriate circumstances for dispersants to work effectively and it is therefore reassuring that, over the decade studied, European response policies do not appear to have prevented spraying during incidents which might have benefited from dispersant use.

When considering the attitude towards dispersant use globally there appears to be a contrast between those countries that require more research on the fate and effects of dispersed oil on their sensitive resources specific to their waters particularly for near shore use, and those countries that routinely use dispersants as the preferred response option and, as a result,

⁹ http://www.sintef.no/content/page13____12029.aspx

¹⁰ Coastal Response Research Centre, a partnership between the National Oceanic and Atmospheric Administration (NOAA) and the University of New Hampshire, which focuses on research to advance the knowledge, technology and practice of spill response and restoration (<http://www.crrc.unh.edu>).

perhaps pay too little attention to whether or not the technique is likely to be effective. The latter attitude is often borne out of a need to be seen to be doing something. Recently, some countries, such as Norway and the Netherlands have altered their policies to allow dispersant use under certain conditions. This change in attitude is attributable in part to results from various laboratory testing and sea trials that have taken place in the last decade or so which, in turn, have enabled a review of existing policy and a more informed Net Environmental Benefit Analysis (NEBA) to be carried out during the contingency planning phase.

The findings from a review of response strategies in European countries were reported by EMSA in 2004. One of the recommendations to come out of this review was that greater consideration should be given to the use of dispersants, especially in view of the volume of crude oil transported in European waters and frequent weather conditions that preclude the effective use of alternative response strategies (EMSA, 2004). Recent workshops and research programmes have focussed on assisting European countries to optimize conditions for effective dispersant use and on expanding the scenarios where they might provide a net environmental benefit, even in situations previously thought inappropriate. A good example of this is consideration of the use of dispersants to treat limited quantities of oil in the Baltic Sea and Gulf of Finland. Here, the reduced salinity and water depth might instinctively warn against dispersant use but, in circumstances where very large numbers of over-wintering birds are present and response strategies are limited by ice, dispersant might provide a means of protection. Furthermore, there has been suggestion that biodegradation of limited amounts of dispersed oil may be enhanced in the conditions existing in the Baltic Sea¹¹, which could counteract the negative consequences of dispersant use. However, further research will be needed to demonstrate this.

Clearly, whilst much is already known about the effectiveness of dispersants on various oils, there is still opportunity to enhance contingency planning to make better use of this response strategy, and to ensure that the logistics for a response using dispersants have been properly addressed, so that they can be used without delay when the opportunity arises. Multidisciplinary research projects and the use of real spills to gather data and trial new technologies, particularly those that will enhance the ability to demonstrate effective use of dispersants in real-time, can only serve to support countries in their decision making.

¹¹ During EMSA workshop 2005. <http://www.emsa.eu.int/end187d010.html>

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