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IMO/UNEP GUIDELINES
ON
OIL SPILL DISPERSANT APPLICATION AND ENVIRONMENTAL CONSIDERATIONS

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PREFACE

This publication contains practical information which may be useful to Governments, particularly those of developing countries, and to other concerned parties, on the use of dispersants for dealing with oil spills at sea.

The Environmental Consultative Committee on the Petroleum Industry of UNEP and the Marine Environment Protection Committee (MEPC) of IMO agreed to prepare guidelines for the use of oil spill dispersants. The MEPC established an expert working group on the subject in which experts nominated by UNEP participated. The outcome of the work of the expert group for the last two years was presented to the seventeenth session of MEPC in June 1982 and received its approval.

These Guidelines should be read in conjunction with the IMO Manual on Oil Pollution – Section IV "Practical Information on Means of Dealing with Oil Spillages" (February 1980).

IMO and UNEP thank the many experts who assisted in the preparation and review of the text.

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IMO/UNEP GUIDELINES ON OIL SPILL DISPERSANT APPLICATION AND ENVIRONMENTAL CONSIDERATIONS

1 INTRODUCTION

The response to an oil spill is likely to involve many different techniques, sometimes used in isolation but more often used in combination. The area where the spill occurs, the surrounding areas to which oil can spread or drift, and the resources at risk in these areas, dictate the best method or methods of response. The use of oil spill dispersants is one of the possible response techniques. During the last decade significant developments have been made with respect to dispersants, and their application techniques. This information is being made available to Member Governments to help them in their oil spill response.

In the right circumstances, there may be an important role for the use of dispersants in marine situations (at the time of writing there exist no effective dispersants for fresh water use). It is the purpose of these Guidelines to provide a review of present day knowledge and experience with respect to dispersants, and to disseminate this information as an aid to contingency planning. It should be remembered, however, that advances in dispersants, dispersant testing and dispersant application techniques, are still taking place, and concerned parties should keep themselves advised of these developments. These Guidelines emphasize environmental considerations, and especially, the very important one of when NOT to use dispersants, as well as when to use dispersants. Section 2 considers the fate of an uncontrolled oil spill and sections 3 to 9 contain a systematic discussion of dispersant use.

1.1 Possible responses

When oil is spilled on the sea possible responses are:

- contain and remove the oil from the marine environment;
- monitor its behaviour but leave it alone for the time being;
- chemically disperse the oil into the water column;
- some combination of the above.

Techniques are available and are being further developed for these operations. These techniques include:

- for containment of an oil slick – physical barriers such as booms;
- for removal of the oil – skimmers, burning;
- for transfer of the oil to the water column – dispersants.

The method(s) to be used depend on many factors, not least of which are the overall objectives of those taking charge of the clean-up (most often Government officials). These objectives will be influenced by environmental and socio-economic factors. The achievement of these objectives will depend on the means available, and the feasibility of using such means.

The subjects of contingency planning and methods of containment and removal of spilled oil are dealt with in detail in IMO's Manual on Oil Pollution, Section II – Contingency Planning, 1978 and Section IV – Practical Information on Means of Dealing with Oil Spillages, 1980. These Guidelines should be read in conjunction with IMO's Manual on Oil Pollution – Section IV, which includes information on dispersants.

2 THE FATE OF AN UNTREATED MARINE OIL SPILL

A marine oil spill, if left alone is affected by:

- the characteristics of the oil;
- the way the oil entered the marine environment (well blowout, tanker wreck, etc); and
- the natural processes to which the oil is subjected after the spill.

These effects are illustrated in Figure 1.

In the IMO Manual on Oil Pollution, Section IV (1980), Chapter 2 discusses the main characteristics of crude oils and products. Chapter 3 discusses the natural processes, of which evaporation, dispersion, emulsification and movement are of immediate importance. An understanding of the foregoing is necessary for the discussion of what happens when dispersants are applied.

3 DISPERSANTS

3.1 Principles

Dispersants are mixtures which include surface active agents to reduce the interfacial tension between oil and sea-water, as shown diagrammatically in Figure 2. This makes it possible for an oil slick to break into very fine droplets (less than 100 microns in diameter) which are rapidly distributed throughout the water volume because of natural water movement. With normal mixing energies, the oil concentration in the water column rapidly decreases to background levels. The droplets may rise slowly to the surface in still water. Special components in the dispersant inhibit reagglomeration or coalescence. The dispersion action is enhanced by mixing energy derived from wave action, propeller wash etc.

Dispersants change the fate of oil at sea by enhancing its penetration into the water column. The removal of oil from the water surface reduces the direct influence of wind and the possible formation of emulsions. It also increases the surface to volume ratio of the oil which may enhance biodegradation. Further details on the effect of dispersants on oil at sea are described in section 5 "Physical Effects".

3.2 Types of dispersants

Two types of oil dispersant are generally available. These are commonly termed "Conventional" and "Concentrate" dispersants respectively[(1, 2)*].

- ***Conventional dispersants*** are usually hydrocarbon-solvent based and contain a mixture of emulsifiers. They are generally applied undiluted, as supplied by the manufacturer.
- ***Concentrate dispersants*** are mixtures of emulsifiers, wetting agents and oxygenated solvents. They contain more active ingredients than conventional dispersants and generally give more rapid and better dispersion of the oil. Some of these products are described by their manufacturers as self-mix dispersants. They are applied:
  - undiluted for aerial application and sometimes when sprayed from surface vessels;
  - sometimes diluted with sea-water when applied from surface vessels.

Laboratory tests have shown that conventional or diluted concentrate dispersants can disperse up to 8 times their own volume of oil whereas concentrate dispersants can disperse up to 80 times their own volume. Because of the fragmented nature of oil slicks and other practical considerations, however, these ratios will not be achieved in practice, and dispersant to oil ratios of 1 : 2 for conventional and diluted concentrate dispersants and 1 : 15 for undiluted concentrate are more typical in temperate climates, although better ratios may be attained in the tropics. If the application rate does not achieve satisfactory dispersion, one possible reason is that insufficient dispersant has been applied. On the other hand, if increasing the application rate has no positive effect, it must be concluded that the dispersants being used are ineffective against the particular oil under the prevailing environmental conditions.

3.3 Effectiveness of oil spill dispersants

The extent to which an oil slick may be dispersed depends very much on its pour-point and viscosity at sea temperature. Weathering and emulsification quickly increase viscosity and pour-point and hence increase resistance to dispersion. Sea state, temperature and salinity also play a role. As a rough guide present day dispersants can treat oils with viscosities up to about 1,000 centistokes reasonably well, although the efficiency of dispersants decreases with oil viscosities exceeding 400 centistokes. Further details on this subject may be found in other publications[(2, 3, 4)*].

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* See references.

Information presented in Tables 1 and 2 and Figure 3 demonstrates that users of dispersants must consider the physical properties of the particular spilled oil at the sea temperatures existing at the time of the spill, as well as the sea conditions and the type of dispersant available. These tables can be used to make an assessment of the expected effectiveness of a dispersant. For example, if Nigerian light were to be spilled into sea-water at 10°C, Table 1 shows that this oil would be below its pour point (in a solid or semi-solid state) and consequently not dispersable.

Similarly, from Figure 3 it can be seen that a spill of intermediate fuel oil may be difficult to disperse in water below 10°C since its viscosity would be over 1,000 centistokes. On the other hand, Figure 3 also shows that Arabian light in water temperatures of, say, 15°C would have a viscosity of about 15 centistokes and would likely disperse easily provided there was sufficient wave action.

Table 2 shows practical dose rates for each type of dispersant. Information on the effectiveness and efficiency of particular dispersants for different oils, circumstances and application methods should be available from the suppliers. Laboratory testing, and experience obtained from research or accidental spills, should add to the knowledge necessary for a good appraisal of what dispersants can do under given circumstances.

In practice, conditions will rarely be ideal. The slick will not cover the ocean in a uniform layer, there will be windrows, and oil layer thickness will not be the same throughout the area covered with oil. Consequently, there will inevitably be over- and under-dosage.

Few quantitative data are available on the performance of dispersants on accidental oil spills, however, considerable information has been generated recently from experimental oil spills. Research has shown that oil will disperse to a depth of as much as 10 metres and, in some cases, it subsequently dilutes rapidly to background concentrations when sufficient water volume is available. Some of the data obtained from experimental spills are presented in Tables 3 and 4 [(5, 6)*] to give an idea of the effect of dispersant application and of resulting concentrations of the oil in the water column as a function of time. In the case of the Protectmar results, some of which are shown in Table 4, it was concluded that the low concentrations recorded at 1 metre and deeper, demonstrate that the oil was distributed mainly in the upper metre of the water and very close to the surface. Some older data on chemical and natural dispersions are also given in Tables 5, 6 and 7 [(7, 8)*]. Results shown in Tables 3 to 7 can be fully appreciated only if the reader considers the experimental conditions described in the papers from which they are drawn. Tables 3 to 7 are summarized schematically in Figure 4 showing essentially that although oil concentrations are initially higher in chemically dispersed slicks, within a very short time oil concentrations return to background levels. Naturally dispersed slicks, on the other hand, remain on the surface longer and result in low concentrations beneath the slick over a prolonged period. However, this general picture may be modified by conditions at sea including wind and currents and also by the oil type.

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* See references.

4 APPLICATION OF DISPERSANTS

4.1 General

The best combination of dispersant and application method has to be selected for the specific situation. Characteristics of dispersants have been discussed in section 3. On the open sea they can be applied from surface vessels (section 4.2) and from aircraft (section 4.3). Onshore, backpacks or vehicle-mounted spray equipment or in some cases aircraft may be used (section 4.4). It is very important to use proven equipment and to follow the instructions of the suppliers of equipment and dispersants.

Spraying operations should be started as soon as possible after it has been decided that dispersant use will form part of the response (see section 9). Many oils will form stable water-in-oil emulsions (chocolate mousse) of which the viscosity will be higher than that of the original oil. The extent of emulsification and the stability of the emulsion will depend upon the type of oil, sea state and temperature. The viscosity also increases because of the evaporation of lower molecular weight hydrocarbons. Both processes may have taken place to a considerable extent within a couple of hours after the spill, and thus dispersant effectiveness may be reduced if application is delayed. Mousse is very difficult to disperse. Treatment with dispersants should therefore start before the mousse formation or extensive weathering has taken place. The fear that early treatment could result in higher concentration of low molecular weight toxic compounds in the water column for longer periods does not seem justified in light of results from experimental spills[(5)*].

4.1.1 *Safety aspects of dispersant application operations*

Dispersants may sometimes be used with intent to reduce fire and explosion hazard and so minimize risk to life and limb. Even when dispersants are applied, or mechanical clean-up is initiated soon after a spill, it must be appreciated that hydrocarbons are usually present in the atmosphere due to evaporation of the more volatile components. These may be concentrated enough to present a health and fire risk, or to cause over-speeding of diesel engines used in clean-up or other equipment. Instrument tests for hydrocarbons in the atmosphere should, therefore, be made in addition to observing all normal safety precautions.

4.1.2 *Industrial hygiene aspects*

The handling and application of chemicals require safey precautions according to the nature of the chemical product. The supplier of the dispersant should also supply the necessary information concerning health hazard. For example, dispersants will affect the skin on prolonged contact. Protective clothing such as gloves and overalls, face protection such as goggles, plastic visors etc. should always be worn.

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* See references.

4.1.3 *Logistics of dispersant supply for large spills*

Supplying an adequate quantity of dispersant to deal with a large spill can often be a problem. Spill response managers should include in their contingency plans an inventory of suitable dispersants and should be aware of how this supply can be augmented from additional resources. In the event that the supply is inadequate, spill response managers should be prepared to use a combination of response techniques.

4.2 Application from surface vessels

Dispersants are sprayed onto the oil slick via special spray guns, or booms with nozzles connected to supply pumps and storage tanks. The sea state will dictate, in large measure, whether such systems can be safely and effectively used.

When using either ***conventional*** dispersants or diluted ***concentrates*** in calm seas, effective mixing energy may have to be supplied by "breaker-boards" towed behind the spray booms which, in conventional systems, are mounted aft of amidships. Alternatively, in the absence of breaker-boards, the ship's propellers may be used to provide the necessary mixing energy. For proper breaker-board performance the speed of the vessel should be between 5 and 10 knots. Concentrates may be diluted, usually to 10 times their volume, by means of a mixing pump or by drawing them into the suction opening of a sea-water pump. For an average slick thickness of 0.1 mm of oil, 20 cubic metres of oil would be treated per hour, assuming a ratio of about 1:2 for conventional dispersants and 1:20 for concentrates, and a single pump capacity in the order of 10 cubic metres per hour for conventional dispersants and dual pump capacity of 1.0/9.0 cubic metres per hour for concentrate and sea-water respectively. With an effective width of the spray path of 20 metres, a vessel could cover 200,000 m^2/h (encounter rate) at a speed of 10 km/h (5.5 knots). The speed of the vessel can be adjusted within limits, according to the nature of the oil and the thickness of the slick. As part of contingency planning such dispersants should be tested in field trials which, along with information from dispersant suppliers, should guide the response managers[(3, 6)*]. It is possible that some dispersants may not require additional mixing energy.

From a chemical point of view, concentrate dispersants are most effective when applied undiluted directly onto the oil slick. In such cases spray booms are usually mounted at the bow so that bow-wave and wake assist mixing. Additional mechanical mixing energy, such as supplied by breaker-boards is not necessary and a wider range of speeds is possible, limited only by slick thickness and the required application rate[(3)*].

An advantage of concentrates over conventional dispersants, from a logistical point of view, is that a vessel can make sorties which, for a given payload and encounter rate, are 10 times longer. When appropriate, bow spraying of undiluted concentrate can be done at high speeds, thus shortening the time of the total operation. On the other hand, bow spraying also allows for much lower speeds, making it

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* See references.

possible to treat a slick at a high dispersant to oil ratio, where otherwise vessels equipped for the use of conventional dispersants or diluted concentrates would have to make multiple passes over the same area. When it is necessary to disperse a large slick at sea, dispersants should be sprayed in a systematic manner. Oil spilled at sea is often fragmented naturally into "windrows" in which case they would be sprayed along their length. If the oil is near land, it should be sprayed along its landward side, and parallel to the land. Where possible, the pattern of spraying (see Figure 5), should be directed from aircraft. If two or more vessels are on the scene, their operations must be properly coordinated. Ideally, their spray paths should be contiguous and slightly overlapping so that no oil escapes treatment.

In general, dispersants should not be applied by means of fire monitors, although a technique for applying concentrate dispersant by eduction into sea-water and the use of special nozzles has been developed(6)*. Hydrocarbon solvent dispersants are not normally used in this way unless specified in manufacturers' instructions. Once chemical dispersants have been properly applied, however, hosing with sea-water has proven valuable for agitating small spills in otherwise inaccessible locations in ports and harbours (e.g. under wharves and pilings).

As a contingency planning measure, the various service craft which may be associated with oil operations should be fitted to accept spray equipment.

4.3 Aerial application

Spraying from aircraft (fixed wing or helicopter) is a technique which some Governments have adopted and used successfully in a number of spills. Aircraft fitted with spray booms, nozzles, pumps and tanks offer the possibility of rapid slick treatment over a large area with a faster response than would be possible with surface vessels. Aerial application may also offer advantages for spills which are a long way from ports. It appears that most concentrate dispersants lend themselves to aerial application. The effective swath width may vary from 1 to 2.5 times the span of the spray nozzles on the aircraft. Flights are generally made into the wind at an altitude of 15 to 50 feet, in a manner similar to that shown in Figure 6. Light conditions, sun angle and direction, may make it necessary to spray in other directions.

A variety of aircraft can be considered for dispersant spraying applications. Helicopters can be fitted with either integral spray units or "slung-buckets" and their associated pumps and spray booms. In principle, any fixed wing aircraft with stable low flight characteristics can be equipped with pumps and spray booms. Nozzles and pumping pressures must be carefully selected to provide optimum droplet size, generally considered to be in the range of 0.4 to 1 mm in diameter. If the droplet is too small, it may be blown away from the slick, while, on the other hand, if it is too large it may pass through the oil layer and be lost in the water column.

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* See references.

As an example of aircraft application rates, one can consider an aircraft flying at 200 km/h, with an effective swath width of 15 m and a payload of 1,000 litres treating a slick of 0.2 mm average thickness. This corresponds to an application rate of 100 litres/hectare for a dispersant to oil ratio of 1 : 20. For this application rate, the aircraft would discharge dispersant at the rate of 500 litres/min. and would treat 20 tons of oil per sortie.

When considering aerial spraying, logistics must receive careful attention, since actual spraying time is only a small fraction of the time per sortie (2.0 minutes in the earlier example), because of payload limitations, flying time to and from the base, refuelling and reloading time. The proper guidance and control of the spraying aircraft should be directed or controlled from a higher flying aircraft from which there is good downward visibility. Details of experience with aerial spraying can be found in a number of publications[5,6,9,10,11,12,13,14]*.

These operations must conform with local civil aviation authority regulations.

4.4 Application on the shore

Methods of shore clean-up are described in IMO's Manual on Oil Pollution, Section IV, 1980, Chapter 5 where, among other things, it is noted that: "Local environmental, social, economic and political considerations must be taken into account to reach a decision that is acceptable at the contaminated area."

Where application of dispersants on the shore is justified, the most appropriate method to use will depend on the type of shore, the type of oil and the degree of clean-up required. The shoreline may consist of rock, boulders, shingle, sand of varying grades, muds and combinations of these. Man-made structures such as sea walls and promenades, as well as boats at anchor, may also become badly oiled and treatment must be adapted to these varying surfaces.

Oil may arrive onshore in liquid form (immediately after the spill), as a viscous emulsion, or in the form of small pellets or larger tarry lumps. Gross pollution should be removed by mechanical collection or water-flushing, after which use of dispersants may be considered for secondary treatment. Marine biologists, ecologists and others should be consulted before dispersants are applied on shore, as shore biota are usually very sensitive.

Dispersants used on beaches are essentially the same as those used at sea, but some countries impose more severe toxicological requirements on dispersants used on shore. Both hydrocarbon solvent dispersants and concentrates diluted with seawater may be used for beach cleaning. As was the case for dispersal at sea, dispersants may not be effective on certain types of oil or mousse. The diluted concentrate may be used for spills of light and medium crude and light and medium fuel oils, but it is important to ensure that means are available for the controlled dilution of the concentrate during application. Where heavy oil or mousse residues remain to be treated, they should first be tested with the dispersant to ensure that

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* See references.

dispersal will occur. Only the hydrocarbon solvent type is likely to be effective for this treatment since the solvent is more able to penetrate oil, especially if a short period of soaking and/or mixing (e.g. with brushes) is possible. The following methods are generally used:

- spraying of oil with conventional dispersant by moving up the shore directly ahead of the rising tide to minimize possible penetration of oil into substrata and exposure of biota to toxic concentrations;
- applying conventional dispersant, followed by hosing with sea-water when seas are calm, or the tide is falling or tidal movements are small;
- applying concentrate by injection into a water lance. This method may result in the formation of recoalesced oil, which must be contained and skimmed or absorbed.

In some cases the latter two techniques are used in conjunction with a hot water wash but it must be remembered that this may be biologically damaging.

A rough indication of the rate of application of dispersants to oil on beaches is 2 litres of conventional dispersant per square metre of beach on a 5 mm thickness of oil. Spraying can be carried out with equipment ranging from individually carried kits ("backpacks") to specialized beach spraying vehicles and aircraft. If the beach is accessible, vehicles can be used; spraying in less accessible places may be carried out by persons with backpacks or aircraft. Care must be taken not to use oil spill chemicals too close to cooling water, desalination or other industrial sea-water intakes. Environmental considerations concerning the possible use of dispersants in the clean-up of oil pollution on shores are given in section 6.

4.5 The cost of dealing with oil spills

The manner in which an Administration deals with oil spills (and consequently the cost) is highly variable, depending on the type of oil spilled and local environmental, social and political considerations. The extent of pollution and the availability and cost of equipment, chemicals and local manpower are all important factors, as is the degree of restoration required. Although cost estimates for dispersants can be given (average in 1981 about US $2,200 per ton for concentrates and about US $1,200 per ton for conventional dispersants F.O.B. manufacturer), account must be taken of the costs of transporting dispersants to the country and subsequently to the site of the spill [(1, 10, 15)*]. Similarly, where equipment for mechanical clean-up is not available locally, costs of transporting equipment and providing skilled operators may be quite high. For manual clean-up on shorelines the cost will be dependent on local labour costs.

With respect to mechanical clean-up versus chemical dispersion, assuming both types of equipment are available, the costs will vary, as shown in a qualitative way in Figure 7, in relation to the thickness of the slick[(15)*]. Obviously each Administration must assess the influence of the foregoing factors on the cost of response to a major oil spill.

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* See references.

5 PHYSICAL EFFECTS

Consideration is now given to the physical effects to be expected when dispersants are used. It should be realized that in practice the cleaning process will never be 100% effective and that minimizing damage to the environment is the aim. Under favourable circumstances the likely physical effects resulting from the timely and correct application of dispersants are as follows:

.1 oil is removed from the surface of the water and slicks are not likely to reform. Oiling of birds resting on the water will be reduced, as will fouling of obstacles or coastline due to floating oil slicks. However, the concentration of oil in the water column is usually much higher at first than would be the case for non-dispersed oil and may cause tainting of fish, shellfish and crustacea for a period of time, which depends on the local circumstances of the spill;

.2 "chocolate mousse" (water in oil emulsions) is not formed;

.3 if dispersants are applied directly after a spillage, or during a continuing spill such as a blow-out in offshore operations, the immediate loss of light hydrocarbons to the atmosphere may be reduced, thereby decreasing explosion and fire hazards. In such cases the lower molecular weight hydrocarbons will dissolve from the oil droplets into the continuous water phase and dilute rapidly to very low levels (below 1 microgram/litre for benzene and toluene) and they will partly evaporate[(5)*];

.4 the droplets and the dissolved oil in the water column will move with tidal and residual currents and with the mixing circulations in the water where they will undergo physical, chemical and biological changes.

It should be borne in mind that, depending on the sea state, an untreated oil slick will also partially disperse in the water column but will not so rapidly dilute as in the case of chemical dispersion (see Figure 4). Reagglomeration and resurfacing will compete with redispersion for a considerable time. Sedimentation may sometimes occur.

6 ENVIRONMENTAL CONSIDERATIONS

6.1 In the open sea

The resources at stake are, among others, birds, especially the surface feeding species, fish spawning and nursery grounds, fishing areas, marine mammals and those organisms on which these resources depend. When a slick moves towards one of these resources, and natural dispersion and/or physical containment and collection would not be effective, dispersant application should be considered. Whilst

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* See references.

some mortality may occur to plankton whether or not dispersants are useo, scant knowledge exists on plankton ecology and no definite conclusions may be drawn. Dispersants should not be used if oil in the water column would cause significantly more damage to the resources at risk in the water column than the untreated slick would cause to resources on the surface. Natural dispersion will in any case take place but is more likely to occur in areas of high wave energy and in the tropics.

6.2 Inshore and onshore

A number of different habitats will be discussed with some general remarks as to possible application of oil spill chemicals. These remarks are generalized statements which require caution in their interpretation, as the ecosystems of the same type of habitat may vary considerably with their geographical location. Ecologists or marine biologists should be consulted as to the best way of handling the oil once it enters the inshore area.

With rare exceptions dispersant application onshore is followed by transference of oil and dispersant to the sea, either by tidal action or hosing with seawater. The impact of this on the near-shore ecosystems has to be balanced against the advantage that may be gained onshore. It should be realized that the biota onshore are not only exposed to a low concentration dispersion, but to direct contact with oil and dispersant together, or to dispersant alone, in places where spraying takes place and accidentally misses the oil patch. Therefore, toxicity tests with chemically dispersed oil would not be sufficient. Special tests should be carried out in which the organisms are in direct contact with the dispersant[16]*.

Various types of coastal environment and recommended clean-up methods are described in the IMO Manual on Oil Pollution, Section IV, Chapter 6 (IMO 1980). Generally, each country will have several shoreline types which vary in their sensitivity to undispersed oil, dispersed oil and dispersant alone. Guidance is given below on use of dispersants inshore and near-shore:

.1 habitats where dispersant spraying generally should not take place are the most sensitive of marine environments, including coral reefs, salt marshes, mangrove swamps, estuaries, tidal flats and lagoons with poor water exchange. When oil enters these environments, it may be best to restrict clean-up activities (including mechanical clean-up) to those methods which do not add to the damage caused by the oil. These areas should receive highest priority for protection before the oil arrives;

.2 habitats where it is generally considered not necessary to spray include: exposed rocky shores, exposed beaches, erosional scarps and eroding wave-cut platforms. Wave energy is high in these habitats and oil is removed naturally;

.3 habitats where spraying can take place on advice of experts and with caution include low energy sand, gravel and shingle beaches and

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* See references.

sheltered rocky shores. Because of the low wave energy characteristics of such locations oil may remain for some time. Dispersants may aid in removing oil on the approaching tide.

In deciding how best to deal with an oil spill, the possible fate and effects of chemically dispersed oil will have to be compared with those of the naturally dispersing slick. The effects can be short-term and/or long-term. They include physical smothering as well as toxic effects. The biological effects of an oil spill might be assessed by trained marine biologists, using acceptable methods. It should be stressed that knowledge about the pre-spill situation is desirable and should be considered in contingency planning.

6.3 Effect on human health

It is not known whether dispersants increase or decrease entry of oil into food species. It is known, however, that for a certain period of time there is an increased concentration of oil droplets suspended in the water column when dispersants are used. Therefore, it is often the practice to avoid the use of dispersants near shellfish and aquaculture areas and to close shell fishery areas as a precautionary measure, when dispersants have been used. Tainting of food organisms occurs at lower levels than that likely to present health problems and could prevent their consumption. However, it is not known if the absence of tainting can be used as a criterion for food safety[1, 17]*.

There is no epidemiological link between gastrointestinal cancers and the ingestion of oil-contaminated marine fish and shellfish[17]* and the general view is that oil-contaminated fish and shellfish present no more of a risk to the consumer than other articles of diet, or other exposures to various chemical substances[18]*.

7 THE TESTING OF DISPERSANTS

Dispersants used in oil spill response should have the approval of the responsible Administration. Many Governments have already developed standard test procedures to evaluate commercially available formulations and have developed lists of approved dispersants. It is recommended that individual Governments should develop their own approved list, based on test methods and species appropriate to their individual situations.

Although there are many different ways of testing the effectiveness, toxicity and biodegradation of dispersants, and there is no consensus between Governments on the best methods, what follows is an outline of the generally agreed steps which should be considered when a country wishes to decide whether a particular dispersant is suitable for its purposes. A general scheme of the steps is shown in Figure 8. The four basic steps, effectiveness test, toxicity test, biodegradation test and consideration of toxicity and biodegradation together, are described briefly below.

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* See references.

Before carrying out any tests the Administration should review the information available with respect to the effectiveness of dispersants at different temperatures and on different types of oil. If it appears as though the dispersant will be effective on oils which are likely to be spilled under local environmental conditions then further testing is likely to be justified.

An effectiveness test in which oil and the dispersant are mechanically mixed under standard conditions could be used. Subsequently, the resulting degree of dispersion can be assessed by either visual observation or by a more objective assessment of droplet size distribution. The rate of biological degradation of the dispersant and also, perhaps, mixtures of oil plus dispersants should be determined under conditions representative of the local environment. Similarly, toxicity tests with respect to marine oil spills would have to use marine organisms of importance locally. To see how such test methods can be adapted one can consider, for example, the adaptation described in references[19] *.

New approaches have been developed to toxicity testing which relate acute toxicity to concentrations of pollutants that can be expected under field conditions. Some results from this approach are given in the literature[20] *. They show toxicity expressed as an index relating time of exposure to concentrations.

Administrations should consider the combined results of toxicity and biodegradation tests. For example, use of dispersants which are harmless or of very low toxicity might be considered even if their rate of biodegradation is quite low.

Both IMO and UNEP are aware of a number of test methods which exist in various countries and these organizations may be contacted for further information on this matter.

8 MONITORING AND ASSESSMENT

Environmental management decisions are often made in a context in which the consequences of options cannot be fully predicted. This is because of inadequate scientific understanding of the functioning of the environment and of how physical/chemical processes work, as well as inadequate data for the phenomena and the area under study. To assist in better environmental management decisions in the future, dispersant application situations should be assessed on the basis of data collected by monitoring. (Monitoring here means the collection of systematic measurements or observations in a defined area for a predetermined purpose.) Thus, whenever dispersants are used, their effects should be monitored.

8.1 Monitoring to determine the fate of untreated and treated oil slicks

With respect to untreated oil, visual observation is the most practical method, preferably from the air, even though mistakes may be made (algae have been mistaken for oil slicks for example). Remote sensing with IR/UV line scanners

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* See references.

and with side looking airborne radar (SLAR) is being practised in certain countries[21, 22]*. In addition, mathematical models have been developed for predicting the movement of oil[23]*. Weathering, mousse formation and consequent viscosity increase can be followed qualitatively by observation, and quantitatively by sampling and measurement.

For treated oil, if part of the slick remains on the surface, this can be monitored as above. During dispersing operations such monitoring is necessary to guide the operation and verify its effectiveness. The dispersed oil should be monitored by sampling and analysis. Simple overall concentration can be determined (test kits such as the one described in the Appendix are now available from commercial suppliers for this purpose) or detailed component analysis can be undertaken, if necessary. Control sample analysis is necessary for good interpretation of the results.

8.2 Monitoring for possible ecological damage

Ideally, this requires good long-term baseline studies. In the absence of such studies, one can resort to comparison with ecologically similar areas that are not affected by oil or dispersed oil from the spillage one is dealing with. This is desirable because there may be considerable natural variation with time. The assessment of the situation right after the impact, compared with that of the baseline study indicates the short-term damage. Predictions can then be made about long-term effects, including indirect effects on neighbouring areas, on the basis of knowledge and experience; these, however, are no more than predictions. They should be followed up by other studies over a period of years, if it is necessary to establish whether or not there are long lasting effects and how important these are. Natural changes, such as occur in ecologically similar areas not affected by the oil, should be taken into account when interpreting the results, as they may mask the effect of the spilled oil.

8.3 Reporting the results of monitoring and assessment

It is very important that results be published and that they include accurate data on dispersant application and effectiveness, since experience and a better understanding of the processes and of the impact of dispersed or untreated oil on the environment will improve the quality of decision-making in the future.

8.4 Sensitivity mapping to assess the vulnerability of environmental compartments

Sensitivity mapping is the mapping of coastal areas to identify resources which may be affected by spilled oil[24]*. Such mapping is highly desirable, as part of the preparation of contingency plans, in order to establish:

– the best way of handling spilled oil, as it approaches, and after it has entered, a particular environment;

* See references.

- priorities in oil spill response when several compartments of the environment are threatened or affected, taking into account the available means that can be marshalled;

- where to carry out the baseline studies mentioned above.

Important elements, among others, are the characteristics of the oil on arrival, its persistence, seasonal variations in distribution and life cycle of important species, the duration of exposure, importance of possible impact on neighbouring compartments, possibility of replenishment of populations from neighbouring compartments. Other considerations may include recreational areas, amenity beaches, industrial installations etc. Thus co-ordination with tourist, industrial and environmental interests is necessary.

9 DECIDING ON HOW TO DEAL WITH AN OIL SLICK AT SEA

9.1 General

It is now appropriate to discuss the decision-making process in dealing with oil spills. The foregoing chapters should contribute to the determination of the possible actions from which one can choose, or which can be combined in larger oil spill situations, and the factors that influence the decisions. The decision-making should not start when the oil is on the sea: it should be a part of the pre-planning process and of the preparation of the contingency plan. It will be clear that for effective oil spill management, a proper organization in place, with well assigned tasks and responsibilities, is essential but not enough. Logistics have to be considered, availability, movement and application of equipment and materials have to be organized so that rapid action is possible. Contingency plans should foresee the need for rapidly obtaining sea state and meteorological data and oil characteristics (present day dispersants are not effective on waxy, heavy and weathered oil and on water-in-oil emulsions). The hydrography, bathymetry and the ecological characteristics of the sea and of the coastal area should be documented, and detailed information on the socio-economic importance of the various compartments of the area (such as fisheries, shellfish beds, aquaculture areas, amenity beaches) must be available in case trade-off decisions have to be made. Although it is true that each oil spill is unique, it is important to visualize beforehand a number of the most likely oil spill situations that may occur and how they may develop, in order to determine the best course of action.

9.2 Objectives

It is necessary to define the objectives of oil spill response, which will usually be national objectives. Apart from life and limb considerations the primary objective will be to mitigate the effects of oil pollution. Other objectives may encompass cost-benefit and socio-economic aspects. Different countries' objectives may require different decision-making processes or decision time and may result in different ways of combating a particular oil spill.

In principle there are three main ways of dealing with an oil spill at sea. Combinations of these may be necessary to deal with the different parts of a large spill:

9.2.1 *Mechanical removal*

Ideally, spilt oil should be physically removed from the marine environment. Considerable effort has been and is still being devoted to the development and improvement of floating booms to confine a spill and of means to recover oil from the surface of the water, which involves skimming the oil or absorbing it. The devices presently available are limited to use in rather low sea states.

9.2.2 *Monitor, but temporarily leave it alone*

Given sufficient time, nature will dispose of oil without help. The "monitor and leave it alone" decision can apply if there is no time to act, if there is a high expectation that the slick will continue to move out to sea and be dispersed naturally without ecological threat, if it will be dispersed naturally before reaching sensitive resources near or on shore, or if on balance this will result in less damage than taking other possible action. It must be recognized that leaving the oil alone for a period of time may make subsequent collection or dispersal more difficult. Continuous monitoring is vital, in case a change of circumstances demands a new decision. Neighbouring countries should be advised and consulted where appropriate.

9.2.3 *Chemical dispersion*

Where mechanical removal would not be effective and "leaving it alone" would cause impact or damage, chemical dispersion should be considered.

9.3 Dispersant usage decision procedure for offshore spills

A number of examples of decision procedures exist[1, 25]* and individual States may develop their own. One example of a procedure for logically deciding which option to take to mitigate an oil spill is indicated schematically in Figure 9. This example applies particularly to the situation in which the objectives are: to remove the oil where it can effectively be removed, and to minimize adverse impacts.

When dealing with larger spills, especially when they are getting closer to or are occurring near the coast, it may be necessary to use all available means in combination, if an effective response is to be achieved.

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* See references.

10 CONCLUSIONS

These guidelines have attempted to direct attention to those factors that should be considered when deciding to use or not to use a dispersant for oil spill response.

In most circumstances there may be benefits and/or disadvantages from the use of dispersants. Thus, the choice is not simply a matter of assessing whether or not dispersed oil is toxic, but whether its toxicity is such as to outweigh the damage that will result from the impact of untreated oil which has escaped attempts at physical removal from the sea surface.

In the right situation, dispersant application can be a valuable technique in clean-up response, but it must be used selectively to protect specific resources and not merely to hide a problem. In massive spill situations it can be used in combination with other methods, but it should be realized that in such cases even the use of all resources at once may not necessarily prevent shoreline pollution.

Faced with this reality, contingency plans must lay down priority areas for protection and indicate in advance what clean-up methods are preferred.

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TABLE 1[4]†

PROPERTIES OF CRUDES

Category	Country	Type	Specific gravity	Viscosity cS	Pour point
				at 38°C*	
1. High paraffin content	Egypt	El Morgan	0.874	13	13°C
	Gabon	Galba	0.872	28.5	30
	Libya	Es Sider	0.841	5.7	9
	Nigeria	Nigerian light	0.844	3.6	21
				at 10°C	
2. Average paraffin content	Qatar	Qatar	0.814	4.5	-18
	USSR	Romaskinskaya	0.859	20	- 4
	Algeria	Zarzaitine	0.816	9	-15
	Libya	Brega	0.824	6.3	-18
		Zueitina	0.808	5	-12
	Iran	Iranian light	0.854	20	- 4
		Iranian heavy	0.869	30	- 7
	Iraq	Northern Iraq	0.845	9	-15
	Abu Dhabi	Abu Dhabi	0.830	6.2	-18
		A.D. Zakum	0.825	5	-15
		A.D. Umm Shaif	0.840	6.5	-15
	Norway	Ekofisk	0.847	9	- 4
				at 10°C	
3. Low paraffin content	Algeria	Hassi Messaoud	0.802	3	-30
		Arzew	0.809	4.3	-30
	Nigeria	Nigerian medium	0.907	60	-30
		Nigerian export	0.872	13	-30
	Kuwait	Koweit	0.869	30	-18
	Saudi Arabia	Arabian light	0.851	12	-30
		Arabian medium	0.874	29	-15
		Arabian heavy	0.887	80	-30
	Iraq	Southern Iraq	0.847	13	-13
	Oman	Oman	0.861	25	- 8
	Venezuela	Tia Juana medium	0.900	70	-30
4. Very low paraffin content - very viscous				at 38°C*	
	Venezuela	Bachaquero	0.978	1280	- 7
		Tia Juana heavy	0.980	2980	- 3

* Because these data were recorded at 38°C, much higher than sea temperature of about 10°C, they must be used with caution.

† See references.

TABLE 2*[4†]

Practical dose rates for conventional and concentrate dispersants
(Ratios are volume of dispersant to volume of oil)

Dispersant \ Viscosity cS	<1000	1000-2000	>2000
Conventional	1:2-1:3	1:1-1:2	of very limited effectiveness
Concentrates Diluted (10% solution)	1:1-1:2	limited effectiveness	not recommended
Undiluted	1:10-1:20	1:10	not recommended

* Based on information provided by CEDRE.

TABLE 3[5]†

1978 USA EAST COAST API/EPA TEST RESULTS

Chemical dispersion of Murban Crude Oil.
Concentration of extractable organics by
IR Spectrophotometry in milligrams per litre

Time after the end of the treatment in minutes	DEPTH IN METRES				
	Surface	1	3	6	9
0	0.06	0.1		0.03	0.04
30	11.0	3.8	2.5	1.0	0.9
75	1.0	0.3	0.3	0.3	0.2
150	0.3	0.1	0.1	0.1	0.1

† See references.

TABLE 4[6]*

PROTECMAR TEST RESULTS

Chemical dispersion of light fuel oil
(concentration of fuel oil at different depths as measured after chromatographic separation of the dispersant in mg fuel oil per litre of sea-water)

Time after the end of the treatment	DEPTH IN METRES			
	Surface	1	2.5	7.5
15-30 mins	3.2	0.1	0.1	
	0.8	0.1	0.1	
	44.	0.2	0.1	
	170.	0.1	0.1	
	560.	0.2	0.1	
	1210.	0.4	0.1	
	0.6	0.2	0.1	
	0.7	0.1	0.2	
1 hour				0.1
				0.2
				0.1
3 hours	0.9	0.7	0.8	
	1.8	0.4	1.7	
	5.2	0.5	0.3	
	1.4	0.2	0.7	

* See references.

TABLE 5[7]*

Ekofisk crude oil — natural dispersion
Sea state 3-4 on the Beaufort Scale
Wind speed 12.7 knots

Oil concentrations beneath the main slick with time

Time after spill (hours)	Depth (metres)	Oil Concentration under edge of main slick (mg/l)	Oil concentration under centre of main slick (mg/l)
½	2	2.49	2.03
1½	2	2.22	0.85
3	2	1.15	0.79
4	2	0.94	3.95
8	2	1.88	1.63
8	5	0.17	0.19
8	10	0.10	0.07
8	15	0.08	0.07
11	5	0.02	0.04
11	10	0.02	0.02
11	15	0.02	0.03
21	2	0.59	1.49

TABLE 6[7]*

Kuwait crude oil — chemical dispersion
Sea state 2-3 on the Beaufort Scale
Wind speed 10 knots

Concentrations of Kuwait crude oil in water with time

Time after spill (minutes)	Concentration of Kuwait crude oil in mg/l in the upper metre of water		
	Run 1	Run 2	Run 3
0	34.4	24.2	0.85
1	-	15.8	-
2	47.8	-	8.7
2.5	-	12.2	-
5	-	9.4	-
7	17.8	-	3.5
10	-	5.2	-
15	-	-	1.7
18	1.9	-	-
25	-	4.2	-
40	0.8	-	1.35
50	-	1.9	-
80	-	-	1.5
100	2.2	0.8	-

* See references.

TABLE 7[8]*

Concentrations of dispersed oil in the water column resulting from chemical dispersion and natural dispersion at sea

Situation	Findings	Source
Experimental chemical dispersion of slick of Kuwait crude	Max. 48 mg/l in first two minutes reducing to 1-2 parts/ 10^6 after 100 minutes	Warren Spring Laboratory trials (Cormack, 1977)
Chemical dispersion of ½ ton slick of Ekofisk oil	18 mg/l in top 30 cm of water column	"
Natural dispersion of Light Arabian crude after oil spill in Tarut Bay, Saudi Arabia	50 mg/l initially present	Spooner, 1970
Heavy gas oil, physically dispersed	1.5 to 0.5 mg/l over the first 90 min.	Nichols, 1973

* See references

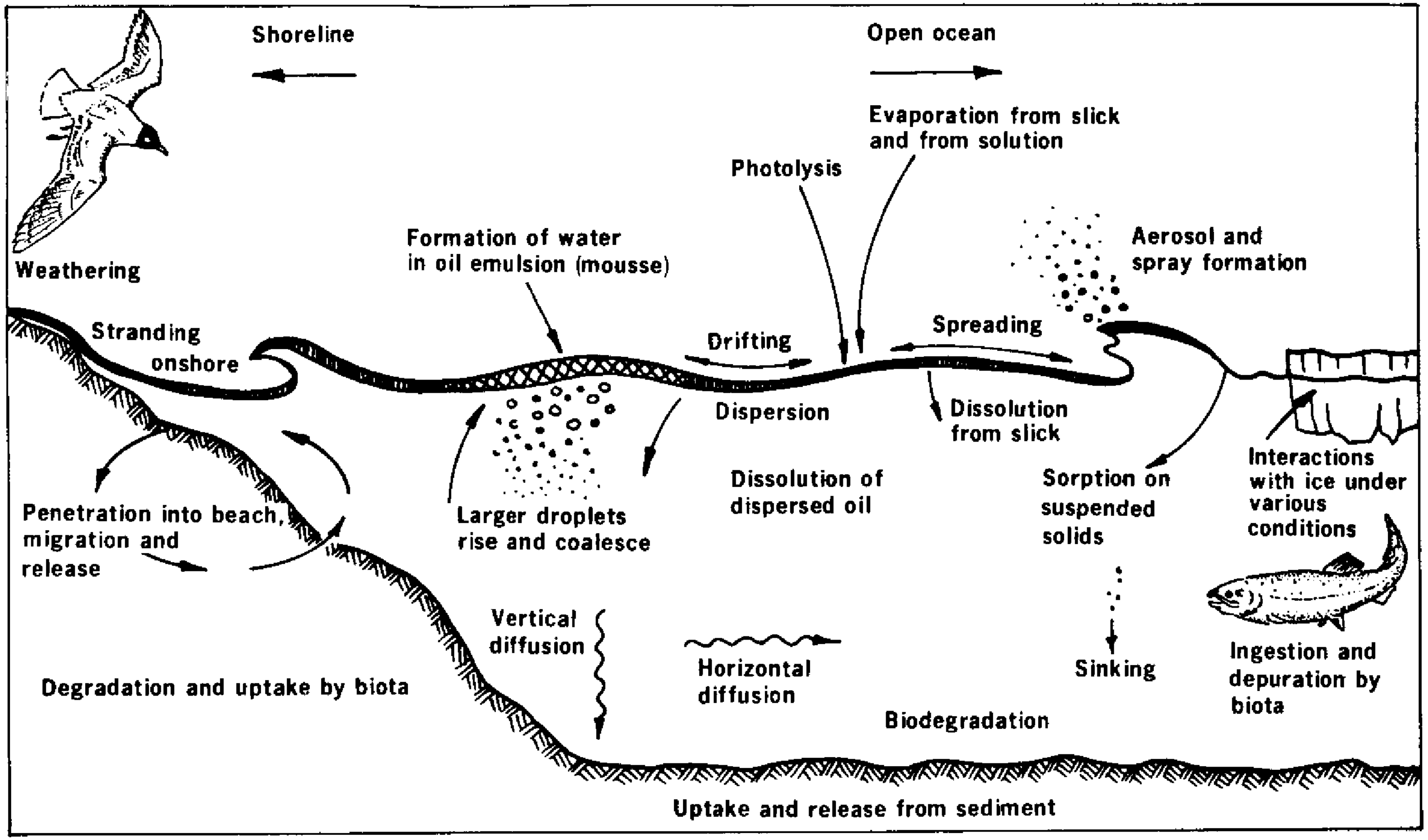


FIGURE 1
Processes taking place after an oil spill
Modified from Sprague T.B., Vandermuelen, J.H. and Wells, P.G., "Oil and Dispersants in Canadian Seas" (1981)

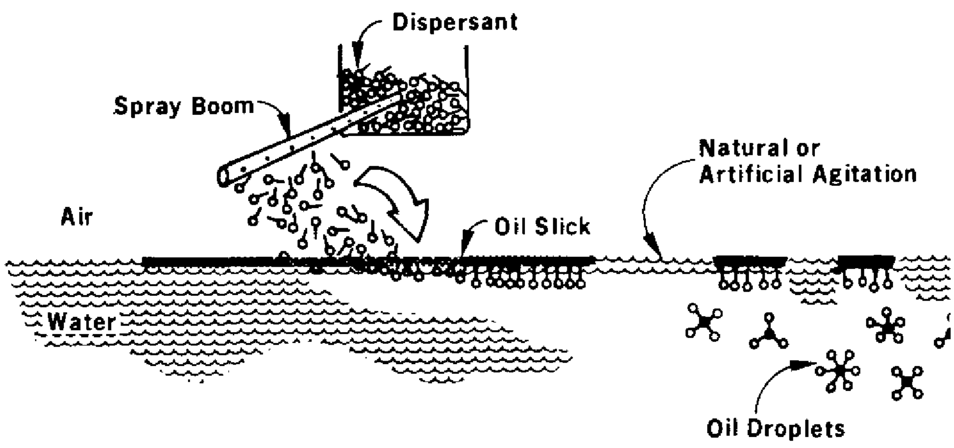


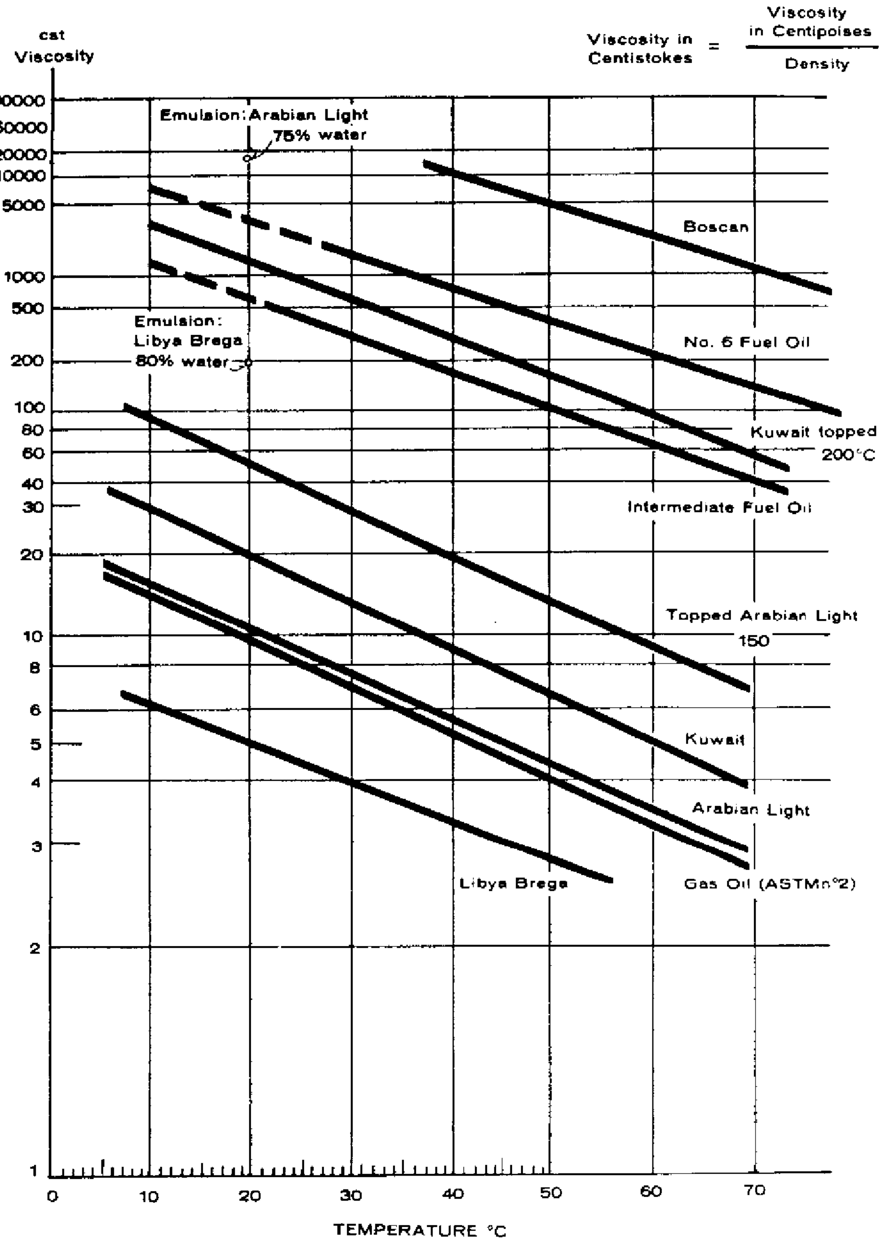
FIGURE 2

Simplified behaviour of surface-active agents

When used at sea, the molecules of dispersant align themselves at the oil/water surface, so that the hydrophilic "head" remains in the water and the hydrophobic (lipophilic) "tail" sticks into the oil. These "tails" enhance the spreading of oil by reducing the forces of attraction that hold it together. By agitation and/or diffusion, the oil breaks up into droplets which are prevented from re-coalescing by their "skin" of hydrophilic "heads".

FIGURE 3[4]*

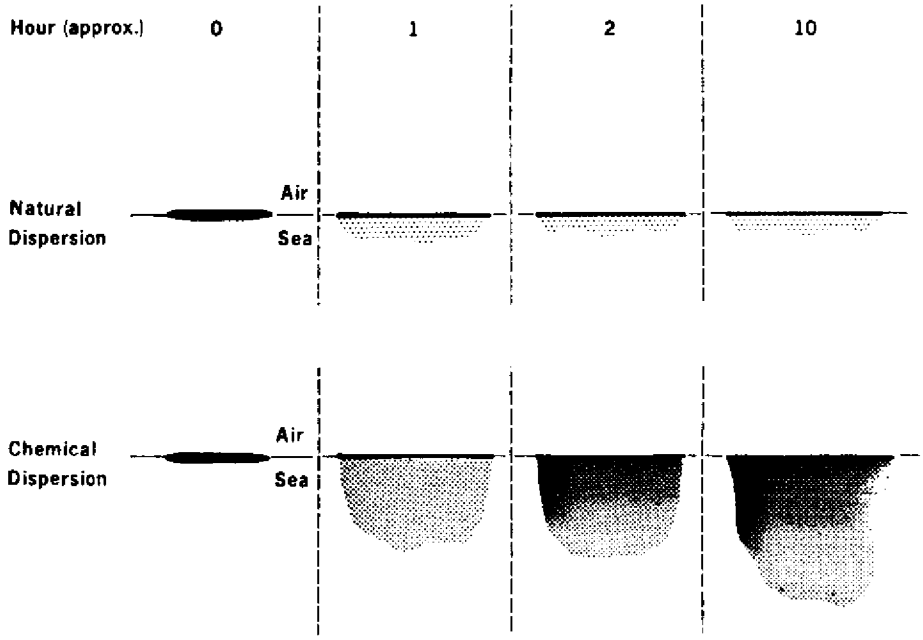
Viscosity variation of different oils as a function of temperature



* See references.

FIGURE 4

Natural vs Chemical Dispersion



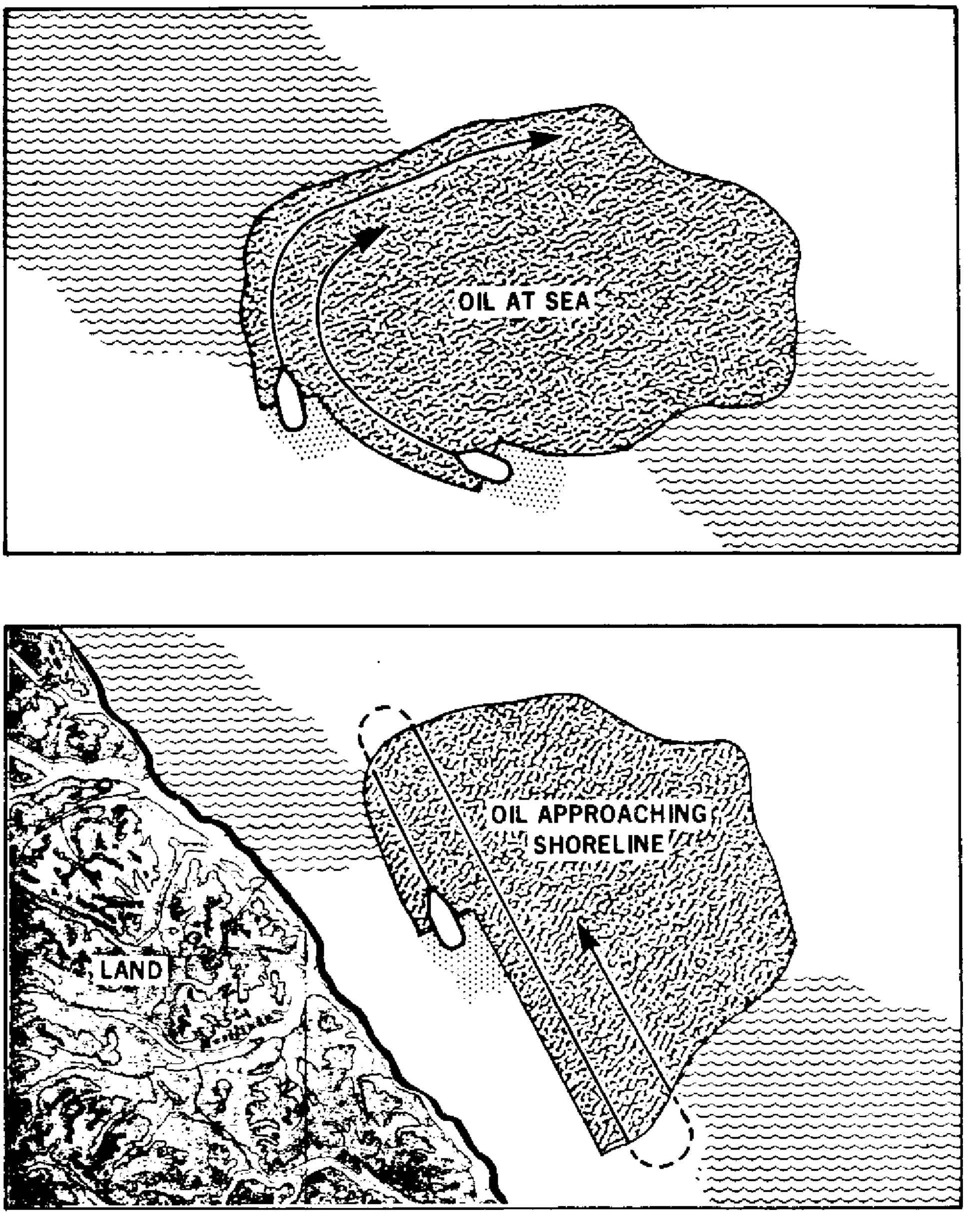


FIGURE 5

Surface Application

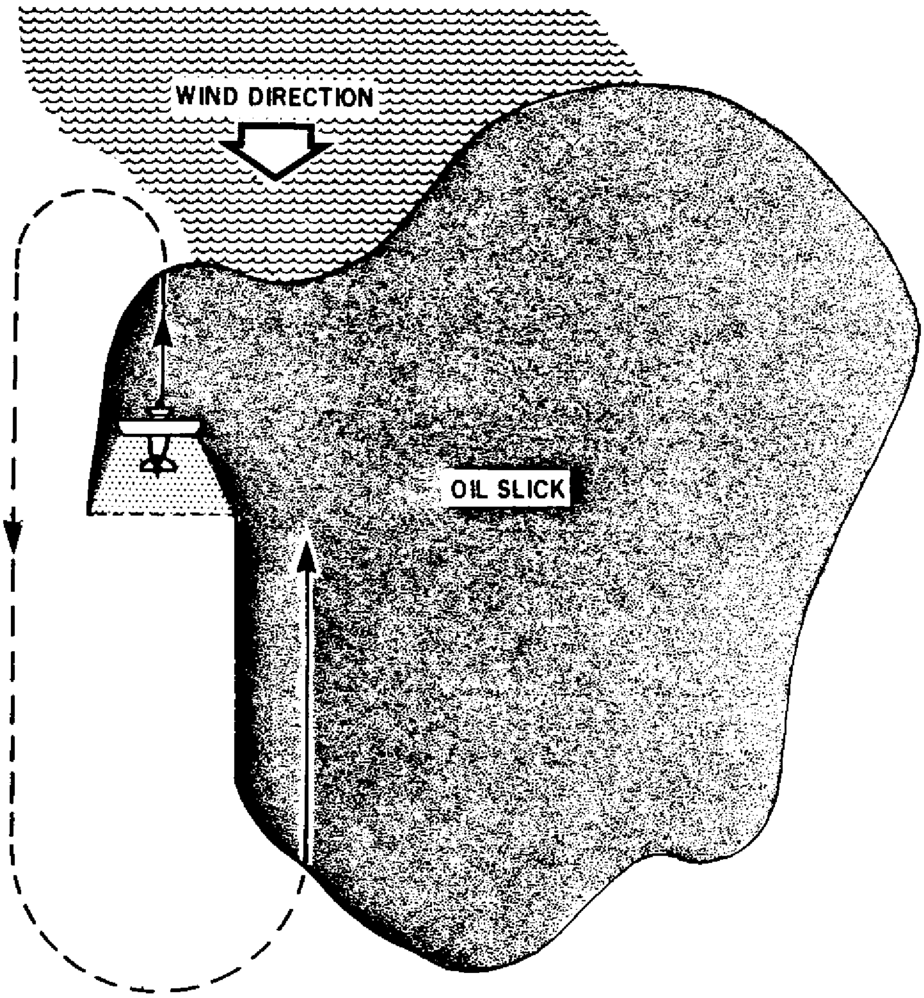
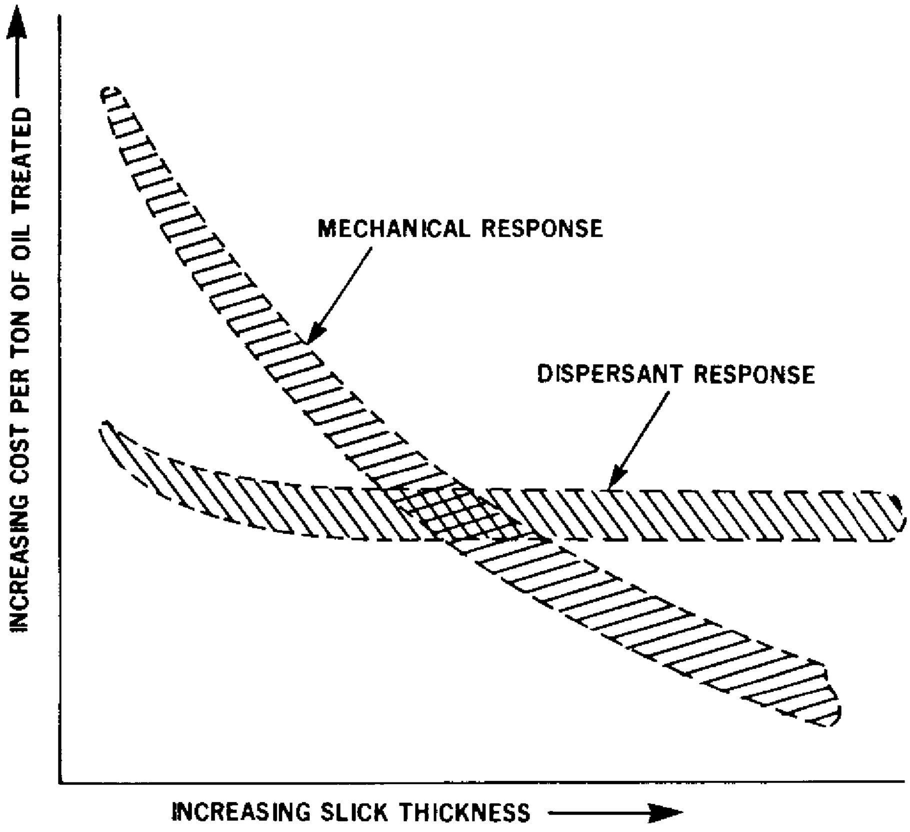


FIGURE 6

Aerial Application

FIGURE 7

Qualitative description of the relative variation of costs
for mechanical and dispersant response to spills
(assuming both types of equipment are available)



(Units are not given here because they vary from country to country)

FIGURE 8

Dispersant testing steps

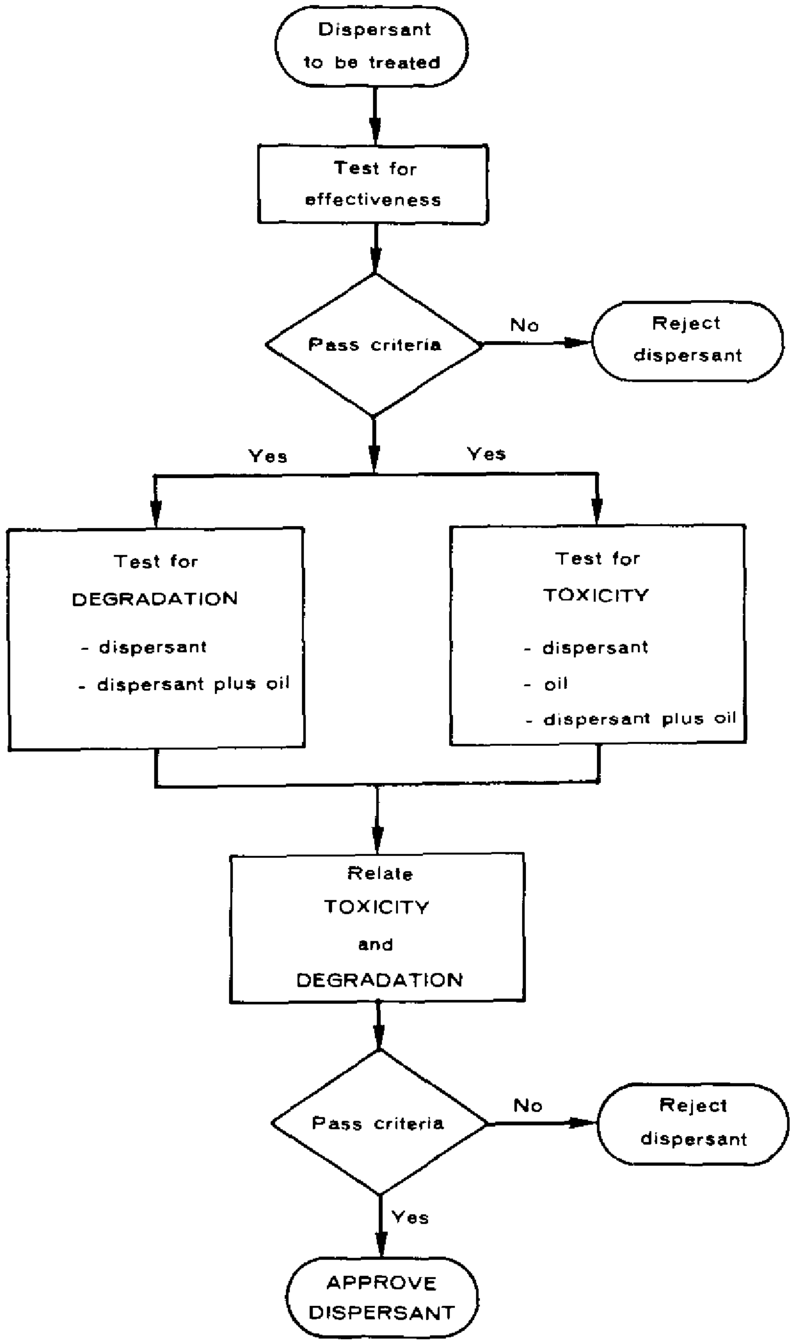
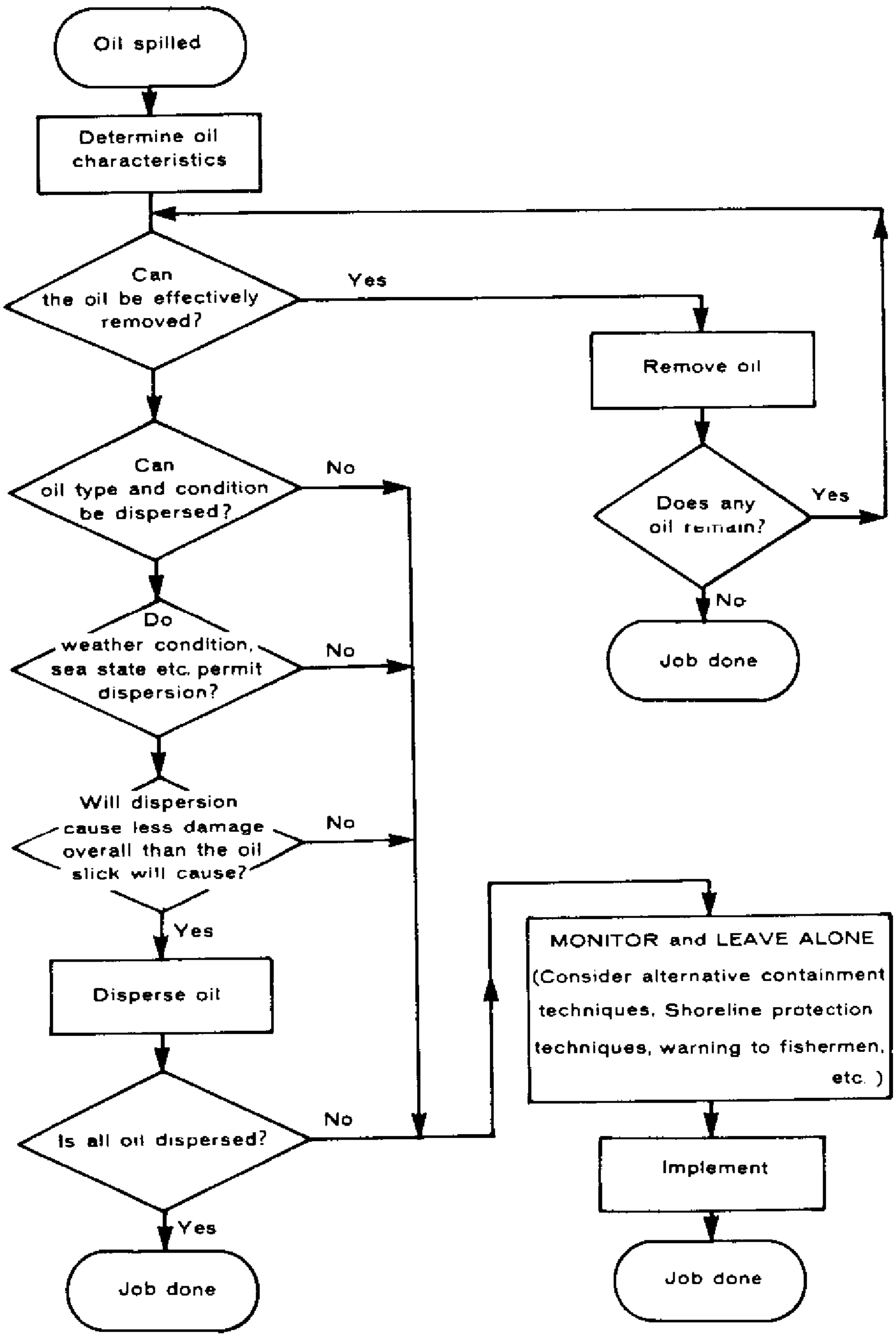


FIGURE 9

An example of a typical oil spill response decision procedure (with particular reference to oil spill dispersants)



APPENDIX

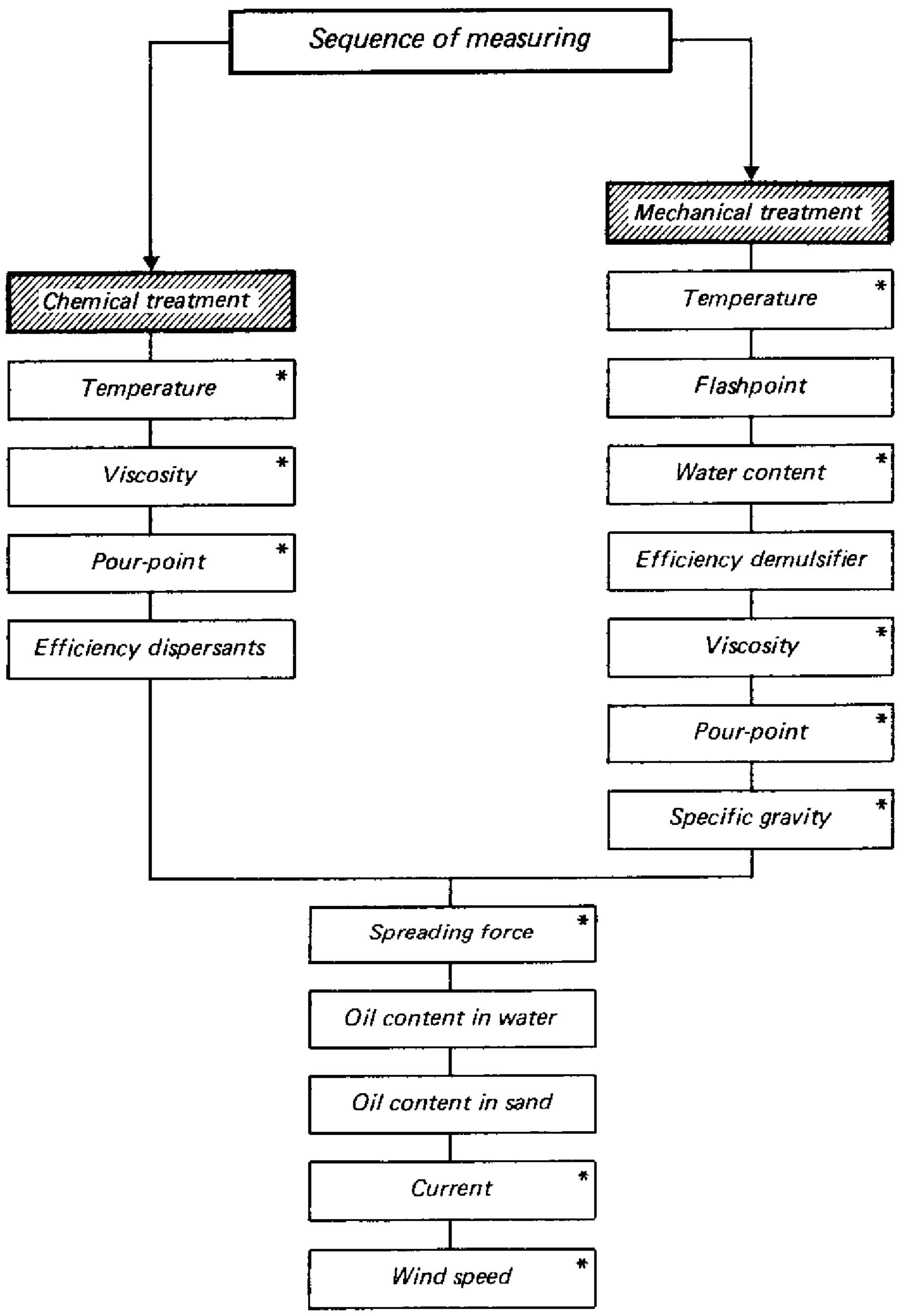
THE OIL SPILL TEST KIT

Introduction

Oils, when spilled on to the sea, change their composition with time due to several physical and chemical phenomena, such as evaporation, dissolution, emulsification and oxidation.

Experience demonstrates that the limit of usefulness of most oil pollution combating techniques is very often dependent on the properties of the spilled oil. An oil spill test kit has been developed by the Dutch Rijkswaterstaat and Labofina, Research Centre of the Petrofina Group, to measure the actual properties of the spilled oil on sea, coast or beach. The oil spill test kit is a portable unit, ready for use and easy to operate so that all data necessary for decision-making can be obtained on the spot. In this way, for instance, the On-Scene Co-ordinator can select rapidly and adequately the methods of treatment.

To select the methods of treatment, the following sequence of tests can be used (Fig. A-1).



* Also important for the fate of oil.

Chemical treatment

To decide whether or not to use the dispersant method it is necessary to know the parameters which might influence the effectiveness of dispersants.

One of the main parameters is the viscosity of the oil which depends on the temperature and the pour-point of the oil. Therefore the water and ambient temperature should be measured first. The measured velocity at ambient temperature should be extrapolated to the water temperature. The higher the viscosity the lower the efficiency will be. In a case where the pour-point is very close to the water temperature it is possible that during sunlight hours the temperature of the oil will increase and thus the efficiency of dispersants will increase.

Because there are different types of dispersants, it is useful to rank the most effective one which is available. With the dispersant efficiency test it is possible to compare, in a simple way, the efficiencies of different types of dispersant in a case where it has been decided to use dispersants.

Mechanical treatment

For mechanical treatment, the first step should be to measure the flashpoint which indicates the flammability of the oil. If the flashpoint is lower than 60°C the oil spill response equipment has to be operated under special safety regulations. A ship which has to store the removed oil, for instance, should comply with the tanker regulations. The flashpoint is determined with the test kit by measuring the initial boiling point.

In the case of an emulsified oil (water-in-oil) it is necessary to know the water content in the oil. If the water content is higher than 50%, demulsifiers could be applied to reduce the viscosity, which increases the pump capacity. Also, should the excess water be drained off, the need for storage capacity decreases. To decide which demulsifier agent should be used, it is desirable to rank the most effective one with the demulsifier efficiency test.

Viscosity can be measured before as well as after treatment with demulsifying agents. The pump (skimmer) capacity mainly depends on the viscosity.

The specific gravity measurement is a simple method to check the water content in the oil in a case where demulsifier agents have been used. The specific gravity is also important for the phase separation and buoyancy characteristics of the oil.

Fate of oil

Most of the previous parameters are also important for the fate of oil to determine the mass balance, the spreading and the transport of an oil spill.

The following data could be used as input data in an oil spill model: temperature, specific gravity, water content, viscosity, pour-point, spreading force, current and wind speed (the latter is not included in the test kit).

Additional data

Oil in water measurement could be useful to determine separation efficiency by measuring the oil content in a water effluent. Also dispersed oil concentration (more than 10 ppm) could be measured by this method.

The determination of oil content in sand can be useful in beach cleaning.

Current measurement is required for proper use of oil spill response equipment such as booms and sweeping systems, whose effectiveness is limited by a maximum current.

The oil spill test kit

The standard oil spill test kit contains equipment for the determination of the following:

- the temperature;
- the specific gravity;
- the water content;
- the viscosity;
- the flashpoint (initial boiling point);
- the pour-point;
- the spreading force;
- the efficiency of a demulsifier agent;
- the efficiency of a dispersant;
- the oil content in water; and
- the oil content in sand.

The analytical methods proposed can be carried out by everyone, after some practice, can be applied all over the world, and give acceptable results as far as accuracy is concerned, for the purpose of combating oil spillages.

The test kit is available at the following addresses:

Fina Nederland B.V. Dept. P.S.D.,
P.O. Box 294,
The Hague,
Netherlands.
Telephone: 070-694331.

or

Labofina S.A. Dept. "detergents",
Chaussée de Vilvorde 98,
B 1120 Brussels,
Belgium.
Telephone: 02-2339850.

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