TECHNICAL INFORMATION PAPER

FATE OF MARINE OIL SPILLS

Introduction

When oil is spilled into the sea it undergoes a number of physical and chemical changes, some of which lead to its removal from the sea surface, whilst others cause it to persist. Although spilled oil is eventually assimilated by the marine environment, the time involved depends upon factors such as the amount of oil spilled, its initial physical and chemical characteristics, the prevailing climatic and sea conditions and whether the oil remains at sea or is washed ashore.

An understanding of the processes involved and how they interact to alter the nature, composition and behaviour of oil with time is fundamental to all aspects of oil spill response. It may, for example, be possible to predict with confidence that oil will not reach vulnerable resources due to natural dissipation, rendering a clean-up response unnecessary. When an active response is required, the type of oil and its probable behaviour and fate will determine which response options are likely to be most effective and should therefore be selected.

This paper describes the combined effects of the various processes acting on spilled oil and the implications for clean-up response.

Properties of Oil

Crude oils of different origin vary widely in their physical and chemical properties, whereas many refined products tend to have well-defined properties irrespective of the crude oil from which they are derived. Residual products such as intermediate and heavy fuel oils, which contain varying proportions of non-refined components blended with lighter refined components also vary considerably in their properties.

The main physical properties which affect the behaviour and the persistence of an oil spilled at sea are specific gravity, distillation characteristics, viscosity and pour point. All are dependent on chemical composition (e.g. the amount of asphaltenes, resins and waxes which the oil contains).

Specific gravity or relative density of an oil is its density in relation to pure water. Most oils have a specific gravity below 1 and are lighter than sea water which has a specific gravity of about 1.025. The American Petroleum Institute gravity scale °API is commonly used to describe the specific gravity of crude oils and petroleum products, and is calculated as follows:

$$°API = \frac{141.5}{\textit{specific gravity}} - 131.5$$

In addition to determining whether or not the oil will float, the specific gravity can also give a general indication of other properties of the oil. For example, oils with a low specific gravity (high °API) tend to contain a high proportion of volatile components and to be of low viscosity.

Distillation characteristics of an oil describe its volatility. As the temperature of an oil is raised, different components reach their boiling point one after another and evaporate, i.e. are distilled. The distillation characteristics are expressed as the proportions of the parent oil which distil within given temperature ranges. Some oils contain bituminous, waxy or asphaltenic residues which do not readily distil, even at high temperatures. These are likely to persist for extended periods in the environment.

Viscosity of an oil is its resistance to flow. High viscosity oils do not flow as easily as those with lower viscosity. All oils become more viscous (i.e. flow less readily) as their temperature falls, some more than others depending on their composition. Since sea temperatures are often lower than cargo or bunker temperatures on board a vessel, viscosity-dependent clean-up operations such as skimming and pumping generally become more difficult as the spilled oil cools. The temperature-viscosity relationships for three crude oils are shown in Table 1 and Figure 1. In this paper, units of kinematic viscosity, expressed as centistokes (cSt) are used.

Pour point is the temperature below which an oil will not flow. The pour point is a function of the wax and asphaltene content of the oil. As an oil cools, it will reach a temperature, the so-called 'cloud point', at which the wax components begin to form crystalline structures. This increasingly hinders flow of the oil until it eventually changes from liquid to semi-solid at the pour point. An example of this behaviour is shown for Bonny Light in Figure 1 and Table 1. For this oil, as it cools from a typical cargo temperature of >30°C, its viscosity rises slowly, but below 20°C it begins to thicken exponentially until at around 12°C the viscosity has increased so much that it will no longer flow. For the other two oils shown, the pour points and cloud points are below 0°C.

Weathering Processes

The physical and chemical changes that spilled oil undergoes are collectively known as 'weathering'. Although the individual processes causing these changes may act simultaneously, their relative importance varies with time. Together they affect the behaviour of the oil and determine its ultimate fate. These processes are illustrated in Figure 2 for a spill of a typical medium crude oil under moderate sea conditions.

Spreading

As soon as oil is spilled, it starts to spread over the sea surface. The speed at which this takes place depends to a great extent on the viscosity of the oil and the volume spilled. Fluid, low viscosity oils spread more quickly than those with a high viscosity. Liquid oils initially spread as a coherent slick but quickly begin to break up. Solid or highly viscous oils fragment rather than spreading to thin layers. At temperatures below their pour point, oils rapidly solidify and hardly spread at all and may remain many centimetres thick. Winds, wave action and water turbulence tend to cause oil to form narrow bands or 'windrows' parallel to the wind direction. At this stage the properties of the oil become less important in determining slick movement.

The rate at which oil spreads or fragments is also affected by tidal streams and currents - the stronger the combined forces, the faster the process. There are many examples of spills spreading over several square kilometres in just a few hours and over several hundreds of square kilometres within a few days, thus seriously limiting the possibility of effective clean-up at sea. It should also be appreciated that, except in the case of small spills of low viscosity oils, spreading is not uniform and large variations of oil thickness from less than a micrometre to several millimetres can occur.

Table 1: Physical characteristics of three typical crude oils.

	Arabian Super Light	Bonny Light	Merey
Origin	Saudi Arabia	Nigeria	Venezuela
°API	48.5	34.6	15.7
SG at 15°C	0.79	0.85	0.96
Wax content	12%	13%	10%
Asphaltenes	7%	No data	9%
Pour point	-29°C	12°C	-18°C

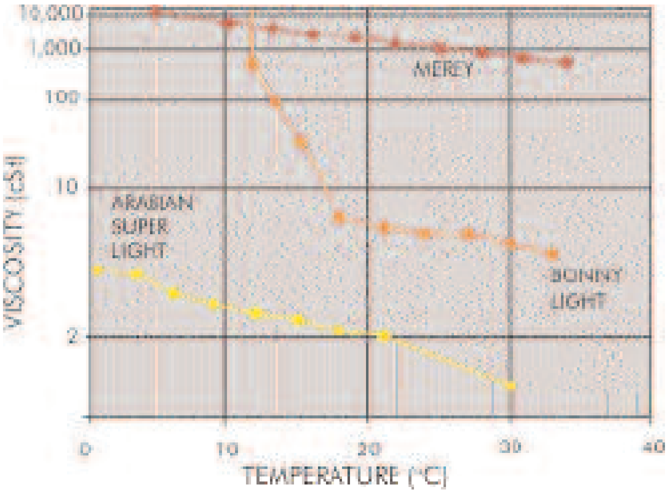


Figure 1: Viscosity/temperature relationship for three crude oils. Viscosity is plotted on a double log scale.

Evaporation

The more volatile components of an oil will evaporate to the atmosphere. The rate of evaporation will depend on ambient temperatures and wind speed. In general, those oil components with a boiling point below 200°C will evaporate within a period of 24 hours in temperate conditions. The greater the proportion of components with low boiling points, the greater the degree of evaporation. The initial spreading rate of the oil affects evaporation since the larger the surface

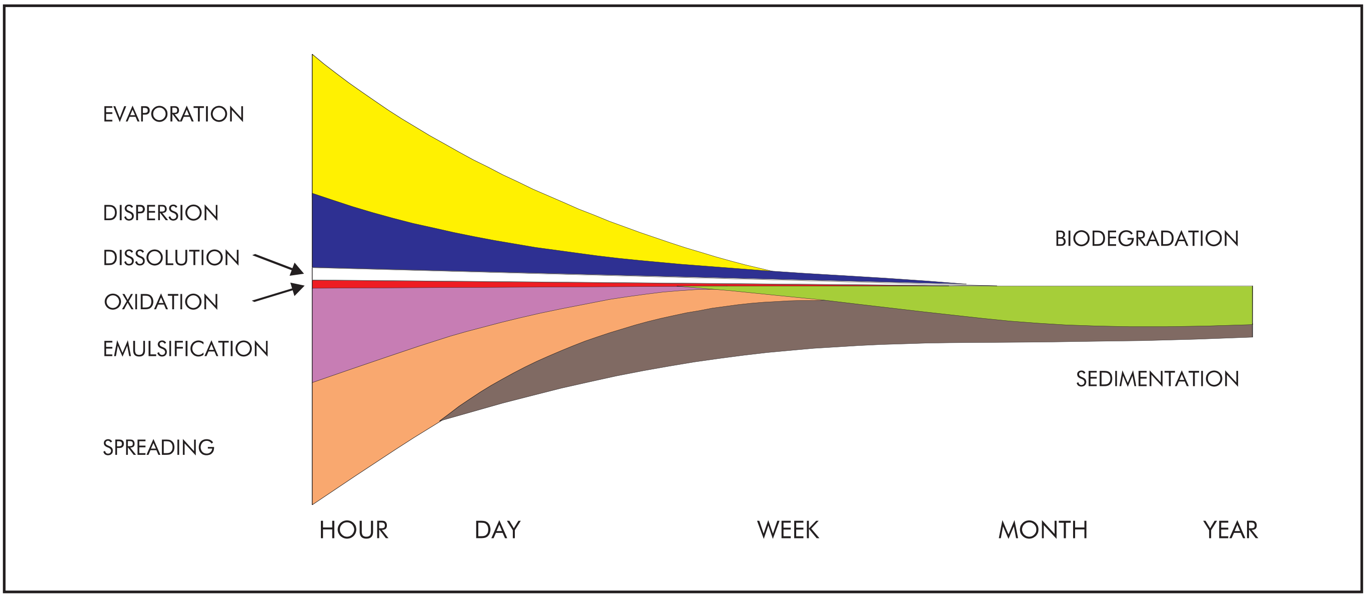


Figure 2: A schematic representation of the fate of a crude oil spill showing changes in the relative importance of weathering processes with time - the width of each band indicates the importance of the process.

area, the faster light components will evaporate. Rough seas, high wind speeds and warm temperatures will also increase the rate of evaporation. Any residue of oil remaining after evaporation will have an increased density and viscosity, which affects subsequent weathering processes and the effectiveness of clean-up techniques.

Spills of refined products, such as kerosene and gasoline, may evaporate completely within a few hours and light crudes can lose up to 40% of their volume during the first day. In contrast, heavy fuel oils undergo little, if any, evaporation. When extremely volatile oils are spilled in confined areas, there may be a risk of fire and explosion or human health hazards.

Dispersion

Waves and turbulence at the sea surface can cause all or part of a slick to break up into droplets of varying sizes which become mixed into the upper layers of the water column. While some of the smaller droplets may remain in suspension, the larger ones rise back to the surface, where they either coalesce with other droplets to reform a slick or spread out in a very thin film, often referred to as 'sheen'. Droplets which are small enough are kept in suspension by the turbulent motion of the sea, which mixes the oil into ever greater volumes of sea water, so reducing its concentration. The increased surface area presented by dispersed oil can promote processes such as biodegradation, dissolution and sedimentation.

The rate of dispersion is largely dependent upon the nature of the oil and the sea state, proceeding most rapidly with low viscosity oils in the presence of breaking waves.

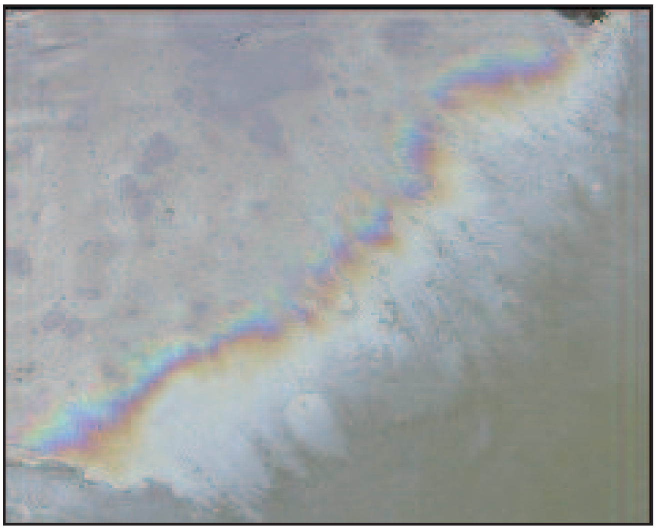
Oils that remain fluid and spread unhindered by other weathering processes may disperse completely in moderate sea conditions within a few days. The application of dispersant chemicals can speed up this natural process. Conversely, viscous oils and oils at temperatures below their pour point, or oils that form stable water-in-oil emulsions, tend to form thick lenses on the water surface that show little tendency to disperse, even with the addition of dispersant chemicals. Such oils can persist for weeks and on reaching the shore may eventually form hard asphalt pavements if not removed.

Dissolution

The rate and extent to which an oil dissolves depends upon its composition, spreading, water temperature, turbulence and degree of dispersion. The heavy components of crude oil are virtually insoluble in sea water whereas lighter compounds, particularly aromatic hydrocarbons such as benzene and toluene, are slightly soluble. However, these compounds are also the most volatile and are lost very rapidly by evaporation, typically 10 to 1,000 times faster than by dissolution. Concentrations of dissolved hydrocarbons in sea water thus rarely exceed 1 ppm and dissolution does not make a significant contribution to the removal of oil from the sea surface.

Emulsification

In moderate to rough seas, most oils will take up water droplets and form water-in-oil emulsions under the turbulent action of waves on the sea surface. This can increase the volume of pollutant by a factor of up to four times. Emulsions form most readily in oils which have a combined Nickel/Vanadium concentration greater than 15 ppm or an asphaltene content in excess of 0.5% when they are fresh. The presence of these compounds and the sea state determine the rate at which emulsions form. Oils which readily emulsify do so rapidly in sea states greater than Beaufort Force 3 (wind speed 7 - 10 knots). Very viscous oils tend to take up water more slowly than more liquid oils. As the emulsion develops, the movement of the oil in the waves causes the droplets of water which have been taken up in the oil to become smaller



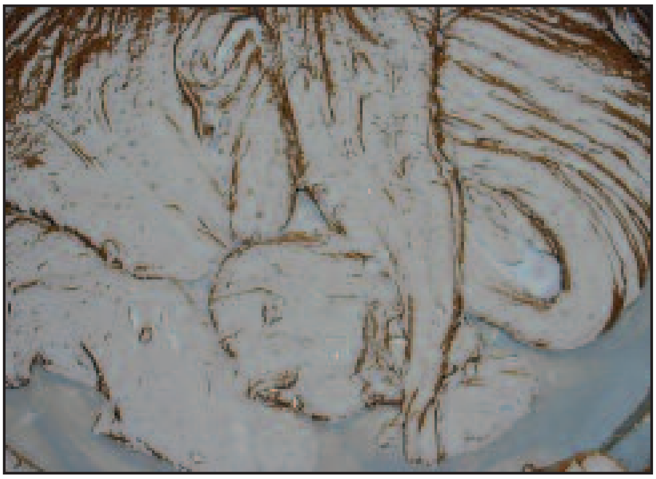
When medium and light oils spread unhindered, the oil will eventually form very thin films. These appear as iridescent (rainbow) and silver sheens, which dissipate rapidly.

When oil becomes mixed with sediment, the density can become sufficiently high for it to sink if it is washed off the beach. In this photo, large patches of sunken oil are visible in shallow water close to the beach.

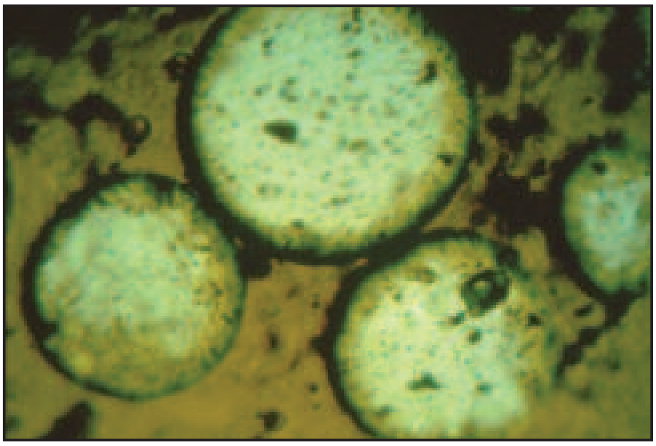
Oils spilled into the sea at temperatures below their pour point form solid fragments. This photo shows Nile Blend crude, pour point +33° C, in sea water of 28° C. Such oils are highly persistent and have the potential to travel great distances.

and smaller, making the emulsion progressively more viscous and stable. As the amount of water absorbed increases, the density of the emulsion approaches that of sea water. Stable emulsions may contain as much as 70% - 80% water and are often semi-solid and have a strong red/brown, orange or yellow colour. They are highly persistent and may remain emulsified indefinitely. Less stable emulsions may separate out into oil and water if heated by sunlight under calm conditions or when stranded on shorelines.

The formation of water-in-oil emulsion reduces the rate of other weathering processes and is the main reason for the persistence of light and medium crude oils on the sea surface.



The dissipation of many oils is slowed by the formation of highly viscous water-in-oil emulsions.



A greatly magnified image (x1,000) of a water-in-oil emulsion showing individual water droplets surrounded by oil.

Oxidation

Hydrocarbons can react with oxygen, which may either lead to the formation of soluble products or persistent tars. Oxidation is promoted by sunlight and although it occurs throughout the existence of a slick, its overall effect on dissipation is minor compared to that of other weathering processes. Even under intense sunlight, thin oil films break down only slowly, and usually less than 0.1% per day. Thick layers of very viscous oils or water-in-oil emulsions tend to oxidise to persistent residues rather than degrade, as higher molecular weight compounds are formed that create a protective surface layer. This can be seen in tar balls which sometimes strand on shorelines and which usually consist of a solid outer crust of oxidised oil and sediment particles, surrounding a softer, less weathered interior.

Water-in-oil emulsions often accumulate on shores in thick layers.

Sediment-oil interactions

A few heavier residual oils have specific gravities greater than sea water (more than 1.025), causing them to sink once spilled. Most crude and fuel oils have sufficiently low specific gravities to remain afloat unless they interact with and attach to more dense sediment or organic particles. Dispersed oil droplets can interact with sediment particles suspended in the water column, thus becoming heavier and sinking. However, adhesion to heavier particles most often takes place when oils strand or become buried on beaches. On exposed, high energy beaches, large amounts of sediment can be incorporated and the oil can form dense tar mats. Seasonal cycles of sediment build-up and erosion may cause oil layers to be successively buried and uncovered. Even on less exposed sandy beaches, stranded oil can become covered by wind-blown sand. Once oil has been mixed with beach sediment, it will sink if washed back out to sea by storms, tides or currents. On sheltered shorelines, where wave action and currents are weak, muddy sediments and marshes are common. If oil becomes incorporated into such fine grained sediments, it is likely to remain there for a considerable time.

Shallow coastal areas and the waters of river mouths and estuaries are often laden with suspended solids that can bind with dispersed oil droplets, thereby providing favourable conditions for sedimentation of oily particles to the sea bed. Like some heavy crudes, most heavy fuel oils and water-in-oil emulsions have specific gravities close to that of sea water, and even minimal interaction with sediment can be sufficient to cause sinking. Fresh water from rivers also lowers the salinity of sea water, and therefore its specific gravity, and can encourage neutrally buoyant droplets to sink. Oil may also be ingested by planktonic organisms and incorporated into faecal pellets, subsequently falling to the seabed.

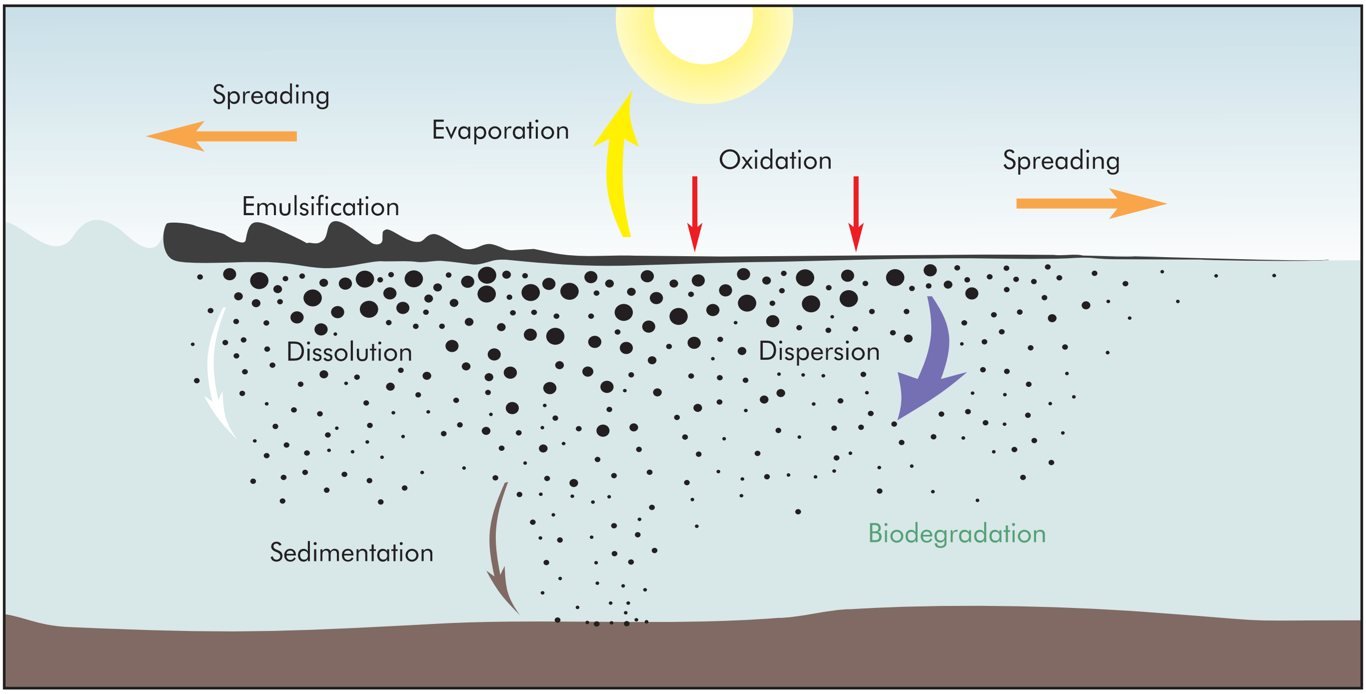


Figure 3: Processes acting on spilled oil.

When oil droplets in the water column adhere to very fine sediment particles or particles of organic matter they can form flocculates, which may be widely dispersed by currents or turbulence. Small quantities of oil in sea bed sediments or on beaches may also become attached to such particles and become suspended in the water as flocculates as a result of storms, turbulence or tidal rise and fall. This process, sometimes referred to as clay-oil flocculation, can result over a period of time in the removal of oil from beaches.

Biodegradation

Sea water contains a range of marine micro-organisms capable of metabolising oil compounds. They include bacteria, moulds, yeasts, fungi, unicellular algae and protozoa which can utilise oil as a source of carbon and energy. Such organisms are distributed widely throughout the world's oceans although they tend to be more abundant in chronically polluted coastal waters, such as those with regular vessel traffic or which receive industrial discharges and untreated sewage.

The main factors affecting the rate and extent of biodegradation are the characteristics of the oil, the availability of oxygen and nutrients (principally compounds of nitrogen and phosphorus) and temperature. Each type of micro-organism involved in the process tends to degrade a specific group of hydrocarbons and thus a wide range of micro-organisms, acting together or in succession, are needed for degradation to occur. As degradation proceeds, a complex community of micro-organisms develops. Although the necessary micro-organisms are present in relatively small numbers in the open sea, they multiply rapidly when oil is available and degradation will continue until the process is limited by nutrient or oxygen deficiency. Whilst micro-organisms are capable of degrading most of the wide variety of compounds in crude oil, some large and complex molecules are resistant to attack.

Because the micro-organisms live in the water, from which they obtain oxygen and essential nutrients, biodegradation can only take place at an oil/water interface. At sea, the creation of oil droplets, either through natural or chemical dispersion, increases the interfacial area available for biological activity and so may enhance degradation.

In contrast, oil stranded in thick layers on shorelines or above the high water mark will have a limited surface area and will be subject to drier conditions which will render degradation extremely slow, resulting in the oil persisting for many years. Similarly, once oils become incorporated into sediments on the shoreline or sea bed, degradation is very much reduced or may stop due to a lack of oxygen and/or nutrients.

The variety of factors influencing biodegradation makes it difficult to predict the rate at which oil may be removed. Although biodegradation is clearly not able to remove bulk oil accumulations, it is one of the main mechanisms by which dispersed oil or the final traces of a spill on shorelines are eventually removed.

Combined Processes

The processes described previously are summarised in Figure 3. All come into play as soon as oil is spilled, although their relative importance varies with time, as shown in Figure 2. Spreading, evaporation, dispersion, emulsification and dissolution are most important during the early stages of a spill whilst oxidation, sedimentation and biodegradation are longer term processes which determine the ultimate fate of oil. An understanding of the way in which weathering processes interact is important when attempting to forecast the changing characteristics of an oil during the lifetime of a slick at sea.

It should be appreciated that the movement of an oil slick on the sea surface is due to winds and surface currents, and may be influenced by the combined weathering processes. The actual mechanisms governing spill movement are complex, but experience shows that oil drift can be predicted from a simple vector calculation of wind and surface current direction, based on about 3% of the wind speed and 100% of the current velocity. Reliable prediction of slick movement is clearly dependent upon the availability of good wind and current data. Accurate current data are sometimes difficult to obtain. For some areas it is presented on charts or tidal stream atlases but often only general information is available. In shallow waters near the coast or among islands, currents may be complex and are often poorly understood, rendering accurate prediction of slick movement particularly difficult.

Table 2: Classification of oils according to their specific gravity. The colours of each group relate to Table 1 and Figures 4 and 5.

Group 1

Specific Gravity **< 0.8** (°API **> 45**)

B Viscosity cSt @ 15°C: **0.5 - 2.0**
C % boiling below 200°C: **50 - 100%**
D % boiling above 370°C: **0%**

	B	C	D
Gasolene	0.5	100	0
Naptha	0.5	100	0
Kerosene	2.0	50	0

Group 2

Specific Gravity **0.8 – 0.85** (°API **35 - 45**)

A Pour Point °C
B Viscosity cSt @ 15°C: **4 - Solid, Average 8**
C % boiling below 200 °C: **19 - 48% Average 33%**
D % boiling above 370 °C: **12 - 50% Average 31%**

High pour point >5° C

	A	B	C	D
Amna	18	S	25	30
Argyll	9	11	29	39
Arjuna	27	S	37	15
Auk	9	9	33	35
Bach Ho	35	S	21	47
Bass Straight	15	S	40	20
Beatrice	12	32	25	35
Bintulu Neat	17	S	24	34
Bunyu	18	S	29	12
Cormorant	12	13	32	38
Dunlin	6	11	29	36
Es Sider	6	11	28	42
Escravos	10	9	35	15
Gippsland Mix	15	S	40	20
Lalang	33	S	19	49
Lucina	16	S	26	41
Nigerian Light	9	S	35	27
Qua Iboe	15	7	29	32
Rio Zulia	27	S	34	30
San Joachim	24	S	43	20
Santa Rosa	10	4	34	27
Sarir	24	S	24	39
Seria	18	S	37	15
Soyo	17	S	20	50
Thistle	9	9	35	38
Zuetina	9	9	35	30

Low pour point

	B	C	D
Abu Dhabi	7	36	31
Arabian Super Light	3	26	39
Berri	9	36	35
Beryl	9	35	34
Brass River	4	45	17
Brega	9	38	32
Brent Blend	6	30	38
Ekofisk	4	46	25
Kirkuk	1	35	36
Kole Marine	1	34	35
Lower Zakum		34	35
Marib Light		40	20
Montrose	7	36	31
Murban	7	32	34
Murchison	7	36	20
Olmeca		32	32
Oseberg	10	28	39
Palanca		30	35
Qatar Land	9	36	33
Sahara Blend	4	48	27
Sirtica	7	44	27
Gas Oil	5		

High pour point oils would only behave as Group 2 at ambient temperatures well above their pour points. At lower temperatures treat as Group 4 oils.

Group 3

Specific Gravity **0.85 – 0.95** (°API **17.5 - 35**)

A Pour point °C
B Viscosity cSt @ 15°C: **8 - Solid Average 275**
C % boiling below 200°C: **14 - 34% Average 22%**
D % boiling above 370°C: **28 - 50% Average 46%**

High Pour Point >5° C

	A	B	C	D
Bakr	7	1,500	14	60
Belayim	15	S	22	55
Bonny Light	12	25	30	30
Cabinda	17	S	18	56
Dai Hung	25	S	30	33
Djeno	6		16	61
Duri	18	S	5	75
Mandji	9	70	21	53
Morgan	7	30	25	47
Nile Blend	36	S	13	59
Soyo Blend	15	S	21	48
Suez Mix	10	30	24	49
Trinidad	14	S	23	28
Zaire	15	S	18	55

Low Pour Point

	B	C	D
Arabian Heavy	55	20	56
Arabian Light	14	24	45
Arabian Medium	25	22	51
Basrah Light		26	45
Bonny Medium		14	39
Buchan	14	31	39
Champion Export	18	15	28
Escravos		30	32
Flotta	11	34	26
Forcados	12	17	37
Forozan		24	49
Forties	8	32	36
Gullfaks	13	21	40
Hout	15	24	48
Iranian Heavy	25	24	48
Iranian Light		26	43
Khafji	80	21	55
Kuwait Export	30	23	52
Leona		14	56
Loreto		17	50
Maya	500	17	61
Miri Light		25	25
Nigerian Medium	40	14	40
Oman		23	45
Qatar Marine		29	39
Santa Maria	250	22	54
Siberian Light		24	52
Tia Juana Light	2,500	24	45
Upper Zakum		26	44
Medium Fuel Oil (IFO 180)	1,500-3,000		

High pour point oils would only behave as Group 3 at ambient temperatures well above their pour points. At lower temperatures treat as Group 4 oils.

Group 4

Specific Gravity **> 0.95** (°API **< 17.5**) **or** Pour Point **> 30°C**
A Pour point °C
B Viscosity cSt @ 15°C: **1500 - Solid**
C % boiling below 200°C: **3 - 24% Average 10%**
D % boiling above 370°C: **33 - 92% Average 65%**

	A	B	C	D
Bachequero	-20	5,000	10	60
Boscan	15	S	4	80
Bu Attifil	39	S	19	47
Cinta	43	S	10	54
Cyrus	-12	10,000	12	66
Daquing	36	S	12	66
Duri	14	S	5	74
Gamba	23	S	11	54
Handil	35	S	23	33
Heavy Lake Mix	-12	10,000	12	64
Jatibarang	43	S	14	65
Merey	-18	7,000	7	70
Minas	37	S	14	57
Panuco	2	S	3	76
Pilon	-4	S	2	92
Quiriqure	-29	1,500	3	88
Shengli	21	S	9	70
Taching	35	S	12	49
Tia Juana Pesado	-1	S	3	78
Wafra Eocene	-29	3,000	11	63
Widuri	46	S	7	70
Heavy Fuel Oil (IFO 380)		5,000-30,000		

Predictions of potential changes in oil characteristics with time allow an assessment to be made of the likely persistence of spilled oil and thereby the most appropriate response option. In this latter regard, a distinction is frequently made between non-persistent oils, which because of their volatile nature and low viscosity tend to disappear rapidly from the sea surface, and persistent oils, which dissipate more slowly and usually require a clean-up response. Examples of the former are gasoline, naphtha and kerosene, whereas most crude oils, intermediate and heavy fuel oils, and bitumen are classed as persistent [see footnote*]. However, this simple distinction fails to recognise the wide variation in the properties of different oil types. Better predictions of persistence can be made by using relatively simple empirical calculations based on oil type. For this purpose commonly transported oils can be roughly classified into four main groups according to their specific gravity (Table 2).

As a general rule, the lower the specific gravity of the oil the less persistent it will be. The concept of a 'half life' is helpful in defining removal rates of less persistent oils. This is the time taken for the removal of 50% of the oil from the sea surface so that after six half-lives, little more than 1% of the oil will remain. Half-life calculations are less useful for heavier oils and water-in-oil emulsions. However, it is important to appreciate that some apparently light oils behave more like heavy ones due to the presence of waxes. Oils with wax contents greater than about 10% tend to have high pour points and if the ambient temperature is low, the oil will be either a solid or a highly viscous liquid, and natural breakdown processes will be slow. Figure 4 shows typical increases in viscosity with time after spillage for groups 2 - 4.

Figure 5 shows a simplified schematic of the rate of natural removal of the four oil groups and also takes into account the effect of the formation of water-in-oil emulsions on the volume of oil over time. The schematic has been developed on the

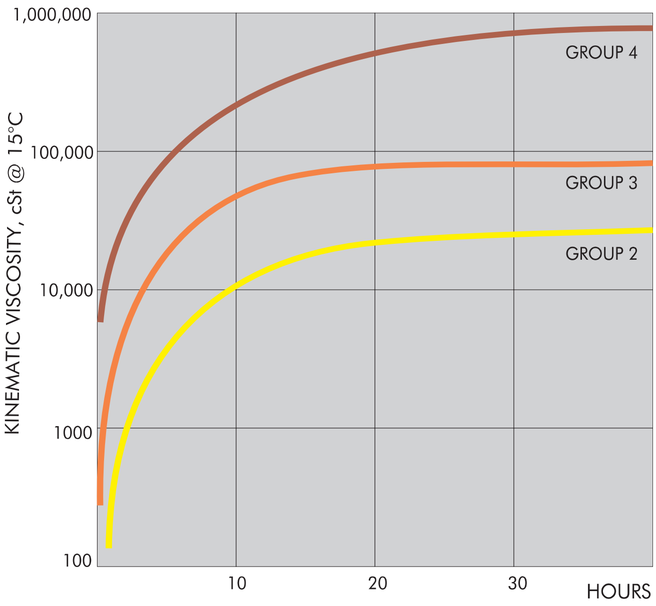


Figure 4: Typical rates of viscosity increase in moderate to rough seas. The viscosity of Group 1 oils never exceeds 100cSt and so is not shown.

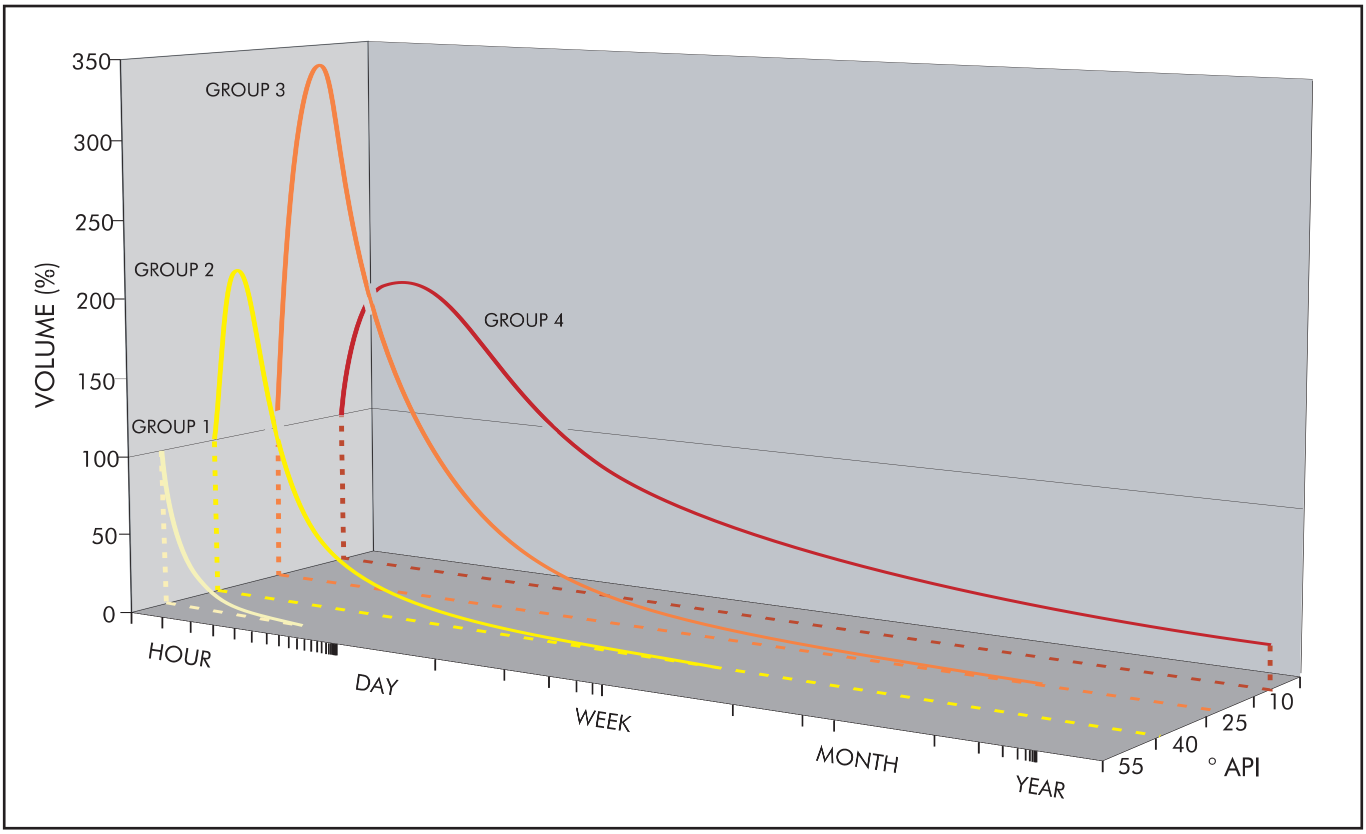


Figure 5: The volume of oil and water-in-oil emulsion remaining on the sea surface shown as a percentage of the original spill volume (100%). The curves represent an estimated 'average' behaviour for each group. The behaviour of a particular crude oil may differ from the general pattern depending on its properties and environmental conditions at the time of the spill.

**Footnote: The international liability and compensation regime for tanker spills does not apply to non-persistent oils, which for this purpose are defined as consisting of hydrocarbon fractions, (a) at least 50% of which, by volume, distils at a temperature of 340°C, and (b) at least 95% of which distils at a temperature of 370°C, when tested by the ASTM Method D 86/78 or any subsequent revision thereof.*

basis of observations made in the field and is intended to give an impression of how persistence varies according to the physical properties of the oil. The precise behaviour of an individual crude oil will depend on its properties and the circumstances at the time of the spill. Weather and climatic conditions will particularly influence the half-life of a slick. For example, in very rough weather an oil in Group 3 may dissipate within a time scale more typical of a Group 2 oil. Conversely, in cold, calm conditions it may approach the persistence of Group 4 oils. Group 4 oils, including heavy fuel oils, which are carried as bunker fuel by many ships, are typically highly viscous and highly persistent, and are amongst the most problematic to clean up. Their persistence gives them the potential to travel considerable distances at sea and cause widespread contamination.

Computerised weathering models have been developed that attempt to predict how a spilled oil will change with time under given sets of conditions. These often draw on databases of the physical and chemical characteristics of different oils, as well as the results of scientific research and observations of oil behaviour. In some cases such weathering models are combined with a trajectory model so that the overall fate and potential impacts of a slick can be forecast. However, due to the complexity of the weathering processes and slick movement, and because their precise interactions remain poorly understood, reliable predictions of overall fate are still difficult to achieve.

It is important therefore to appreciate the assumptions on which weathering and trajectory models are based and never to place too much reliance on the results. Model predictions should be verified by observations of actual oil distribution and behaviour. This is equally true both for simple empirical models and complex computerised numerical models. Nevertheless, models can provide a useful method of evaluating which clean-up techniques are likely to be effective and for how long, and what problems might be faced. Model simulations for specific circumstances can be of particular value during contingency planning and training.

Implications for Clean-up and Contingency Planning

The movement of slicks and the changing nature of the oil through weathering can determine whether a response, beyond monitoring slick dissipation, is necessary at all. The tendency of oil to spread rapidly and fragment, especially in rough sea conditions, will always place constraints on the effectiveness of any response option and should not be underestimated. Once oil is scattered over many square kilometres of sea surface, which for low viscosity oils can happen in just a few hours, it becomes very difficult to encounter large quantities since oil recovery systems typically have a swath width of only a few metres. This is the main reason why response at sea rarely results in the removal of more than a fraction of a widely spread slick.

Where a response is called for, the weathering processes which can change an oil from a liquid to a semi-solid or solid state will require clean-up techniques to be re-evaluated and modified over time. For example, dispersants applied at sea reduce in efficiency as the oil spreads and as oil viscosity increases. Depending on the characteristics of the particular oil, many dispersants become significantly less effective once viscosity reaches the 5,000 - 10,000 cSt level and most cease to work at all when the viscosity rises above this. Because oil viscosity can increase very quickly, the time available for using dispersant can be very short and the effectiveness of the dispersant application should therefore be checked frequently. In a similar fashion, if collection methods are employed, the type of pumps or skimmers used may need to be changed as the oil weathers and the viscosity rises.

An understanding of the likely fate and behaviour of different oils and the constraint that this imposes on clean-up operations is fundamental to preparing effective contingency plans. In addition, information on the prevailing winds and currents throughout the year will indicate the most likely movement of the oil and which sensitive resources might be affected for a given location. Data on the types of oil handled and transported can enable predictions to be made regarding the probable lifetime of slicks and the quantity and nature of the residue that may require a clean-up response. It will also determine the selection of appropriate clean-up techniques and types of equipment.

For fixed installations such as oil terminals and offshore oil fields, where a limited number of oil types are involved and prevailing conditions are well known, fairly accurate predictions can be made, which simplifies the development of an effective plan. Plans for areas where a wide range of oil types are handled or where tankers pass in transit cannot cover all eventualities. It is therefore even more important that the type of oil spilled is established at the earliest opportunity so that when a response is required, the most appropriate techniques may be used.

The International Tanker Owners Pollution Federation Limited (ITOPF) is a non-profit making organisation involved in all aspects of combating spills in the marine environment. Its highly experienced technical staff have responded to more than 450 ship-source spills in over 85 countries to give advice on clean-up measures, environmental and economic effects, and compensation. They also regularly undertake contingency planning and training assignments. ITOPF is a source of comprehensive information on marine pollution through its library, wide range of technical publications, videos and website. For further information contact:

ITOPF

The International Tanker Owners Pollution Federation Limited (ITOPF)
1 Oliver's Yard, 55 City Road, London EC1Y 1HQ, United Kingdom
Tel: +44 20 7566 6999   Fax: +44 20 7566 6950   Email: central@itopf.com
Web site: www.itopf.com