RECOGNITION OF OIL ON SHORELINES

TECHNICAL INFORMATION PAPER

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Introduction

The arrival of oil on the shore may be the first indication of an oil pollution incident. Depending on the quantity and type of oil involved, a clean-up response may have to be organised to remove the oil and to prevent it remobilising and affecting sensitive areas nearby. A reliable early report and estimate of the extent of the pollution can prove invaluable in determining the appropriate scale of the clean-up operation and organising adequate manpower and equipment to meet the task. Estimating the amount of stranded oil with accuracy is difficult and even identifying the type of oil can be a problem, particularly if the oil has weathered extensively.

In cases of large spills, the source of stranded oil may be obvious, but the question of identification frequently arises when a small amount of oil is involved and compensation is sought for damage or clean-up costs. The purpose of this paper is to assist the reader in recognising both the type and quantity of oil on differing shorelines.

Types of oil

It would be impractical to list all the different oils carried by sea which could pollute shorelines, in part because stranded oil can be a mixture of several types. It is therefore more useful to describe the most common types of oil in relation to their likely source.

Accidental spills from oil tankers can involve either crude oil and/or a product refined from crude oil. Crude oil is typically a black liquid when fresh (*Figure 1*). However as the oil weathers over time, the properties of the oil change. For example, as the lighter components evaporate, the viscosity increases. At the same time, many crude oils can take up water and form viscous water-in-oil emulsions which may be brown, red or orange in colour (*Figure 2*). Under hot sunny conditions, stranded emulsions can release water and can revert back to black oil.

Refined fuel oils are carried either as cargo in tankers or as fuel in bunker tanks of a wide variety of vessels. Freshly spilt fuel oil may be a black liquid, similar in appearance to fresh crude oil but with a characteristic smell (*Figure 3*). Fuel oil may also form stable emulsions that can be highly persistent (*Figures 4 and 5*).

Following an incident involving a tanker, both crude oil and fuel oil may be spilt and washed ashore either separately or as a mixture. Differentiating between the two may not be straightforward, particularly as the residue of both oils mixed with sand can assume a non-sticky consistency (*Figure 6*). Chemical analysis may assist in identifying the oil.

Other refined petroleum products shipped in bulk, for example petrol or kerosene, are relatively volatile and are unlikely to persist when spilt because of their rapid spreading and high evaporation rates. Lubricating oils used in vessel engines are relatively non-volatile and are an exception. Such oils may resemble car engine oil and have a tendency to form discrete lenses or discs when deposited on sand. Other oils can take the same form when spilt (*Figure 7*).

▲ *Figure 1: Fresh crude oil and debris on a sand beach. The oil is typically black and of low to medium viscosity.*

Lubricating oils, greases and hydraulic fluids accumulate as waste oil in ship bilges. If the correct oil/water separation and monitoring procedures have not been followed, or associated equipment has malfunctioned, discharges of oily bilge water from a vessel can give rise to pollution.

Oil also reaches the sea through urban run-off into rivers, discharges from land-based industries and effluents from municipal sewers. However, the concentration of oil in these discharges is seldom high enough to cause gross contamination of the seashore although sometimes brown bands or oily sheen may be seen in the tide marks left by waves on a sandy beach.

Some oils encountered on a shoreline may not be mineral in origin as animal fats and vegetable oils are also shipped in bulk. When spilt on water these non-mineral oils may float and behave in a way similar to petroleum oils. Several oils in this category have characteristic rancid smells distinct from petroleum and may be translucent, white or vivid yellow/red in appearance, dependent upon the extent of processing. The emulsions may also be yellow/red or grey/white in

▲ Figure 2: Emulsified crude oil. The inclusion of water within the oil has caused a typical change in colour to deep orange. (Image courtesy NOAA).

▲ Figure 3: Fresh fuel oil, in this instance relatively fluid and black in colour.

▲ Figure 4: Emulsified heavy fuel oil, highly viscous and brown in colour.

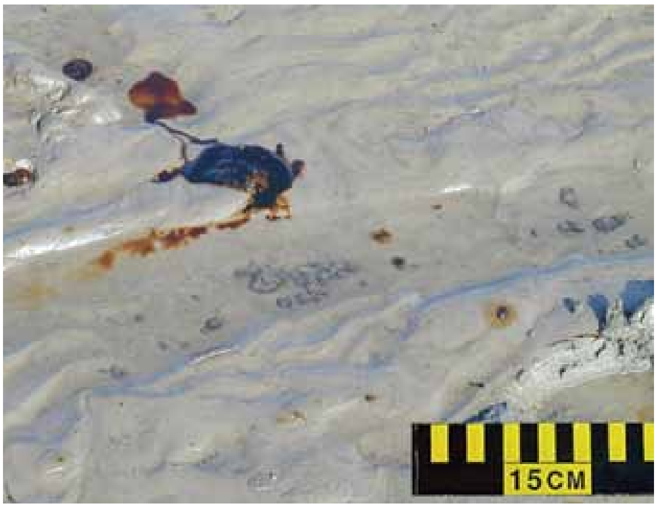
▲ Figure 5: Close-up image of emulsified heavy fuel oil, showing the highly viscous consistency. The high levels of water in the oil reduce the ability of the oil to adhere to underlying substrate.

▲ Figure 6: Weathered oil on a sand beach.

▲ Figure 7: A translucent base oil, used in the manufacture of lubricating oils, has formed lenses on the water surface. This oil was difficult to quantify due to its lack of colour.

▲ *Figure 8: Grey water-in-oil emulsion of palm oil on a rocky shoreline.*

▲ *Figure 9: Tarballs scattered on a sand beach.*



▲ *Figure 10: A fresh tarball.*

▲ *Figure 11: Sheen emanating from a pebble beach.*

colour (*Figure 8*). Examples of non-mineral oils are palm oil, rapeseed oil and olive oil.

Appearance and persistence of oil on shorelines

An understanding of the locations where floating debris collects is useful when predicting where oil may accumulate naturally. Small coves and inlets, as well as under jetties, piers and other man-made structures, are examples of locations from where trapped oil can remobilise and subsequently contaminate other areas.

The appearance, persistence and impact of stranded oil depends to a large extent on the type of coastline, which can vary from exposed rocky shores through pebble and sand beaches to sheltered muddy marshes. Oil pollution is seldom uniform in either thickness or coverage. Contamination can range from pools of liquid oil (*Figures 3 and 4*) through varying degrees of coverage to widely scattered tarballs (*Figures 9 and 10*) or sheen (*Figure 11*). Winds, waves and currents often cause oil to be deposited ashore in streaks or patches rather than as a continuous layer. On tidal shores the affected zone can be comparatively wide, particularly on flat, sheltered beaches, but elsewhere the pollution is often confined to a narrow band close to the high water mark.

Oil stranded on sand beaches may be rapidly covered with further layers of sand by subsequent tides or wind. Excavation or digging may reveal one or several layers of oil that have become buried by clean sand (*Figures 12*).

Liquid oils with a low viscosity may soak into sand, dependent upon the composition, grain size and moisture content of the substrate. For example, wet quartz sand composed of small grains will absorb less oil than coarse, dry shell sand. Penetration into larger beach substrate such as pebble, shingle or shells can reach substantial depths (*Figure 13*).

The rate of weathering processes such as evaporation, oxidation and biodegradation determines the persistence of stranded oil. However, the most active processes of oil

▲ *Figure 12: Layers of oil buried between clean sand by wave action.*

▲ *Figure 13: Heavy oiling with penetration into a shingle beach.*

▲ *Figure 14: Light oil staining of a stone jetty. This may be easily confused with algae growth.*

▲ *Figure 15: Heavy oiling of a sea wall following a storm tide.*

removal from shorelines are usually abrasion and natural dispersion as mineral- or clay-oil-flocculates, accelerated by elevated temperatures and exposure to wave action. In the longer term, the rate of weathering processes such as biodegradation and oxidation determines the persistence of stranded oil.

Tarballs, which are otherwise very resistant to weathering, may soften in strong sunlight and become more amenable to degradation. Alternatively, thin layers of oil on solid surfaces, such as rock or harbour walls, can become more difficult to remove as they may adhere strongly to these surfaces under intense sunlight (*Figures 14 and 15*). Wave action can eventually reduce even the most persistent lumps of oil to smaller fragments which are more readily degraded by chemical and biological processes. On sheltered shores less wave energy is available and, as a consequence, the oil may persist for longer periods. If oil becomes buried in soft sediment it is protected from wave action as well as from degradation due to the lack of oxygen. Significant breakdown will only resume if the buried oil is exposed again by erosion or by tilling or other actions. The factors that affect the persistence of stranded oil are described in the separate paper on the Fate of Marine Oil Spills.

A number of naturally occurring features and processes can be confused with oil, examples of which are shown in Figures 16–24. Silvery or multi-coloured sheens of biological origin covering the surface of rock pools give the appearance of oil but are often the result of biological processes, e.g. bacterial degradation (*Figure 16*). Similar effects are associated with peat outcrops in marshy areas. Sometimes reports of shore pollution prove to be unconnected with oil upon inspection; algae or lichen on rocks (*Figure 17*) and stranded seaweed (*Figure 18*) or other matter of vegetable origin (*Figure 19*) are good examples. In addition, charred wood particles, coal dust (*Figure 20*), black sand (*Figure 21*), pumice or other black rock (*Figure 22*) and wet sediment or roots (*Figure 23*), can be deceptive. On some beaches it is possible to dig down to an oxygen-free or anoxic layer, often grey or black in colour with a sulphurous smell of rotting vegetation. This is a natural feature and should not be mistaken for oil (*Figure 24*).

▲ *Figure 16:Natural sheen produced by rotting seagrass.*

▲ *Figure 17: Lichen on a rocky shoreline.*

▲ *Figure 18: Stranded sea vegetation resembling light oiling from a distance.*

▲ *Figure 19: Black vegetable matter.*

▲ *Figure 20: Coal dust resembling oil on a sandy beach.*

▲ *Figure 21: Layers of black sand and yellow sand give the impression of contamination of the shoreline by weathered oil (compare with Figure 6).*

▲ *Figure 22: Black rock resembling oil contamination.*

▲ *Figure 23: Dark, wet mangrove roots may be confused with oiled mangrove roots (inset).*

▲ *Figure 24: Anoxic sediment is a natural feature and should not be mistaken for oiling.*

Describing and quantifying stranded oil

A rough assessment of the quantity of oil present across a stretch of coastline is needed for the purposes of initiating a shoreline clean-up operation and monitoring its progress. The distribution of oil along a shoreline can vary significantly and the task of estimating the quantity of stranded oil can lead to errors unless it is approached with care and consistency. The assessment is largely a visual one and will be more difficult or impossible if the oil is hidden from view, for example by layers of sand brought on-shore by subsequent tides (*Figure 12*) or a covering of snow (*Figure 25*). Oil stranded on debris or seaweed laden shores (*Figures 26 and 27*), in mangroves (*Figure 28*) or on other types of vegetation (*Figure 2*), on rocky shores (*Figure 4*), on sea defences (*Figure 29*) or under jetties or quays will also be difficult to accurately quantify without further investigation.

Where the oil is visible the problem can be addressed in two stages:

Extent of contamination

Firstly, the overall extent of the contamination along a coastline can be estimated and marked on a chart or map. In the case of a major spill, aerial surveillance is usually the most efficient and convenient way of gaining a general impression. A helicopter is preferable as fixed wing aircraft usually travel too fast for a detailed coastal inspection at low altitude. Please refer to the separate paper on the Aerial Observation of Marine Oil Spills for more information on conducting aerial surveys.

Aerial surveillance should always be combined with spot checks on foot (*Figure 30*) because, as previously discussed, many shoreline features viewed from a distance bear a close resemblance to oil. Careful attention should be given

▲ *Figure 25: A covering of snow may obscure the presence of oil.*

▲ *Figure 26: Oil stranding on a coastline covered in debris can be difficult to quantify as the oil may be hidden from view.*

▲ *Figure 27: Oil stranding on a coastline covered in seaweed can be similarly difficult to quantify.*

▲ *Figure 28: Oil can get caught up in the complex root system of mangrove forests.*

▲ *Figure 29: Oil may become trapped between sea defences, such as these tetrapods, concealing the true amount that has arrived on shore.*

▲ *Figure 30: Walking the shoreline or 'ground-truthing' allows a more accurate quantification of the extent of contamination.*

to identifying locations where the character of the shoreline changes or where the degree of oil coverage appears to change. Examination of the oil to evaluate its consistency and smell may assist with identification.

In addition to a description of the oil itself, reports of shore pollution should include *inter alia* the location, date and time of the observations, the extent and parts of the shore affected by oil, the type of substrate, the key shoreline features and the identity of the observer.

The use of GPS and photographs are a very useful support to any written description of the location and appearance of oil on shorelines. A reference, such as a ruler or pen, allows the viewer a sense of scale (*Figures 10 and 12*). Photographs also serve as a record against which subsequent changes in the degree of pollution may be compared. When oiled sites are to be visited on more than one occasion, it is useful to take photographs from specific reference points so that they may be compared easily in the future.

Volume of oil

The second stage of quantifying stranded oil involves selecting representative samples of shoreline to calculate the amount of oil present. It is useful to split the shoreline into segments based on the shoreline type and degree of contamination. The sample area of shoreline chosen should be small enough to allow a reliable estimation of oil volume in a reasonable time, yet large enough to be representative of the whole shore section similarly affected.

The dimensions of the section of beach affected by oil should be estimated and, if the degree of contamination is consistent, the average thickness of oil should be relatively easy to measure. Thus, the volumes of oil on the beach in Figure 31 can be roughly estimated as described in the accompanying caption.

If the degree of oiling varies from the low to high tide lines as seen in Figures 32 and 33, then a representative strip of beach, for example one metre wide, running from the top of the beach to the water's edge should be surveyed. The volume of oil on the beach can then be estimated by visually determining the oil thickness in a representative number of locations within the strip and multiplying by the area of the strip to obtain a figure for the volume of oil. Multiplying by the length of the entire beach provides an estimate of the total volume of oil, as described in the captions accompanying the figures. This exercise has to be repeated on other sections where the nature of the shoreline or the degree of oil coverage may be different.

Quantifying stranded oil in this way only yields an approximate figure due to several unavoidable sources of error. On a sandy beach the affected area can be calculated relatively easily, but the possibility of oil penetrating into the beach substrate should be remembered (*Figures 12 & 13*). Oil penetration is likely to be greater as the grain size of the beach substrate increases and, therefore, the larger the grain size, the more difficult it can be to estimate the volume of oil on the shoreline.

The volume of oil that has penetrated may be very difficult to estimate (*Figure 34*), but when sand is uniformly saturated, a useful rule-of-thumb is that the pure oil content will be approximately one tenth of the depth of oily sand. For example, if oil has penetrated uniformly to a depth of 5cm, the volume of oil below the surface would be approximately $0.005m^3/m^2$ or 5 litres/m^2. Furthermore, when calculating oil volumes the degree of emulsification needs to be taken into account. Stable water-in-oil emulsions typically contain 40 – 80% water, i.e. the volume of 'pure' oil may be as little as a fifth of the observed volume of pollutant. Consequently, if the oil observed in Figure 31 was an emulsion containing 70% water, the volume of pure oil would be approximately $2.7m^3$ along the length of the beach, rather than $9m^3$. However, when organising shoreline clean-up it is the overall volume of pollutant, i.e. in this example, $9m^3$, that is significant.

If, in some situations, use of the relatively time-consuming methods outlined above prove to be impractical, alternative qualitative methods may be employed to estimate the percentage coverage. For example, the degree of pollution may be described as 'light', 'moderate', or 'heavy', or estimated by use of similar terms, against standard references (*Figure 35*), or by comparing the oiled shoreline with the photographs on page 10 in this paper. Individual or scattered occurrences of weathered oil may be described according to their size.

Often the most compelling reason for quantifying stranded oil is to facilitate clean-up. Therefore, the total amount of oily material, as opposed to the amount of oil spilt, is the most relevant figure as any debris, sand or water mixed with the oil will also require removal. However, on sandy beaches it is worth noting that removal of oil-saturated sand may involve a quantity of material of up to ten times greater than the quantity of oil on the beach. This may lead to problems with beach erosion, temporary storage and final disposal of the collected material. Please see the separate paper on the Clean-up of Oil from Shorelines for further advice on this issue.

Quantifying shoreline oiling has been formalised in some countries in the process known as SCAT (Shoreline Clean-up Assessment Team or Technique). During a SCAT survey, suitably trained personnel methodically record geo-referenced observations on prepared forms using specific and standard terminology, for example, as shown in Figure 35. Such descriptions and definitions allow a comparison over time and between different sites and observers to build a spatial image of the nature and extent of shoreline oiling.

The information gathered from quantifying and describing the oil can be used during various stages of the response, including: decision making and planning of response operations, monitoring, termination and any subsequent damage assessment. An understanding of the full nature and extent of shoreline oiling is important to allow the comparison and prioritisation of oiled sites. This will assist with planning of the resources, manpower and time required for shoreline clean-up, based on the size of the affected area and the volume of oil and/or oiled material.

Heavy oiling

Figure 31: Heavy oiling of a 300 metre long sand beach.

Volume of oil may be calculated as follows:

Average oil thickness is roughly 1cm

Width of oil band is roughly 3 metres from high to low tide lines

300m x 0.01m x 3m = 9m^3 total
or
9,000 litres/(300m x 3m) = 10 litres / m^2
or
Approximately 30 litres of oil per metre strip down the beach

Moderate oiling

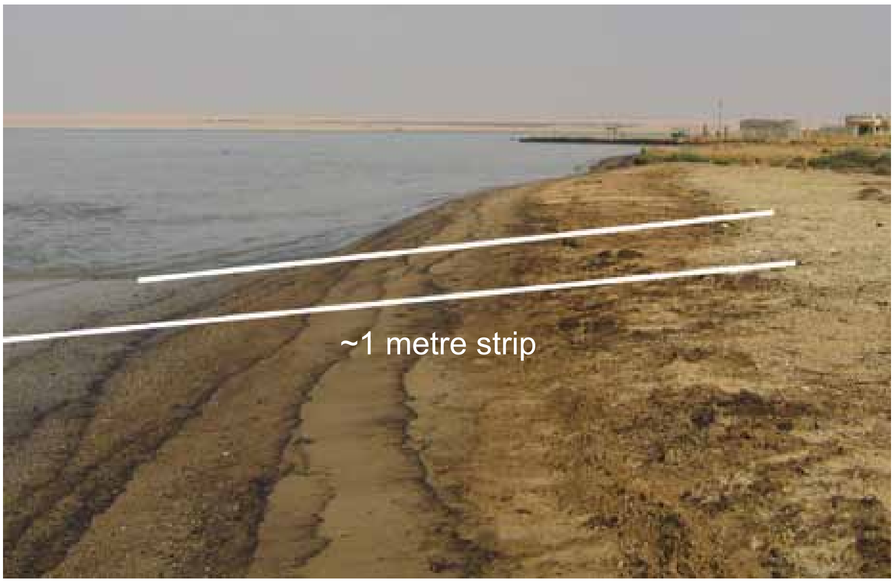
Figure 32: Moderate, broken oiling of a 500 metre long sand beach.

Volume of oil may be calculated as follows:

Average oil thickness is roughly 1mm

Width of oil band is roughly 5 metres from high to low tide lines

500m x 0.001m x 5m = 2.5m^3 total
or
2,500 litres/(500m x 5m) = 1 litre per m^2
or
Approximately 5 litres of oil per metre strip down the beach



Light oiling

Figure 33: Light, uneven oiling of a 200 metre long sand beach.

Volume of oil may be calculated as follows:

Average oil thickness is again roughly 1mm but in this instance covering approximately 10% of the width of the beach from high to the low tide lines

Width of oil band is roughly 5 metres

200m x 0.001m x 5m x 10% = 0.1m^3 (100 litres) total
or
100 litres/(200m x 5m) = 0.1 litre / m^2
or
Less than 0.5 litre of oil per metre strip down the beach

Figure 34: Locating and quantifying the extent of buried oil can be a difficult task.

Sampling Guidelines

Oil pollution causing damage to resources or necessitating shoreline clean-up may lead to claims for compensation. Evidence will be required to link the damage or costs incurred to the source of the pollution. Sometimes the link is easy to demonstrate, but on occasions chemical analysis of oil taken from the suspected source and the polluted site is necessary. As chemical analysis is relatively costly, it would be prudent to take and store a number of different samples but only to analyse key samples if a dispute arises.

Where sampling is undertaken for the purpose of environmental damage assessment, it is important to compare the results of chemical analysis for polluted areas with those of reference samples taken from similar, yet unaffected environments in the vicinity of the incident. Please refer to the separate paper on Sampling and Monitoring of Marine Oil Spills for more details.

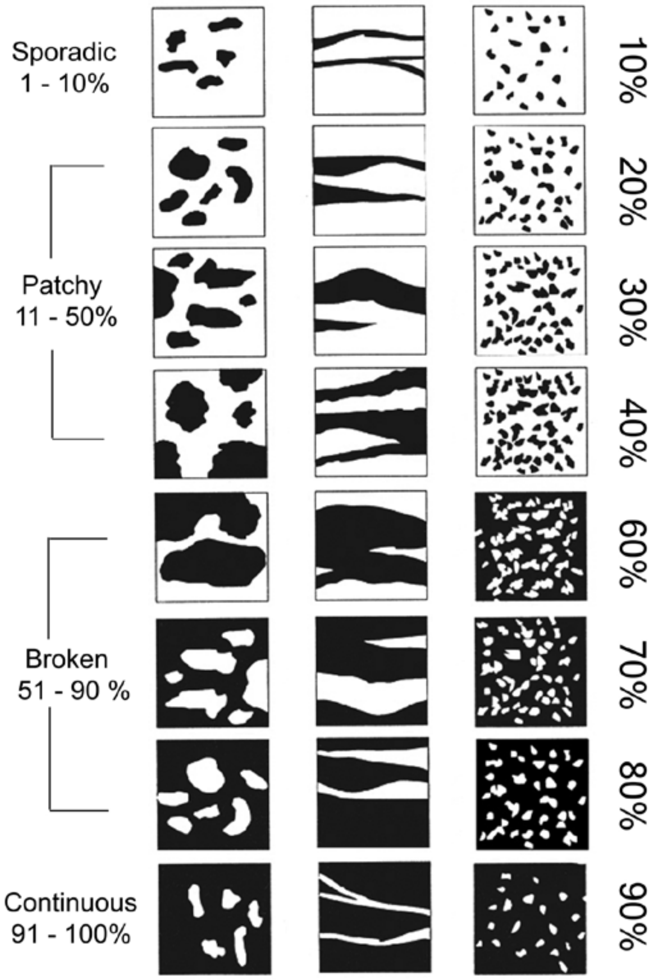


Figure 35: Indicative percentage coverings of oil to allow comparative, qualitative estimates of contamination. (Adapted from Owens, E.H. & Sergy, G.A.. 2000. The SCAT manual. A field guide to the documentation and description of oiled shorelines. 2nd edition. Environment Canada, Edmonton, Alberta, Canada).

Key points

- Considering the possible sources of oil on shorelines and noting the physical appearance and smell will often give clues as to its identity.
- Many features on a shoreline resemble oil and may be misinterpreted; a closer examination of reports of oil pollution is therefore advisable.
- Useful estimates of the quantities of stranded oil can be achieved with simple techniques, but precise calculations are impossible.
- Collation of information on the location, type and estimated quantity of oil, as well as shoreline type, is essential when planning an appropriate response.

TECHNICAL INFORMATION PAPERS

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

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