RECOGNITION OF OIL ON SHORELINES

TECHNICAL INFORMATION PAPER No 5 2008

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 protect sensitive areas nearby. A reliable early report and estimate of the extent of the pollution can prove invaluable for organising the most appropriate clean-up equipment and manpower for 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 rigs, pipelines and tankers can involve large volumes of crude oil which is typically a black liquid when fresh. 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 are usually brown, red or orange in colour (Figure 2). Under a hot sun, stranded emulsions often release water and can revert to the appearance of black oil. Eventually the residue of stranded oil assumes a non-sticky consistency, similar to tar (Figure 3).

Spills from ships can also involve fuel oil carried either as cargo or for fuel for the ship, as bunkers. Even with chemical analysis it can be difficult to distinguish between heavy fuel oil and weathered crude oil, particularly since fuel oil may also form stable emulsions. Following an incident involving a tanker, both types of oil may be washed ashore, either separately or as a mixture.

Figure 1: Scattered tar balls on a sandy shore

Most of the other refined petroleum products shipped in bulk are relatively light/volatile and unlikely to persist very long when spilled because of their rapid spreading and high evaporation rates. Lubricating oils are relatively non-volatile and therefore an exception, but can be identified by their resemblance to car engine oil and a tendency to form discrete lenses or saucer shapes when deposited on sand.

Lubricating oils, greases, hydraulic fluids and other waste oils accumulate in ship bilges so that if the correct oil/water separation and monitoring procedures are not followed or associated equipment has malfunctioned, discharges of oily bilge water from any vessel can lead to pollution. The resulting oil mixture often arrives ashore in the form of viscous patches, tarry lumps or tar balls (Figure 1).

A substantial volume of oil 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 sea shore 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 of mineral origin since animal fats and vegetable oils are also shipped in bulk.

Figure 2: Brown water-in-oil emulsion or "mousse"

Figure 3: Weathered oil on a sand beach

Figure 4: Grey water-in-oil emulsion of palm oil on a rocky shoreline

Figure 5: Heavy oiling of a rocky shoreline, with significant pooling between rocks

Figure 6: Moderate oiling of a pebble beach, where some penetration into the substrate is likely

Figure 7: Light oiling of a shingle beach

When spilled on water they float and behave in a similar way to petroleum oils. Several oils in this category have characteristic rancid smells distinct from petroleum and are usually translucent or white in appearance. The emulsions are typically yellow or grey/white (Figure 4). Examples of non-mineral oils are palm oil, rapeseed oil, olive oil and other vegetable oils.

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 (Figure 5) through varying degrees of cover (Figure 6) to light staining (Figure 7) or sheen (Figure 8). Winds, waves and currents 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 which initially coats a sandy beach can soon be partly covered with sand by wind and wave action. Digging may reveal one or several layers of oil that have become buried by clean sand (Figures 9 and 23).

Liquid oils with a low viscosity will soak into sand to some extent, depending on 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 and shingle can reach substantial depths (Figure 10).

A number of naturally occurring features can be confused with oil, examples of which are shown in the accompanying photographs (see page 4). 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 11). Similar effects are associated with peat outcrops in marshy areas. Sometimes, reports of shore pollution prove unconnected with oil upon inspection. Algae or lichen on rocks (Figure 12) and stranded seaweed (Figure 13) or other matter of vegetable origin (Figure 14) are good examples. In addition black mineral sand, charred wood particles, coal, (Figure 15) volcanic sand, pumice and wet sediment or roots (Figure 16) can also be deceptive. On some beaches it is possible to dig down to an oxygen-free layer, often grey or black in colour

▲ *Figure 8: Sheen emanating from a pebble beach*

▲ *Figure 9: Oil and oily substrate buried between layers of clean sand by wave action*

▲ *Figure 10: Penetration of oil into a shingle beach*

▲ *Figure 11: Natural sheen produced by rotting seagrass*

▲ *Figure 12: Lichen on a rocky shoreline*

▲ *Figure 13: Stranded sea vegetation resembling light oiling from a distance*

▲ *Figure 14: Black vegetable matter*

▲ *Figure 15: Coal dust resembling oil on a sandy beach*

▲ *Figure 16: Dark, wet mangrove roots may be confused with oiled mangrove roots (inset)* and smelling of rotting vegetation. This is a normal feature and should not be mistaken for oil.

The rate of weathering processes such as evaporation, oxidation and biodegradation determines the persistence of stranded oil. However, the most active process of oil removal from shorelines is usually abrasion and physical dispersion accelerated by elevated temperatures and exposure to wave action. Tar balls which are otherwise very resistant to weathering may soften in strong sunlight and become more amenable to degradation. However, thin layers of oil exposed to strong sunlight can become baked on and difficult to remove from solid surfaces such as rock (Figures 17 and 18). Wave action can eventually reduce even the most persistent lumps of oil to smaller fragments which are more readily attacked by chemical and biological processes. On sheltered shores less wave energy is available and 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. A summary of the factors having a bearing on the persistence of stranded oil is given in Table 1.

Figure 17: Light oil staining of a stone jetty. This may be easily confused with algae growth

Figure 18: Heavy oil stain running down a sea wall following a storm tide

Describing and quantifying stranded oil

A rough assessment of the quantity of oil present on a stretch of coastline is needed for the purposes of arranging shoreline clean-up and monitoring its progress. The variable distribution of the oil can cause errors unless the task of estimating the quantity of stranded oil is approached with care and consistency. The assessment is largely a visual one and will be impossible if the oil is hidden from view, for example, by beach substrate, snow, or mangroves. Where the oil is visible the problem can be met in two stages.

First, 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 a helicopter over-flight is usually the most efficient and convenient way of gaining a general impression. A fixed-wing aircraft usually travels too fast for a good coastal inspection at low altitude. Aerial surveillance should always be combined with spot checks on foot since, as previously discussed, many shoreline features viewed from a distance bear a close resemblance to oil. Careful attention should be given to identifying locations where the character of the shoreline changes or where the degree of oil coverage appears to change. Please refer to the separate Technical Information Paper on Aerial Observation of Oil for more details.

Table 1: Factors affecting the persistence of stranded oil

Liquid oil	Increasing persistence →	Tarry residues
Thin patches		Thick covering
High temperatures		Low temperatures
Exposed shores		Sheltered shores
Strong wave action		Calm waters
Surface oil		Buried oil

Figure 19:
Heavy oiling of a 300 metre long sand beach.

Average oil thickness ≈ 1cm
Width of oil band ≈ 3 metres

$300m \times 0.01m \times 3m \approx 9m^3$ total

or

9,000 litres/(300m x 3m) ≈ 10 litres / m^2

or

Approximately 30 litres of oil per metre strip along the beach

Figure 20:
Moderate, broken oiling of a 500 metre long sand beach.

Average oil thickness ≈ 1mm
Width of oil band = 5 metres

$500m \times 0.001m \times 5m \approx 2.5m^3$ total

or

2,500 litres/(500m x 5m) ≈ 1 litre per m^2

or

Approximately 5 litres of oil per metre strip along the beach

Figure 21:
Light oiling of a 200 metre long sand beach.

Average oil thickness < 0.05mm
Width of oil band = 5 metres

$200m \times 0.00005m \times 5m = <0.05m^3$ total

or

50 litres/(200m x 5m) = <0.05 litre per m^2

or

Less than 0.25 litre of oil per metre strip along the beach

Any changes detected at a distance should always be verified by a closer inspection, or 'ground truthing' (Figure 22). Examination of the oil to evaluate its consistency and smell may assist in 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; which parts of the shore are affected by oil and to what extent; the type of substrate and key shoreline features.

The use of GPS and photographs are a very useful support to any written description of the location and appearance of oil on shorelines. Photographs also serve as a record against which later 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 easily compared in the future.

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 19 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 20 and 21, then a representative strip of the beach, for example one metre wide, running from the top of the beach to the water's edge should be surveyed to establish the volume of oil on the beach. This can be roughly calculated by visually estimating the oil thickness in a representative number of locations within the strip, and multiplying by the area of the strip to get the volume of oil. As described in the captions accompanying the figures, this volume can then be multiplied by the length of the entire beach to estimate the volume of oil on the beach. The 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. 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. Occasionally the volume of penetrated oil will be impossible to estimate, but when sand is uniformly saturated, a useful rule-of-thumb is that the pure oil content is approximately one tenth of the depth of oily sand. The presence of debris or stones and crevices on rocky shores can be an added complication. Furthermore, when calculating oil volumes the occurrence of water-in-oil emulsions can be misleading. Stable emulsions typically contain 40 – 80% water i.e. the volume of 'pure' oil may be as little as 1/5 of the observed volume of pollutant.

▲ *Figure 22: Walking the shoreline or "ground truthing" allows a more accurate quantification of the extent of contamination*

If in some situations it proves impractical to use the relatively time-consuming methods outlined above, it should often be possible to estimate the percentage coverage and/or describe the degree of pollution as 'light', 'moderate' or 'heavy' by comparing the oiled shoreline with the photographs in this paper.

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 spilled, is the most relevant figure since 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 at least ten times greater than the oil itself. This may lead to problems with beach erosion, temporary storage and final disposal of the collected material.

▲ *Figure 23: Locating and quantifying the extent of buried oil can be a difficult task*

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. 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 quantification and description of the oil can be used during various stages of the response, including: decision making and planning of response operations; monitoring, termination and consequent damage assessment. An understanding of the full nature and extent of shoreline oiling is key in allowing the comparison and prioritisation of oiled sites, and helps in the 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. Knowledge of the quantity of oily material is also important when determining waste storage, transportation and disposal needs.

Sampling guidelines

Oil pollution causing damage or necessitating shoreline clean-up may lead to claims for compensation. Evidence will be required linking the damage or costs incurred to the alleged polluter. 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 analyse key samples if there is a dispute.

Where environmental quality sampling is carried out for the purpose of 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 Technical Information Paper on Sampling for more details.

Key Points

1. Many features on a shoreline resembling oil of petroleum origin may be misleading and a close examination of reported pollution is advisable.
2. Considering the possible sources of oil on shorelines and noting their physical appearance and smell will often give clues to their identity.
3. Useful estimates of the quantities of stranded oil can be achieved with simple techniques, but precise calculations are impossible.
4. Collation of information on the location, type and estimated quantity of oil, as well as shoreline type, is essential in planning an appropriate response.

ITOPF is a not-for-profit organisation established on behalf of the world's shipowners to promote effective response to marine spills of oil, chemicals and other hazardous substances. Technical services include on-site clean-up advice, pollution damage assessment, assistance in spill response planning, and the provision of training. ITOPF is a source of comprehensive information on marine oil pollution through its library, wide range of technical publications, videos and website. For further information contact:

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