USE OF SORBENT MATERIALS IN OIL SPILL RESPONSE

TECHNICAL INFORMATION PAPER

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Introduction

Sorbent materials can provide a useful resource in a response to a spill of oil, allowing oil to be recovered in situations that are unsuitable for other techniques. However, sorbents should be used in moderation to minimise secondary problems, particularly by creating excessive amounts of waste that can greatly add to the costs of a response.

This paper considers the types of sorbents available and how they may be used beneficially in a response. It should be read in conjunction with other ITOPF papers in this series, particularly on the use of booms, the use of skimmers, shoreline clean-up techniques and the disposal of oil and debris.

Overview

Oil sorbents comprise a wide range of organic, inorganic and synthetic products designed to recover oil in preference to water. Their composition and configuration are dependent upon the material used and their intended application in the response.

While widely used in spill response, sorbents should be employed with caution to minimise inappropriate and excessive use that can present major logistical difficulties associated with secondary contamination, retrieval, storage and disposal. These all contribute significantly to the overall costs of clean-up operations. In particular, synthetic sorbent material should be used in moderation and care taken to ensure it is used to its full capacity to minimise subsequent waste disposal problems.

In general, sorbents are used most effectively during the final stages of shoreline clean-up (*Figure 1*) and for recovering small pools of oil that cannot be easily recovered using other clean-up techniques. Sorbents are not appropriate for use in the open sea and are generally less effective with more viscous oils, such as heavy fuel oil, and with oils that have become weathered and emulsified, although some sorbents have been specifically engineered for viscous oils.

▲ *Figure 1: Polypropylene sorbent boom used to collect oil released during flushing operations.*

How sorbents work

In order for a material to act as a sorbent, it should attract oil preferentially to water, i.e. it should be both oleophilic and hydrophobic. Sorbent materials can act either by adsorption or, less commonly, by absorption. In adsorption, the oil is preferentially attracted to the surface of the material whereas absorbents incorporate the oil, or other liquid to be recovered, into the body of the material. The majority of products available for oil spill response are adsorbents; few are true absorbents.

Absorbents

Liquids diffuse into the matrix of a solid absorbent material by a process similar to capillary action, causing it to swell and combine with the material in such a way that it will not leak out, nor can it be squeezed out under pressure. Absorbents available for pollution response are made from engineered polymers with a high surface area to promote rapid absorption. As they may reduce the surface area of the liquid, absorbents can be used with volatile products. While absorbent materials are, in theory, capable of recovering light fuel oils and some crude oils, the time required for absorption may be longer than is practical or desirable and, as a consequence, they are suited more to the recovery of low viscosity liquids and spilt chemicals, particularly hazardous and noxious substances, as discussed in the separate ITOPF paper on Response to Marine Chemical Incidents. Absorbents are therefore less commonly encountered in oil spill response than adsorbents.

Adsorbents

To minimise confusion, the widely used generic term sorbent is adopted in this paper as its primary focus is the use of adsorbents in oil spill response. The various mechanisms that allow a material to adsorb oil are described below.

Wetting properties

For successful adsorption, oil should wet the material and therefore spread over its surface in preference to water. A liquid will wet a solid if its surface tension is less than the critical surface tension (γ_c) of the solid. Therefore, for a sorbent to fulfil the required criteria, it should have a γ_c value below that of water and above that of oil. The surface tension of seawater is approximately 60–65 mN/m; the value for oil varies depending on the composition but is typically around 20 mN/m. Therefore, for example, PTFE with a γ_c value of 18 mN/m will adsorb neither oil nor water whereas polypropylene with a γ_c value of 29 mN/m makes an ideal oil sorbent.

Many natural and synthetic solids have suitable γ_c values. Inorganic solids that do not have the required value can be modified by various surface treatments, including heating, to produce the desired condition. An example of such a product is exfoliated vermiculite. For a number of materials, notably sorbent foams and loose fibres, the oleophilic properties can be enhanced once they have initially been wetted or primed with oil.

Capillary action

With some materials, adsorption occurs via capillary action. While this is also dependent on the relative surface tensions of the solid and liquid, the viscosity of the oil has an important effect on the rate of penetration into the structure of the sorbent. Oil penetration rates can be fast (a matter of seconds) for low viscosity oils, such as light crudes, or slow (several hours) to negligible for high viscosity oils, such as heavy fuel oil or weathered oils.

Capillary action is particularly important with foam-based sorbents. Foams with fine pores recover low viscosity oils easily but the pores quickly become clogged with thicker oils. Conversely, foams with a coarse cell structure are effective with viscous oils but are unable to effectively retain low viscosity oils.

Cohesion / adhesion

Cohesion refers to the attraction of a material to itself thereby opposing spreading on a solid surface, while adhesion refers to the attraction of one material to another. Sorbents rely on both adhesion of the oil to the sorbent surface and the cohesive properties of oil which allow greater quantities of oil to be retained by the sorbent. If the sorbent is in the form of a hank of loose strands, the cohesion of the oil among the sorbent elements can serve to produce a congealed mass that retards the spreading of the oil making it easier to recover the oil and sorbent mixture. Cohesion is greater for more viscous oils.

Surface area

In addition to the wetting, spreading and capillary characteristics of a particular sorbent material, its sorption rate and capacity are directly related to the exposed surface area. A successful sorbent material should have a high surface area to volume ratio, including external and available internal surfaces.

For viscous oils that are unable to flow rapidly into a sorbent material, the performance will be determined by the available external surface area. For example, loose strands of sorbent have a greater relative external surface area than a boom and so might be expected to have a higher sorption rate and be more effective with viscous oils.

In contrast to absorbents, adsorbent materials should be used on volatile liquids with caution. Spreading of the liquid over the internal and external surface area of an adsorbent material can increase the rate of vapour release, with attendant consequences for combustion and/or human health.

Sorbent materials and forms

Sorbent materials

A wide variety of materials can be used as sorbents. These include organic materials such as bark, peat, sawdust, paper-pulp, bagasse (the waste product from processing sugar cane), cork, chicken feathers, straw (*Figure 2*), wool and human hair; inorganic materials such as vermiculite and pumice; and synthetic material such as polypropylene

▲ *Figure 2: Improvised sorbent booms constructed from straw and netting. Such booms are cheap and easy to construct and can provide effective short-term protection when deployed in suitable areas.*

▲ *Figure 3: Strips of polypropylene enclosed in netting. The loose inhomogeneous structure of the boom may allow oil to readily penetrate into the structure allowing inner surfaces to adsorb oil but the enclosing netting may be easily damaged.*

▲ *Figure 4: The surface of a continuous, homogeneous sorbent boom cut away to show only partial use. The inner volume remains unoiled, either because the boom has been deployed for an insufficient period or because the oil is too viscous to penetrate into the structure.*

▲ *Figure 5: Continuous flat sorbents, such as this sheet laid on a shoreline, are characterised by a high surface area to volume ratio. The large scale use of sorbent in this manner should be balanced against the generation of considerable volumes of potentially unoiled waste.*

(*Figures 3, 4 and 5*) and other polymers.

Synthetic sorbents are generally the most effective in recovering oil. In some cases a ratio by weight of oil to sorbent of 40:1 can be achieved compared to 10:1 for organic products and as little as 2:1 for inorganic materials. Despite the limited adsorptive capability, organic and inorganic materials may be attractive as they are often either abundant in nature or are the waste by-product of an industrial process, and can be purchased readily at low cost or are freely available.

The relative effectiveness of different sorbent materials has been tested by a number of organisations to assess how much oil a given weight of a particular sorbent material

	Material	Benefits	Disadvantages
Bulk	• Organic – including bark, peat, sawdust, paper-pulp, cork, chicken feathers, straw, wool and human hair. • Inorganic – vermiculite and pumice • Synthetic – primarily polypropylene	• Often naturally abundant or widely available as waste by-product of industrial processes • Can be low cost • Can serve to protect wildlife at haul-out sites	• Difficult to control, can be spread by the wind • Difficult to retrieve • Oil and sorbent mixture can be difficult to pump • Disposal of oil sorbent mixture more limited than oil alone
Enclosed	• All of the above bulk materials can be enclosed in mesh or nets	• More straightforward to deploy and retrieve than loose sorbent • Enclosed boom has a greater surface area than continuous boom	• Structural strength limited to that of the mesh or net • Organic booms can rapidly become saturated and sink. Oil retention is limited
Continuous	• Synthetic – primarily polypropylene	• Long-term storage • Relatively straightforward to deploy and retrieve • High oil recovery ratio possible if used to full capacity	• Limited efficiency for weathered or more viscous oils • Do not readily decompose limiting disposal options
Fibre	• Synthetic – primarily polypropylene	• Effective on weathered and more viscous oils	• Less effective on fresh light and medium oils

▲ *Table 1: The benefits and disadvantages of available types of adsorbent material.*

▲ *Figure 6: Local villagers constructing snares from strips of polypropylene. The manufacture of sorbent from locally available materials can be cost effective in terms of price as well as efficiency of transport.*

▲ *Figure 7: Snare strung across an estuary to catch floating oil. The open structure and large surface area of the material are particularly suited to the recovery of viscous oils.*

might be expected to retain. Although these test results can be useful in the comparative ranking of the effectiveness of one sorbent material over another, they are performed under laboratory or controlled field conditions and may therefore be misleading. In practice, sorbents are subject to wind, waves and currents and under these natural and unpredictable conditions, their performance is unlikely to match the outcomes reported in such tests.

Forms of sorbent

Sorbents are marketed in various forms according to their composition and their intended use, but can be categorised generally as one of four types: bulk loose material, often as particulate; enclosed in a mesh as pillows or booms; continuous in the form of mats, sheets, booms or rolls; and as loose fibres combined to form snares or sweeps (*Table 1*). Other types of sorbent may be available for specific applications.

Sorbent in bulk

Most of the materials listed above are marketed as loose sorbent and serve a useful purpose to recover small spills of oil on land. Primarily due to the difficulties of controlling their application and retrieval, their use in the marine environment should be limited to specific scenarios described in the section below on the use of sorbents on shorelines.

Enclosed sorbent

Bulk loose sorbent materials are often enclosed in an outer fabric, mesh or netting to form a boom, pillow or sock that is more straightforward to deploy, control and subsequently easier to retrieve than the loose material itself. Enclosed sorbent products vary in shape and volume but booms are the most common (not to be confused with the continuous form of boom described below). Enclosed sorbent is typically produced using readily available organic or inorganic natural materials such as straw (*Figure 2*) but may also comprise individual elements of synthetic material such as polypropylene (*Figure 3*).

Continuous sorbent

Continuous cylindrical sorbent, primarily boom, differs from the enclosed loose material boom described in the previous section by having a greater homogeneity and a lower surface area to volume ratio, meaning oil is less readily able to penetrate to the core of the boom (*Figure 4*). Continuous flat sorbents such as sheets, rolls, mats, pads and webs are characterised by their high surface area to volume ratio (*Figure 5*).

Continuous sorbents are primarily manufactured from synthetic materials with woven, melt-blown, polypropylene being one of the materials most commonly used during spill response. However, sorbents produced from other materials such as polyurethane, nylon and polyethylene may be encountered occasionally.

Loose fibre sorbent

While bulk, enclosed and continuous sorbent products are effective on a wide range of oils, they are less efficient in the recovery of more weathered and high viscosity oils. Bundles or hanks of loose sorbent fibres are available that allow these oils to be recovered through a combination of adhesion to a large surface area and cohesion within the oil itself. Primarily produced from strips of polypropylene, these are usually attached together to form snares also known as 'pom poms' (*Figure 6*). Several individual snares may be attached along a length of rope to form viscous oil sweeps, or 'snare boom' (*Figure 7*). Rope mop skimming machines use a form of sweep in a continuous band often many metres in length to recover and collect oil. Please see the separate ITOPF paper on the Use of Skimmers for further information.

Viscous oil snares have also been used successfully to assist with the detection of sunken and sub-surface oil, either by suspension in the water column from floats and anchors or by sweeping or trawling the seabed attached to a metal frame. The presence of oil in the sea is indicated by oiling of the sorbent, allowing more quantitative methods to focus on identified areas. Further details are given in the separate ITOPF paper on Sampling and Monitoring of Marine Oil Spills.

Criteria for selecting sorbents

In addition to the form in which the sorbent is presented and the ability of a particular material to selectively take up oil, other factors also affect a sorbent's effectiveness.

Buoyancy

For sorbents to be used effectively on floating oil they must have and retain high buoyancy, remaining afloat even when saturated with oil and water. A number of natural organic materials such as straw and sawdust have good initial buoyancy but eventually become waterlogged and sink. However, buoyancy can in some cases be detrimental to the effectiveness of a sorbent. For example, some lighter, less dense materials may remain on top of heavy, viscous oils. In such instances the sorbent material may require manual mixing with the oil to promote saturation and allow effective recovery to proceed.

The buoyancy of foam sorbents is directly related to the ratio of enclosed cells to open cells; the greater the number of open cells, the greater the sorption capability at the expense of buoyancy.

Saturation

Sorbents can quickly become saturated by oil. Even a relatively small slick may quickly overwhelm a sorbent boom and oil may be released from the sorbent to contaminate the resource that it was intended to protect. Once saturated, sorbents cannot recover further oil and should be removed as quickly as possible to avoid any subsequent leaching. The level of saturation can be difficult to identify, often requiring the boom to be cut open. Incomplete saturation is frequently experienced with viscous oils where booms may be recovered and discarded mistakenly, leaving the inner layers unused (*Figure 4*). Such unnecessary wastage can be avoided or decreased by using sorbent boom with a small diameter, reducing the volume of unused material in the centre of the boom, while at the same time maintaining its effectiveness, or by using oil snares.

▲ *Figure 8. Sorbent materials by their nature are bulky products. Storage and transport before, during and after a response to a spill can pose logistical and cost issues.*

Sorbent sheets can become quickly saturated when placed in contact with even small quantities of oil and their use should be restricted to small scale incidents where the amount of oil to be recovered is limited.

Oil retention

One of the key aspects of the overall performance of a sorbent is its ability to retain oil. Some materials rapidly adsorb oil but, unless retrieved in good time, the sorbent may subsequently release much of it as a result of the effects of wind, waves and currents. Similarly, some sorbents release oil when lifted from the water as the weight of recovered liquid can cause the sorbent to sag and deform, squeezing oil from within pores or internal surfaces. Oil retention can be a particular problem when using sorbents with low inherent strength, in particular those constructed from organic materials.

Sorbent materials with fine pores, such as vermiculite and some foams, generally exhibit good oil retention characteristics. The drawback with these materials is their poor performance in the recovery of viscous oils. Snares can become quickly saturated with oil, primarily due to their large surface area. However, they may release oil when they are lifted from the water surface. The rate of release is directly dependent upon the viscosity of the oil, with lighter, less viscous oils dripping off more rapidly.

Strength and durability

The durability of a sorbent is important in those situations where it may be left in-situ for an extended period of time before recovery. Sorbent booms may start to degrade and fall apart within a matter of hours as a result of environmental effects, such as wave action or abrasion on rocks. The strength of some sorbent booms, particularly those composed of enclosed loose material, is dependent on the durability of the retaining netting material, which may break open in adverse environmental conditions. Once damaged, the contents of these booms will be easily lost and may become a secondary source of contamination.

Fermentation

Some organic sorbents can ferment when left in contact with water for an extended period of time. In addition to altering their composition and efficiency in selectively recovering oil, this can give rise to problems with recovery, storage and disposal of the resultant sorbent/liquid mixture.

Cost

The cost of sorbent products varies greatly and is primarily dependent upon the material used. Organic and inorganic materials are comparatively less expensive than synthetic products. However, this low unit cost will require a trade-off to be made to take account of the additional quantities required due to their low relative efficiency. The additional costs of disposal of higher volumes of material should also be considered when selecting the most appropriate product. Despite the high cost of synthetic products, they are often many times more effective and, in some instances, they can be reused.

Availability, storage and transportation

The performance of synthetic sorbents makes their use attractive but they may not always be immediately available at the site of the spill. While organic and inorganic sorbents may be less efficient, they may offer a pragmatic alternative as they are often more widely available. However, the requirement for a number of organic products to be pre-treated before they can be used effectively as sorbents may limit their availability in an emergency response.

Sorbents are bulky by nature (*Figure 8*) and, in large amounts, the space required for storage can be significant. Where storage space is limited and large quantities of sorbents are required, storage may only be possible outside. If this is the case, protection from sunlight will be necessary to prevent degradation by UV light, especially in the case of synthetic sorbents. Storage of organic sorbents should take account of the potential for deterioration in damp conditions and damage as a result of mildew, rodents or insects.

As with storage, transportation of large volumes of sorbents can invoke logistical problems, both from the warehouse to a distribution centre in the general vicinity of the spill and from there into the field where the sorbents are to be used. In particular, flying plane-loads of sorbents to a spill site is unlikely to be cost-effective.

Use of sorbents on or near the shoreline

Sorbents can play a number of useful roles in nearshore and onshore clean-up operations. However, the use of large quantities of sorbents should be avoided where possible to minimise secondary problems associated with disposal (*Figure 9*). Consequently, the large-scale use of sorbents on shorelines should be restricted to those situations where other techniques are not likely to be effective or feasible. Oil on hard sand beaches, for example, can usually be recovered without the extensive use of sorbents by workers equipped with shovels or through the use of trenches. On the other hand, in circumstances where oil is held against a shoreline, inaccessible other than on foot, and where skimmers and pumps cannot be deployed, it is very difficult to handle fluid oil without the aid of sorbents. Nevertheless, many of the concerns relating to availability, transportation and storage of sorbents, both before and after use, still apply.

Anchored close to shore, sorbent boom can be used effectively to catch run-off from shore washing operations, for example during high pressure washing of oiled rocks (see front cover), or in the intertidal zone to collect refloated/remobilised oil. Sometimes referred to as 'passive cleaning', sorbent and snare booms can be very effective in trapping oil mobilised on successive tides from highly sensitive areas, particularly saltmarshes and mangroves, where other response techniques may cause unacceptable additional damage. Similarly, the technique may be used to recover oil released from rock armour and rip- rap over successive tides. The fine-mesh netting material used as dust screen for scaffolding works has also been used in this way successfully to capture viscous oil released from shorelines comprising boulders, cobbles and coarse sand. One end of the netting is secured on the shore while the other is free to move in the sea. Provided environmental conditions are suitable, in particular the water velocity through the boom is not too high, snare boom can also be effective when strung across industrial water intakes to help limit the ingression of floating high viscosity oil (*Figure 7*).

In general, the use of sorbents in conjunction with shoreline washing techniques during the final phase of a clean-up operation is preferable to sorbents being used directly for wiping rocks since this latter technique results in large amounts of material requiring disposal. Nevertheless, sorbents can be useful for the removal of small amounts

▲ *Figure 9: The large-scale use of sorbent to recover oil on a hard sand beach. The use of sorbent material should be appropriate to the scale of contamination, bring an appreciable benefit to the response and not unduly add to the waste requiring disposal.*

▲ *Figure 10: Organic particulate sorbent material such as peat or bark may be applied on rocky shores of importance to wildlife (e.g. penguins and seals), to minimise contamination to fur and feathers as they come ashore.*

▲ *Figure 11: Sorbent pads applied at sea. Considerable effort will be required to subsequently recover the pads to eliminate secondary contamination. Use of containment boom and skimmers may afford a more effective means of recovering the oil than the use of sorbents.*

▲ *Figure 12: Sorbent boom towed in a 'U' formation behind two vessels, with the aim of recovering sheen (very thin oil films) at sea. Saturation of the boom by seawater limits its effectiveness and the lack of skirt on the boom limits the ability to contain oil. Here oil can be seen escaping from the boom.*

of residual oil that would otherwise be difficult to recover with reasonable cost and effort. Contaminated rock pools in particular are candidates for cleaning with sorbents, for example polypropylene snares that are capable of removing both viscous and weathered oils. The use of sorbents to recover sheen is generally not necessary in most climates, as sheen will normally dissipate naturally.

The large-scale use of bulk loose sorbents near-shore or on the shoreline is generally not advocated, primarily because of the difficulties of controlling the application of the material and its subsequent recovery. Nevertheless, situations may arise where recovery is not contemplated and its use may be advantageous. For example, organic products such as peat or bark can be spread on oiled shorelines to adsorb bulk oil and afford a measure of protection to local fauna, especially sensitive marine mammals and birds such as seals or penguins at haul-out sites (*Figure 10*). In some countries, organic and inorganic bulk sorbents are used in the final stages of clean-up in the knowledge that, although the sorbents will not be recovered, the oil/sorbent mixture will be removed over time by natural processes, which also bring about its distribution over a wide area and the gradual breakdown of the oil.

Use of sorbents at sea

The use of sorbents as a primary response tool in a major oil spill response at sea is to be discouraged. In addition to problems of control of the material on the water surface and increased volumes of oily waste requiring disposal (*Figure 11*), the application of sorbents to an oil slick does not ease the problems inherent in at-sea containment and recovery operations. The resultant oil-sorbent mixture will likely hinder the operation of skimmers and will still be subject to the effects of the wind, currents and waves, resulting in the break-up of slicks that will be no easier to control than the original spill.

Application

The use of bulk sorbents at sea raises a number of efficiency and safety issues, as broadcasting loose powder or particulate sorbents over open water has several inherent disadvantages. Any wind is likely to cause the product to be carried away from the slick, causing wastage and additional pollution. Blowers are sometimes used to broadcast bulk loose sorbents over a spill and personnel undertaking such activities need to protect their eyes from dust and should take precautions against accidental inhalation or ingestion. Without suitable mixing of the sorbent material into the oil the sorbent may simply float on top of the oil resulting in poor efficiency. In order to overcome these obstacles, a number of special devices have been designed to discharge powder and particulate sorbents over the side of a ship in a controlled manner. To be of benefit such devices would need to be within easy reach of a spill site, whereas they are not widely available.

Sorbent boom is far easier to deploy than bulk loose sorbent. However, the limitations imposed on the use of containment boom by currents, winds and sea state are even more applicable to sorbent boom. Sorbent booms are relatively light, especially immediately after deployment, and may be lifted by the wind. They therefore require lashing or anchoring and some sorbent booms are available with lashing points provided. In order to combine the advantages of sorbents with conventional containment boom, some manufacturers have produced sorbent booms with a ballasted skirt. For minor spills of oil, for example in marinas or fishing harbours, this product may assist both the containment and the recovery operations. This is marketed as a disposable product unsuitable for reuse, bringing attendant costs of disposal.

Towing sorbent boom to recover thin films of oil or sheen from the water surface (*Figure 12*) is generally considered to be an inefficient use of resources, as sheen will usually evaporate or disperse readily. Furthermore, the effects of waves and turbulence frequently lead to saturation of the sorbent boom by water, severely limiting the recovery of oil. Saturation is more noticeable for boom composed of bulk loose sorbent material and less so for boom containing homogeneous continuous material. In addition, the forces imposed by towing are likely to be too great for most sorbent booms causing them to tear, with the consequent release of sorbent material and loss of any contained oil.

Sorbent sheets and pads are even more susceptible to being blown by the wind than sorbent booms, as they are not designed for lashing or anchoring and it is impractical to do so. The large-scale use of sorbent sheets or pads at sea is not a recommended technique as they can rapidly spread over a wide area and, although their retrieval is more feasible than recovery of bulk sorbent, it relies on slow and inefficient manual recovery. Sheets, pads and other free-floating sorbent materials stranding on beaches can rapidly become buried by successive tidal movement of the substrate and can be difficult to locate subsequently (*Figure 13*).

Figure 13: Sorbent pads stranded on a shoreline at high tide, after deployment at sea. Unless removed quickly, sand movement during subsequent tides will cover the pads, hindering recovery.

Use with other clean-up techniques

Careful management of a response and of response personnel is required to ensure that the clean-up techniques employed do not counteract each other. It is important to remember when using sorbents that the surface tension of both oil and water can be significantly altered by the surface active agents present in dispersants. As a result, the use of dispersants or other spill response chemicals can interfere with the ability of sorbents to function as designed, as they can decrease both the oleophilic and hydrophobic properties, significantly increasing the amount of water and decreasing the amount of oil recovered. Consequently, to be used effectively, sorbents should not be employed alongside dispersants in a response.

Similarly, the use of sorbents is not compatible with the mechanical recovery of oil with skimmers. Bulk loose sorbent, sorbent pads and other forms of loose sorbent can block or severely restrict weirs and pumps, while sorbent boom can restrict the flow of oil into a skimmer.

Recovery

Unless sorbent is recovered from the water surface, it becomes as much a pollutant as the oil itself. Loose particles of bulk sorbent can be blown great distances and may endanger fauna, primarily through ingestion. In particular, its use is not recommended near mariculture facilities as it may be mistakenly identified as fish food.

Recovery of any mixture of oil and sorbent material from the sea surface presents a number of difficulties. The mixture may be more viscous and bulky than the oil alone and only some heavy duty pumps and skimmers would be capable of dealing with such materials. If the material cannot be pumped, storage tanks on board recovery vessels will become redundant, calling for larger on-deck storage.

The use of seine type fishing nets has been attempted in the recovery of bulk loose sorbent/oil mixtures. However, problems encountered with the recovery of oil alone, such as clogging and reflective waves, are equally applicable to this method. The oiled nets will also require recovery, storage and either cleaning or disposal. Recovery options in these situations may be limited to inefficient and labour-intensive scoops or mechanical grabs.

The recovery of sorbent boom, sheets and pads from the water surface is a similarly time-consuming and labour-intensive operation. In particular, the increased weight of saturated sorbent boom can make hauling-in an arduous task.

Use of sorbents in 'housekeeping' and other roles

One of the most common uses of sorbents is to mop up small spills both on land and on board ships but they also find significant application in general 'housekeeping' functions, such as improving the safety of workers and preventing wider contamination. Sorbent mats can be used to minimise slippery conditions on board recovery craft and at equipment decontamination points and also at cleaning stations to separate clean and dirty sides of the operations. Similarly, sorbent mats are frequently placed at the threshold of ships' accommodation or command centres onshore to avoid oil being walked inside. As with all of the above scenarios, the sorbent should be used to capacity before it is discarded in order to avoid wastage.

In the mariculture industry, sorbent sheets have been used successfully to recover floating oil and oil films from the water surface inside fish cages, where the oiled sheets are contained and easily recovered. In relatively calm conditions, sorbent booms can be used to surround the outside of a fish cage or other sensitive resource to reduce the chance of contamination. A range of sorbent materials from loose fibres to inorganic bulk materials have also been used in the construction of filters designed to prevent oil being carried into water intakes supplying seawater to a variety of onshore facilities, such as hatcheries and salt pans.

▲ *Figure 14: Oil leaching from a recovered sorbent boom is a source of secondary contamination.*

▲ *Figure 15: Used sorbent piled in a temporary storage site. Compression will cause recovered oil to be squeezed from the boom and care is needed to avoid secondary contamination.*

▲ *Figure 16: Recovered sorbent snare hung on a pole to allow oil to run into a container, thereby minimising the amount of free oil in the waste.*

Storage, transport and disposal of used sorbents

Temporary storage and transport of oiled material

Once recovered, sorbent used at sea will need to be stored both on-board any collection vessel and then on the shore prior to final disposal. As saturated sorbent, particularly boom, is compressed through the weight of further material placed on top, adsorbed oil may leach out. On-board storage should, therefore, be enclosed to ensure leachate does not contaminate decks or gangways rendering them unsafe, or flow overboard causing recontamination. Oiled sorbent also needs to be unloaded with care to minimise contamination of quays and jetties (*Figure 14*).

Oiled debris and material, including sorbents, landed ashore and collected from the shoreline will usually require temporary storage while the logistics of transport and disposal are organised. In a large spill, the amount of material collected may exceed the capacity of available treatment or disposal facilities in the local area. The excessive use of sorbent materials exacerbates this problem (*Figure 15*) necessitating a larger temporary storage site which in many parts of the world would need to be licensed. Prior to transport, as much free oil as possible is usually removed (*Figure 16*) and, ideally, sorbents are compressed to minimise bulk and optimise transport logistics. Oil and water released as a result of compressing the sorbents must be recovered and temporary storage sites should be bunded to prevent the escape of leachate.

Disposal routes

The disposal options available for oiled sorbent materials are relatively limited when compared with those for recovered fluid oils. Even small amounts of sorbent material present in the waste stream can preclude disposal by certain routes, for example, as a feedstock in refineries.

Reuse

In theory, some types of sorbent can be reused if the oil can be extracted. This can be achieved either by compression using a mangle or wringer (as in rope mop skimmer systems), by centrifuge or by solvent extraction. Compression is generally the more practical option and is feasible for some synthetic products. However, the number of reuse cycles that can be endured before the sorbent material becomes unusable due to tearing, crushing or general deterioration should be considered.

Other factors to consider with the reuse of sorbents are contamination of the waste oil stream from particles of sorbent detached during compression, the rate of decrease in adsorption capacity and the percentage of oil that can be removed with reasonable levels of manpower and equipment. Nevertheless, some sorbents exhibit an increase in sorption capability upon repeated reuse, particularly for more viscous oils.

Incineration

Burning contaminated sorbent may be a viable option if the sorbent material is combustible and does not contain excessive quantities of water. This latter criterion often excludes the burning of used organic sorbents, as they are often less selective in the recovery of oil versus water and may contain too much water. Although incinerators may be available in the country where an incident occurs, their capacity is usually matched to domestic demand and they are likely to be overwhelmed by the sudden influx of the vast amounts of oily waste typical of a major spill. Of the different types of incinerator available, rotary kiln and open hearth furnaces are the most appropriate for large amounts of solid debris. Large pieces of debris, such as oiled sorbent booms, will need to be removed from the waste stream and reduced in size prior to burning.

The high calorific value of synthetic sorbents can make temperature control of the kiln or furnace difficult, and blending the oiled sorbents into a waste stream comprising less combustible materials may be necessary to lower the feed rate. With complete combustion of synthetic and organic sorbents, a significant reduction in the volume of material destined for landfill can be achieved. On the other hand, incineration of inorganic materials will eliminate the oil content but will not significantly reduce the volume for final disposal.

Incineration is normally strictly controlled and high temperature combustion, together with close monitoring of exhaust gases, will be required to ensure that toxic dioxins, PAHs and HCl are not discharged to the atmosphere, particularly in the case of synthetic sorbents. The cost of incineration is often considerably higher than other disposal techniques and this should be taken into account if this method is selected.

Landfill

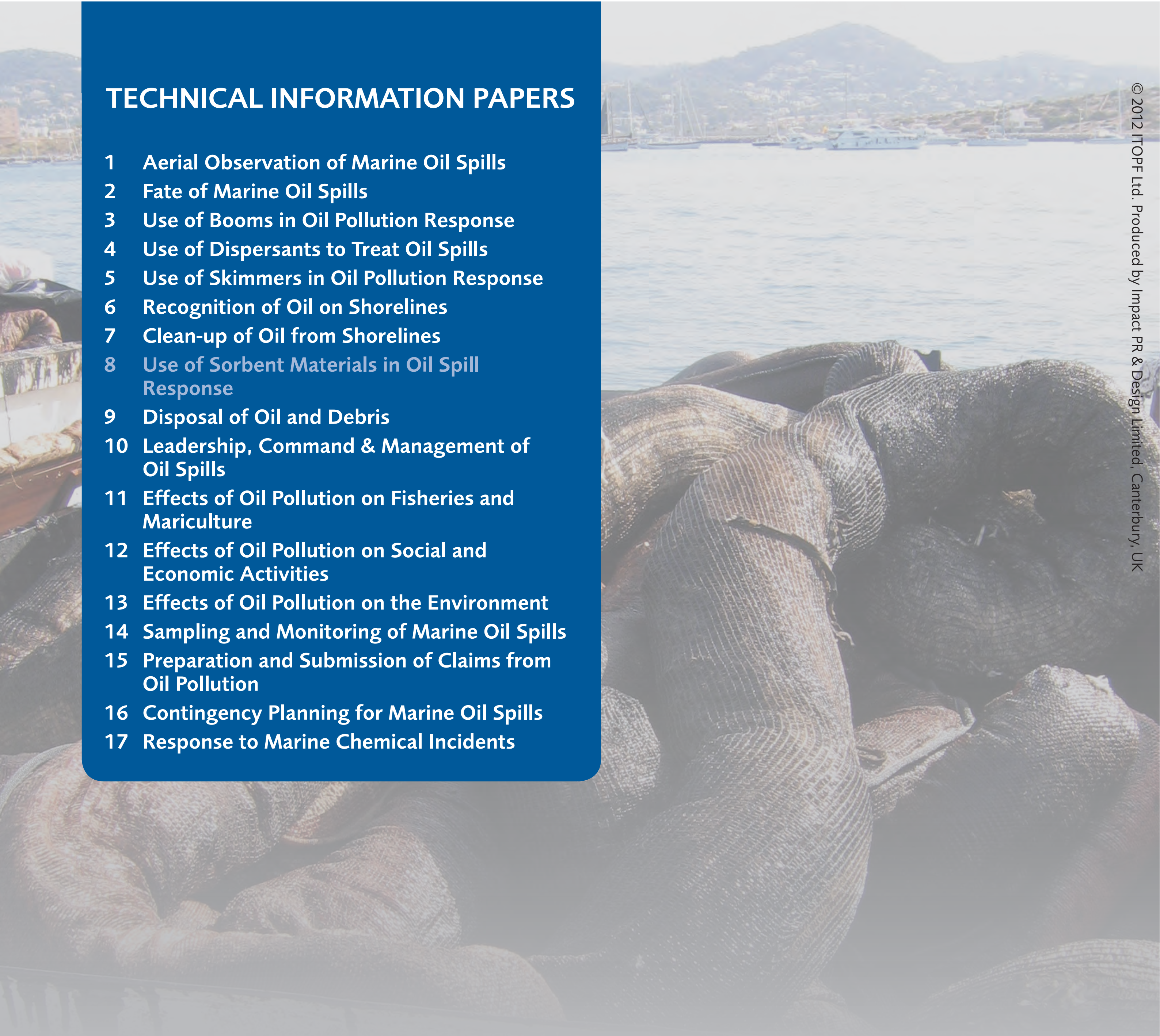
Disposal of sorbent material as landfill is also usually strictly controlled by local or national regulations. In some countries, oiled sorbent material is treated as a hazardous waste and the use of designated hazardous material landfill sites may be required, with consequent increases in the cost of transport and disposal. Modern sites are usually enclosed by an impermeable membrane to prevent run-off. Nevertheless, in parts of the world where such linings are not regularly used, attention should be given to measures to prevent contamination of nearby ground and surface waters.

Biodegradation

Organic sorbent materials generally have the advantage of being biodegradable. Depending on local waste disposal regulations and assuming a relatively low oil content, disposal of organic sorbents by land farming may be permitted. The oiled sorbent is spread over a large area of land and biodegradation is allowed to proceed. Degradation may take a number of years, although faster degradation can often be achieved by aeration using cultivation equipment and the application of fertilisers. Composting of certain organic sorbents may also be a viable disposal route.

Key points

- The large-scale use of sorbents should be strongly discouraged both onshore and at sea because it generates excessive volumes of oily waste for disposal.
- The use of sorbents can nevertheless be appropriate and effective in certain scenarios, primarily during shoreline washing operations or where other techniques are not feasible.
- The use of sorbents in the open sea to recover oil from the water is considered a highly ineffective and inefficient use of resources due to the difficulties of accurately broadcasting the material onto the oil and, more significantly, its subsequent retrieval once oiled.
- Operations utilising clean-up techniques such as dispersants and skimmers conflict with the use of sorbents and careful management of the response is necessary to avoid techniques interfering with each other.
- Sorbents are bulky to store and transport. Storage arrangements must be carefully considered to prevent damage from rodents, insects, mildew, damp, UV radiation or fire.
- Low-cost, locally available organic or inorganic materials may provide a more cost-effective option than stockpiled synthetic sorbents, despite a lower recovery efficiency for the same weight of sorbent material.
- Excessive and inefficient use of sorbent material can lead to secondary contamination and can create significant logistical and financial issues during the temporary storage, transport and disposal of oiled material. Consequently the release of sorbents from stockpiles needs to be controlled and the workforce carefully supervised to avoid these problems.



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