

DISPOSAL OF OIL AND DEBRIS

TECHNICAL INFORMATION PAPER



Introduction

Most oil spill clean-up operations, particularly those on shore, result in the collection of substantial quantities of oil and oily waste. The storage and disposal of waste is an important aspect of any response operation and adequate provisions for waste management should be clearly highlighted in any oil spill contingency plan. It is essential that arrangements made at the beginning of an incident act to prevent waste issues from compromising the response effort and becoming a costly problem that continues long after the spill clean-up is complete.

This paper explores the various options available for the management of waste material generated as a result of ship-source oil spills in the marine environment.

The waste problem

Experience has shown that the most time-consuming and costly component of a response to an oil spill is often the treatment or disposal of collected waste. The amount of waste generated is dependent on many factors, such as the type and quantity of oil spilt, the extent to which the oil spreads and affects the shoreline and, most importantly, the methods employed to recover the spilt oil and oiled material from the sea surface and the shoreline.

During even relatively minor oil spills, the amount of waste collected can quickly overwhelm existing disposal facilities. To ensure this problem can be readily addressed, methods for dealing with waste should be a key component of any oil spill contingency plan. Decisions on response techniques should take account of the amount of waste likely to be generated, where possible giving preference to those techniques that minimise the amount of waste collected. In addition, especially in the case of shoreline clean-up, firm supervision of the workforce is essential. Nevertheless, even with the use of appropriate and reasonable response methods, the volume of waste generated can sometimes be as much as ten times greater than the volume of oil originally spilt.

Once collected, the effort and expense required to deal with the waste will depend on the storage, transport, treatment and disposal options available and on local regulatory requirements. Decisions on the treatment of waste should be made at the beginning of an incident, based on a realistic estimation of the amount and type of waste likely to be generated. Effective organisation of all parts of the waste handling process is essential to avoid a major and costly problem. As global environmental awareness increases and regulatory requirements concerning waste disposal become stricter, innovative ways of using, recycling or disposing of waste are likely to be needed.

Waste management options

The 'Waste Hierarchy' is a well-established international framework for classifying and prioritising waste management options applicable to all forms of waste and is equally valid as a basis for the management of waste from oil spills. The



▲ *Figure 1: Cleaning of oiled sand in-situ by low pressure flushing, with sorbent boom deployed appropriately to capture released oil.*

hierarchy comprises five distinct steps in order of desirability:

1. **Reduce** the amount of oily waste generated, for example through the use of selective shoreline clean-up techniques that minimise collection of clean material and/or water or through the *in-situ* treatment of oiled material (*Figure 1*). Careful control of consumables, notably the use of sorbent material, will also serve to reduce waste. The separate ITOPF papers on clean-up of oil from shorelines and use of sorbent materials describe appropriate practices in greater detail.
2. **Reuse** the resources used during clean-up, for example by cleaning and reusing oiled equipment and protective clothing where possible (*Figure 2*).
3. **Recycle** liquid oil by incorporation into refinery streams or stabilise oil and oiled material for use in land reclamation or road building projects.
4. **Recovery** of the calorific value of the waste material as fuel for power or heat generation.
5. **Disposal** of waste that cannot be dealt with by one of the above options may be achieved through incineration, landfill or composting.

In reality, waste management decisions are driven by the cost and capacity of the available options that comply with waste disposal regulations in the region where the incident has



▲ *Figure 2: Minimisation of waste is an essential consideration in spill response. Personal protective equipment (PPE), including clothing, should be cleaned and reused where possible.*

occurred. Where a range of options are technically feasible (Table 1), cost effectiveness is likely to be a significant factor in the selection of the disposal route. However, oil spills are often,

by their nature, emergencies that require a rapid response, and unless due consideration has been given to waste management during contingency planning, the most practicable and cost-effective disposal options may take precedence over more sustainable waste management options.

Nature of oil and oiled material

As a general rule, spills of persistent oils, such as crude oils, heavier grades of fuel oil and some lubricating oils, are likely to generate considerable quantities of waste. Once spilt, the oil will start to weather with an associated increase in water content and viscosity. Oil collected with minimal delay is more likely to be fluid and relatively free of contamination. Over time, the oil may accumulate debris, either as a result of the break-up of the ship, from lost cargo (Figure 3) or debris originating from the shore (Figure 4).

Even if the oil is free from solid debris, recovery at sea may involve collection of significant amounts of water due to the recovery methods used, or the formation of a water-in-oil

	Type of material	Separation methods	Disposal options
Liquids	Non-emulsified oils and waste water	- Settling/gravity separation of free water - Recovered water may require further treatment/filtration	- Use of recovered oil as fuel or refinery feedstock - Return treated water to source
	Emulsified oils	Emulsion broken to release water by: - Heat treatment - Emulsion-breaking chemicals	- Use of recovered oil as fuel or refinery feedstock - Stabilisation and reuse - Incineration
Solids	Oil mixed with sand	- Collection of liquid oil leaching from sand during temporary storage - Extraction of oil from sand by washing with water or solvent - Removal of solid oils or tarballs by sieving	- Use of recovered liquid oil as fuel or refinery feedstock - Return treated water to source - Stabilisation and reuse - Degradation through land farming or composting - Landfill - Incineration
	Oil mixed with cobbles, pebbles or shingle	- Collection of liquid oil leaching from beach material during temporary storage - Extraction of oil from beach material by washing with water or solvent	- Return cleaned stones to source - Stabilisation and reuse - Landfill
	Oil mixed with wood, plastics, seaweed, shellfish and sorbents Oiled fishing equipment and stock – nets, floats and racks	- Collection of liquid oil leaching during temporary storage - Flushing of oil from debris with water - Removal of free water - Compression	- Stabilisation and reuse following removal of plastics and large debris - Degradation through land-farming or composting for oil mixed with seaweed, shellfish or natural sorbents - Landfill - Incineration
	Tarballs	Separation from sand by sieving	- Stabilisation and reuse - Landfill - Incineration

▲ *Table 1: A summary of the main options typically available for separation and disposal of oil and debris.*

emulsion (*Figure 5*). Alternatively oils with a pour point above sea temperature may quickly become semi-solid (*Figure 6*), necessitating recovery by scoops or grabs that also tend to recover significant amounts of water. Spills of non-persistent oils tend to evaporate and disperse naturally within a short period of time and are therefore less frequently associated with waste generation issues.

Oil recovered from the shoreline will usually be mixed with substantial amounts of other material, such as sand, pebbles, wood, plastics and seaweed; each material may require a different method of treatment or disposal and separation can be difficult. For example, oily wood may be burnt under controlled conditions, possibly *in situ*, whereas burning oily seaweed is impractical. Oiled materials from response operations, such as adsorbent materials (*Figure 7*), protective clothing (PPE), damaged containment boom, storage sacks (*Figure 8*) and other types of waste receptacles can also contribute significantly to the volume of waste produced following an oil spill, particularly if large numbers of inexperienced workers or volunteers are used. Considerable amounts of waste can also be generated if fishing gear and mariculture facilities are contaminated and cannot be cleaned satisfactorily, or if stock is condemned. These issues are

considered in more detail in a separate ITOPF paper on the Effects of Oil on Fisheries and Mariculture.

Transport, storage and preparation for disposal

The large volumes of waste requiring disposal following clean-up can often present major logistical problems during handling and transportation. In order to allow clean-up operations to continue unhindered, it is usually necessary to store the material temporarily to provide a buffer between collection and final treatment and/or disposal. This also allows authorities time to select the appropriate method for dealing with the waste, if not already identified. In the case of waste resulting from shore clean-up, storage at the back of the beach above the high water mark (*Figure 8*) enables the transportation to be undertaken in two stages: from primary storage on the beach to intermediate storage and eventually to final treatment and/or disposal as necessary. This reduces the risk of contamination of roads by restricting the number of vehicles involved in the first stage transfer from the beach.



▲ *Figure 3: Waste plastic from containers lost overboard, mixed with oil and stranded in mangroves.*



▲ *Figure 4: Oil mixed with discarded plastic, domestic rubbish, timber, vegetation and other waste.*



▲ *Figure 5: Emulsified oil stranded on sand. Selective manual recovery serves to minimise the amount of clean substrate removed.*



▲ *Figure 6: Semi-solid oil contained within a boom. The difficulties of pumping the oil can limit the available disposal routes.*

Oily waste must be transported, stored and disposed of in accordance with local regulations. In some countries, licences will be required for temporary disposal sites and by the contractors engaged for the various disposal tasks. Consultation with regulatory and licensing authorities, from the outset of the incident, will assist with this important administrative component of the disposal process.

As far as possible, and provided more than one disposal route is available, the different waste streams should be segregated at the point of collection and stored separately. The loss of control and discipline at any stage of the disposal route can lead to later complications and unnecessary additional costs (*Figure 9*). For example, bulk oil, oily debris and non-oiled materials should be stored in separate areas so that different methods of treatment and disposal can be followed for each category. Provided the bulk oil can be pumped at ambient temperatures, it can be stored in enclosed tanks. However, care should be exercised during the bulk storage of more viscous materials, particularly if the tanks are not fitted with heating coils, as emptying the tanks may be difficult without heating. Large volumes of recovered oil may be stored in tanker vessels, if available, although this may be an expensive option.

Highly viscous oils should be stored in open containers such as barges, skips or drums to facilitate treatment and transfer operations. If waste oil is to be stored for a significant length of time, covered containment is essential to prevent rainwater ingress (*Figure 10*), which may cause the oil to float and overspill. If purpose-built containers are not available, bulk oil from shorelines can be held within compacted earth walls or in simple storage pits lined with heavy gauge polyethylene (or other suitable oil-proof material). Long narrow storage pits approximately 2 metres wide and 1.5 metres deep are preferable to maintain ready access to all parts of the pit (*Figure 11*). However, the size and number of pits should reflect the volume of waste expected. If there is a possibility of heavy rainfall, allowance should be made for this when filling the pits. Where temporary storage of bulk oil is required in sensitive areas, such as sand dunes, it is important to avoid disturbance of the stabilising vegetation as this could lead to erosion. Wherever dug, pits should be filled in after complete removal of the oil and, as far as possible, the area restored to its original state.

Plastic sacks should be regarded as a means of transporting oily material rather than for storage as they tend to deteriorate and degrade in sunlight, releasing their contents (*Figure*



▲ *Figure 7: Partially oiled sorbent boom. The large-scale use of sorbent materials should be avoided in order to minimise waste generation.*



▲ *Figure 8: Plastic bags containing oiled beach material stored temporarily above the high water mark, on plastic sheeting to contain any leachate.*



▲ *Figure 9: A well-lined pit containing poorly segregated waste, requiring considerable additional effort to separate and treat.*



▲ *Figure 10: Recovered oil stored in a barge. A cover is required to prevent rainwater ingress.*

12). If the contents are to be treated in some way prior to disposal, it will usually be necessary to empty the bags and dispose of them separately. Irrespective of whether waste is stored in containers, in heaps or piles or by other means, the storage area should be lined and provisions made to catch and treat leachate to prevent secondary contamination of the surrounding area and groundwater (*Figure 13*). Odours resulting from decomposing oiled vegetation, flies and vermin can be a nuisance if temporary sites are located close to populated areas.

Security of temporary waste storage areas should be proportionate to the risks associated with unauthorised access and might range from signage and cordoned-off areas to more impenetrable fencing and 24-hour surveillance. Without adequate security, especially close to urban centres, there is the additional risk of domestic or commercial waste being dumped at temporary storage sites. The time taken to transfer waste to designated final disposal sites should be minimised so as to avoid problems caused by waste being dumped and from secondary contamination.

Where final disposal methods have been identified and capacity allows, transport of waste from the shoreline directly

to the site of final disposal negates the need for temporary storage. This avoids double-handling, minimises the build-up of waste and allows the overall response to be completed more quickly and cost effectively.

It is good practice to record the quantities and types of oily waste being collected to allow progress to be monitored within the command centre. Records will also be useful for the formulation of a subsequent claim for compensation.

Minimisation of waste

The problems associated with disposal will be reduced if priority is given to minimising the amount of waste generated during the response. Unless other overriding factors are present, this should be an important factor when considering clean-up techniques.

Disposal is often complicated by the amount of debris recovered with the oil. Coastal surveys to identify where debris collects naturally will often indicate where oil is likely to come ashore. Debris can sometimes be removed from these shorelines before the arrival of oil, at nominal cost



▲ *Figure 11: Skip emptying emulsified fuel oil into a lined temporary storage pit.*



▲ *Figure 12: Degradation of plastic sacks by long-term exposure to sunlight can lead to recontamination.*



▲ *Figure 13: Capture and treatment of leachate from oiled sand piled in temporary storage prevents secondary contamination of the surrounding area and groundwater.*



▲ *Figure 14: Removing debris from the shoreline before oil strands will help reduce the quantity of oiled material requiring disposal.*



▲ Figure 15: Decanting of water into the spill area, after settling and separation of recovered oily water in a vacuum truck.

relative to the cost of its disposal once oiled (Figure 14). Alternatively, debris collection areas could be prioritised for protection with boom, to reduce the risk of clean debris becoming oiled.

In an effort to minimise the amount of waste water for final disposal, it may be possible to decant water that has separated from the oil/water mix recovered at sea or nearshore. After the oil has settled and separated in tanks onboard skimming vessels, vacuum trucks (Figure 15), or other devices, water may be run off from bottom valves into a boomed area. Concentrating the oil in this way serves to maximise the capacity of temporary storage, thereby reducing interruptions in the recovery operations while additional capacity is arranged. However, it should be noted that in some countries local legislation may prohibit the discharge of any liquid to sea without specific dispensation from the relevant authorities.

It may be possible to recover oil from contaminated beach material *in situ*. For example, oil seeping from collected beach material and debris can be contained within a ditch or bund surrounding the storage area. Oiled beach material may then be flushed with water, sometimes in conjunction with a suitable solvent, such as a citrus-based cleaner, to release the oil. Washing can be carried out using low pressure hoses to loosen and lift off oil from debris contained in a temporary storage pit. The resulting oil/water mixture can then be pumped to subsequent gravity separation. Another approach is to place contaminated material on a grill or wire mesh, with the oil draining into a skip or tank positioned beneath (Figure 16). This process can be assisted by washing the waste with water, although significant volumes of oily water can be generated. Separation can also be achieved in a closed system using water or a solvent. Devices have



▲ Figure 16: An improvised waste filtration system, where recovered oil is passed through a grilled funnel to filter out debris.

been developed based on a range of equipment, from standard cement mixers for small-scale batch operations to mineral processing equipment for large-scale continuous treatment. Although these large-scale systems have proved successful in specific circumstances, they are slow to achieve satisfactory levels of cleanliness and high levels of fines or tailings in the waste water can be difficult to separate. Consequently, they have not yet found widespread application at oil spill incidents.

The volume of waste can also be reduced by separating oil, in the form of tarballs, from clean sand by selective manual picking where a site might require a high standard of cleanliness, such as on tourist beaches. Sieving devices, both static and mechanical, are also sometimes used to remove oily sand residues and tarballs from lightly contaminated sand (Figure 17). While often labour intensive, the cost of cleaning large amounts of oiled beach material on-site could compare favourably with other methods that involve transporting the material some distance from the shoreline and subsequent disposal.

In many incidents, a large percentage of the waste generated is synthetic adsorbent material and a significant proportion of this material is often lightly oiled or not oiled at all (Figure 7). Waste problems will be subsequently reduced if adsorbent is used only when other techniques are unsuitable and if care is taken to ensure it is used to its full capacity.

Where oily waste is to be co-disposed with domestic refuse by incineration, agreement on a sliding scale of costs according to the calorific value of the waste can be an incentive to minimise the amount of non-oiled waste collected: the higher the oil content and hence the calorific value, the lower the price of disposal.



▲ *Figure 17: Mechanical sieving of tarballs from sand in order to reduce the amount of waste generated.*



▲ *Figure 18: Stabilisation of oily waste using quicklime.*

Treatment and disposal options

A number of options are available for the final treatment and disposal of oil and oily waste and these are summarised in Table 2 and detailed below. The disposal method most appropriate in an incident will depend on several factors, including the nature and consistency of the waste, the availability of suitable sites and facilities, the costs involved, as well as regulatory restrictions.

Recovery of oils

Oily waste may be treated to recover sufficient quantities of oil for eventual processing or blending with fuel oils for subsequent use. This process makes use of the calorific properties of the oil and has the potential to generate financial income from its sale, to offset the costs of disposal. This is often the most cost effective use of recovered oil and should be among the first options to be considered. Possible recipients for processing or blending are refineries, oil recovery contractors specialising in recycling waste oils, power stations and cement works. However, most of these facilities can only accept feedstocks with narrow specification criteria, so the recovered oil must be of a suitable quality. For example, the oil should be pumpable, low in solids and have a salt content of less than 0.1% for processing through a refinery, or less than 0.5% for blending into fuel oil. Assuming that the oil is suitable for recycling, it is likely that the potential refiners or other users will have limited storage or processing capacity and alternative intermediate storage may be required. Vessel slop reception facilities and tanker deballasting stations may be appropriate in this regard but may also have limited capacity.

Oil collected from the sea is likely to be the easiest to prepare for processing since it will usually only require separation from any associated free water. The extraction of water from water-in-oil emulsions is more difficult. Unstable emulsions may be broken by heat treatment at temperatures of up to 80°C, allowing the oil and water to separate by gravity. More stable emulsions may require the use of chemicals known as 'emulsion breakers' or 'demulsifiers'. Both heat treatment and demulsifiers can reduce the viscosity of most oils, rendering them more pumpable.

No single chemical is suitable to break all types of emulsion and on-site trials may be necessary to determine the most effective agent and optimum dose rate. Typical dose rates are in the range of 0.1% to 0.5% of the bulk volume to be treated. Treatment should be undertaken during transfer of the emulsion from the collection device to a tank or from one tank to another to ensure good mixing and to minimise the dose required. The emulsion breaker can be injected into the inlet side of a pump or an in-line static mixer incorporated into a vacuum intake. After separation, the water phase will contain most of the emulsion breaker and up to 0.1% of oil and therefore, care should be exercised when disposing of this mixture.

Stabilisation

Oily sand that does not contain large amounts of driftwood and other debris can be bound with an inorganic substance such as quicklime (calcium oxide) to form an inert product that prevents the oil from leaching out and that can be disposed of under less stringent conditions than untreated oily sand (*Figure 18*). Alternatively, such mixtures may be used for land reclamation and road construction, where high load-bearing properties are not required, such as service roads or roadside embankments. Clearly the suitability of the technique is dependent upon a plentiful supply of stabilising material. Quicklime can usually be sourced from cement works and has the advantage that the heat generated by its reaction with water in the waste reduces the viscosity of the oil, facilitating binding. Other materials such as cement, zeolite, pulverised fuel ash waste and some commercially available products may also be applicable.

The optimum amount of binding agent required is primarily dependent on the water content of the waste rather than the amount of oil and this can be determined by experiment. For quicklime, the amount required is typically between 5 and 30% by weight of the bulk material to be treated. Treatment can be carried out either at a central facility or at the spill site. At a treatment centre, the agent would be mixed with the waste in a continuous process. This method requires the use of expensive equipment such as a continuous drum mixer. Smaller quantities could be treated in a batch

process using concrete mixers, although the heat generated by the process and the corrosive nature of the reaction may preclude their use.

Alternatively, waste can be spread out in treatment beds at the final disposal site in layers up to 30cm thick and mixed using a pulverising mixer which incorporates the lime. Following treatment, the waste is either left in place and covered over or sent to landfill. Provided sufficient land is available, this can be a more cost effective method.

On occasion it may be preferable to carry out primary mixing in pits at the site of the spill so that the mixture can be more easily transported, for example in open-top trucks or skips rather than in tank trucks. The final treatment can then be undertaken at a larger reception facility using specialised equipment.

This technique can give rise to a great deal of corrosive dust and if possible the treatment site should be selected in order to minimise its spread to adjacent areas. It is also important that operating personnel wear protective clothing and face masks to protect skin, lungs and eyes. If, after mixing, the material is to be utilised in road construction, compaction using road building equipment is essential.

Incineration

In certain situations, *in-situ* burning of freshly spilt, floating oil can be a successful method of removing large amounts of oil quickly. However, spilt oil tends to lose its volatile

components after a short time at sea and typically picks up a high proportion of water. Consequently, burning oil that has stranded on the shore can be difficult without first reducing the water content, particularly if the oil has been at sea for a long period. The direct burning of uncontained oil or oily debris onshore is not recommended, except in very remote areas, as the resultant fire and dense smoke can be difficult to control. When oil is burnt on land in the open, it also tends to spread and be absorbed into the ground. In addition, a tarry residue may remain as it is rarely possible to achieve complete combustion.

These problems can be overcome using an incinerator that destroys the waste by controlled burning at high temperatures. Portable incinerators have been developed for use in remote locations, primarily to burn medical waste. However, local legislation and environmental concerns may prohibit the use of such devices to burn oily waste on the shoreline and they can only accommodate small-scale waste in small batches. On a larger scale, cement factories and industrial kilns are an effective way of incinerating oily waste, subject to technical constraints, such as the removal of large solids, and problems associated with heavy metals, chlorine or sulphur in the waste.

Co-incineration in a cement works is also a cost effective method of disposal, as waste with an adequate calorific value can be used as a substitute for fuel that would otherwise be needed to fire the kiln. In addition, the ash resulting from waste combustion provides aluminium, silica, clay and other minerals typically added in the raw material feed stream

	Benefits	Disadvantages
Re-Processing	- Recycling through use of the calorific properties of the oil - Permanent storage not required	- Oiled waste may require treatment before processing - Facilities and processing capacity are limited - Long term storage of waste may be required whilst awaiting processing
Stabilisation	- National legislation often allows for easier disposal of stabilised oiled material - Recycling through use of stabilised oiled material in construction	- Only appropriate for oiled sand, shingle and pebbles with debris of limited size - Treatment of oiled material requires skilled personnel and suitable reception facilities and equipment
Incineration	- Can be employed for many types of oiled material - Permanent storage not required	- Relatively expensive disposal process - Appropriate facilities and processing capacity are limited - Long term storage of waste may be required
Land-farming or composting	Enhances natural process of biodegradation	- Suitable sites are increasingly difficult to find - Only applicable to relatively small spills because of the large area of land required - Not all oil components may be degraded - Slow process, requiring periodic tilling and monitoring
Landfill	- Organic waste may biodegrade naturally at a landfill - Can rapidly deal with large amounts of waste	- Restricted application dependent on local legislation - Sites designated for hazardous waste are scarce and can charge high rates - Many types of waste likely to persist for a long time

▲ Table 2: A summary of the benefits and disadvantages of the options typically available for treatment and disposal of oil and debris.



▲ *Figure 19: Sacks of oiled waste being fed into the loading chute of a large industrial incinerator for co-disposal with domestic waste.*

for cement manufacture. However, the type of oily waste accepted is limited and cement works are often located far from the shoreline, so transportation costs and logistics must be considered.

As a general rule, incinerators used for domestic waste are not suitable for disposal of large amounts of oil, as chlorides from seawater may cause corrosion of the incinerator infrastructure. Co-disposal of low amounts of oily waste with other refuse may be acceptable at some facilities, but the volume of oiled to non-oiled waste will require careful consideration in order to control the incineration temperature (Figure 19). Oiled protective clothing, sorbents, netting or other materials that may have a low oil content are often treated in this way. High temperature industrial waste incinerators, while more likely to tolerate salts, are limited in number and may be located in remote parts of the country. They may not have sufficient capacity to deal rapidly with the additional burden created by a large quantity of oily waste. However, this may be an acceptable and effective disposal route if long term storage is available that would allow oily waste to be incorporated into the waste stream gradually.

Pyrolysis, the thermal degradation of waste into gas and solid residues in the absence of oxygen, is another process that has been used during a major incident, although this is a specialised and expensive process for which facilities are limited.

Land-farming and composting

Oil and oily wastes will, given sufficient time, usually break down through biological processes (biodegradation). However, the rate at which this occurs is too slow for it to be a viable short term clean-up option. Biodegradation of oil by microorganisms can only take place at an oil-water interface so that, on land, the oil must be mixed with a moist substrate. The rate of degradation depends upon temperature and the availability of oxygen, nitrogen and phosphorous. Some oil components, such as resins and asphaltenes, are resistant to degradation and may persist for prolonged periods.

Bioremediation is the term used for methods that accelerate the



▲ *Figure 20: Landfill waste facility. Waste with low oil concentrations can be placed with domestic waste under carefully controlled conditions.*

microbial breakdown of oil. One such method is land-farming, whereby the oil and debris are spread over a designated area of land. For many years, oil refineries constructed land-farms to deal with oily wastes but increasingly, legislation is restricting its use and sites suitable for land-farming are becoming difficult to find. Land-farming is only likely to be applicable to relatively small spills because a large area of land is required and because degradation rates are slow. The contaminated material should have a relatively low oil content and, ideally, the land selected should be of low value, located well away from drinking water supplies and should not be permeable. The top soil should first be loosened by means of a harrow and the area banded to contain any oil run-off. The oily debris is then spread over the surface to a depth of no more than 20cm, the maximum application rate being about 400 tonnes of oil per hectare of land. The oil should be left to weather until it is no longer sticky before being thoroughly mixed with the soil using a plough or rotovator. Mixing should be repeated at intervals to increase aeration and hence the rate of biodegradation. Fertilisers may also be added to enhance biodegradation rates. If land-farming techniques are employed, the use of natural adsorbents, such as straw, peat or bark, during clean-up operations is preferable to synthetic materials as they break down more rapidly. Large items of debris, such as timber and boulders, should be removed. Once most of the oil has degraded, the soil should be capable of supporting a wide variety of plants, including trees and grasses. If crops are grown they should be carefully monitored for heavy metal content.

Another effective means of enhancing degradation is to employ composting techniques, particularly for contaminated seaweed and for natural adsorbent materials. Provided the mixtures contain relatively low levels of oil they can be stacked into heaps to facilitate composting and some success has been achieved by introducing air to accelerate decomposition. Because the heaps retain heat generated during composting, the technique is particularly suitable in colder climates where degradation through land-farming is slow.

The use of commercially available bioremediation agents and fertilisers may be appropriate in certain circumstances,

to accelerate natural oil degradation. However, they should be employed with caution to ensure the benefits of their use are cost effective.

Landfill

Disposal of oily waste to specially designated landfill sites is the most commonly used method and although this is now severely restricted by legislation in many countries, it may provide the only realistic option to cope with the quantities of waste generated in a spill. Landfill sites are often licensed under specific conditions and acceptance of waste may be limited to certain types or volumes of waste, or to waste where the concentration of contaminant is below a certain threshold. In some countries, oil-contaminated waste will need to be disposed of in a site designated for hazardous refuse. These sites are typically few in number and may be a considerable distance from affected shorelines.

Where direct disposal is acceptable, the material intended for disposal should have a low oil content to avoid secondary contamination from leachate. The exact content varies according to location. Sites for oily waste disposal should be located well away from fissured or porous strata to avoid the risk of contamination of ground water, particularly if this is abstracted for domestic or industrial use. The co-disposal of oil and domestic waste may be acceptable in some countries (*Figure 20*) as the oil appears to remain firmly adsorbed by all types of domestic waste with little tendency to leach out. The oily waste should be deposited on top of at least 4 metres of domestic refuse, either in surface strips 0.1m thick or in trenches 0.5m deep to allow free drainage of water, and

should be covered by a minimum of 2 metres of domestic waste to prevent the emergence of oil to the surface when subjected to compression from site vehicles.

Contingency planning

Contingency plans should review the disposal options available for dealing with different amounts and types of oily material. Plans should be local in scope, as the clean-up and disposal methods adopted will be largely dependent on national and local waste legislation, as well as on the availability of raw materials, equipment and suitable disposal sites close to the spill. Plans should be updated regularly to incorporate changes in legislation that may affect the availability of some disposal options. Contact details of contractors specialising in oil recovery and/or processing and the locations and capacities of refineries, incinerators and other facilities that could accept waste should be included in the Information Directory of the plan.

The risk assessment undertaken as part of the contingency planning process will identify areas where spills are more probable and where oil might come ashore. Sites for the temporary storage of waste, close to these high risk areas, should be identified at an early stage. The problem of final disposal can then be approached in stages to avoid exceeding the capacity of each disposal route. Pre-agreement with landowners and regulatory authorities will simplify the construction of storage sites when a spill occurs. Further guidance is given in the separate ITOF paper on contingency planning.

Key points

- Disposal of oil and oily waste is a major problem, particularly following shoreline clean-up when there is likely to be a large quantity of associated debris. Therefore consideration of waste disposal during contingency planning is essential.
- Although a variety of techniques have been developed for dealing with oil and oily wastes, many have limited application and capacity. In the event of a major spill, all options need to be considered.
- Decisions on waste treatment are best made at the start of an incident and should be based on realistic expectations of the types and amount of waste likely to be generated.
- In determining potential waste recovery or disposal routes, local waste legislation should be adhered to and relevant authorities consulted.
- The availability of temporary storage should be pre-identified in areas of high spill risk to act as a buffer between the collection of oil at sea or on shore and final disposal.
- Where disposal routes exist for different waste streams, waste should be segregated from the point of collection.
- The feasibility of recovering usable oil should be examined before disposal and consideration given to realising some credit in respect of the calorific value of the waste.
- Techniques which lead to the destruction of the oil are preferable to landfill, although they are likely to be more costly.
- The costs of disposal, including handling and transportation, are likely to be a very significant component of the overall cost of a spill response.

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- 2 Fate of Marine Oil Spills
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ITOPF is a not-for-profit organisation established on behalf of the world's shipowners and their insurers to promote effective response to marine spills of oil, chemicals and other hazardous substances. Technical services include emergency response, advice on clean-up techniques, pollution damage assessment, assistance with spill response planning and the provision of training. ITOPF is a source of comprehensive information on marine oil pollution and this paper is one of a series based on the experience of ITOPF's technical staff. Information in this paper may be reproduced with the prior express permission of ITOPF. For further information please contact:



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