Environment Canada — Environnement Canada
Atlantic Region — Région de l'Atlantique

Information Bulletin

Cleanup of Oiled Shorelines

A discussion of the methods by which oil can be cleaned from different types of shorelines.

Canada

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BACKGROUND

Petroleum may be second only to food as the most important substance consumed in modern society. It is the great provider, supplying raw materials for a continually expanding range of plastic and synthetic products, and also the fuels that supply more than half the world's energy.

Petroleum is consumed globally on a vast scale. Canada's present demand for oil is almost two million barrels per day, or approximately 3% of the world's consumption.

But as often happens with many of the materials that benefit humankind, there is a price to pay. With such wide-scale global production, use and transport of oil, it has become a significant pollutant in many environmental media, but particularly in the oceans of the world.

It has been estimated that of the nearly three and a half billion tonnes of oil produced per year, about three million tonnes enter the oceans. A small but significant portion of this amount will eventually come to rest on the shoreline.

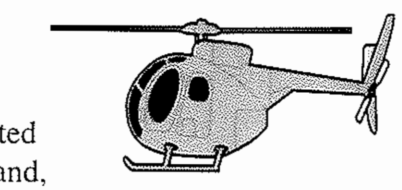
RELEVANT CONSIDERATIONS

This booklet will detail the techniques and options that apply to the cleanup of oil on shorelines. However, in making a decision regarding the choice of cleanup options, a number of factors must be assessed. These include an estimate of the amount of oil on the shore; the extent of polluted coastline; the type and properties of the spilled oil; the type of shoreline affected and the behaviour of the oil onshore.

Amount and Extent of Oil

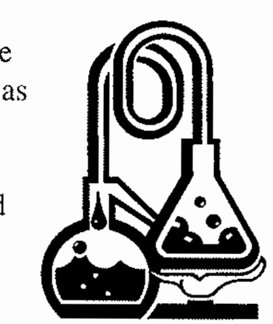
One of the most difficult tasks in determining the type and intensity of the cleanup effort is estimating the quantity of oil that has come ashore. This is made increasingly difficult if the shoreline is pocked with notches and holes into which the oil can seep and accumulate.

The general extent of oil accumulation is often determined by aerial surveillance, conducted using low flying airplanes or, more often, helicopters. Aerial surveys are complemented by more detailed surveys conducted along the shore on foot and, where practicable, using vehicles. These detailed surveys are often vital for deciding on such matters as access routes and feasibility and type of cleanup.



Oil Types and Characteristics

Although "oil" is a general term that can be applied to a wide variety of natural substances that can be organic or mineral in origin, as well as to many synthetic materials, this booklet addresses only crude oils and products resulting from the refining of such oils.



Crude oils are very complex mixtures of hydrocarbons, some containing as many as three hundred different compounds. Because of the complexity of their makeup, crude oils possess a wide range of physical and chemical characteristics. For example, all crude oils contain what are known as "lighter" fractions, portions of the oil which are similar to gasoline in nature. Heavier fractions, more tarry or waxy in consistency, may also exist.

No two crude oils are exactly alike, and indeed, depending on the source, the oil may vary in consistency from a rather light and volatile liquid to one which is heavy, thick and viscous.

Once crude oil is released at sea, it is immediately subjected to the vagaries of the ocean and the atmosphere. Its properties begin to change and it takes on different characteristics. Some of the lighter fractions may evaporate, some may dissolve in the water column or be dispersed, some may be degraded by bacteria, and some may be whipped by the wind and sea into a water and oil emulsion colloquially known as "chocolate mousse", which is a quite accurate description of its appearance.

In any event, given that it is very unlikely that oil released at sea can be completely recovered before some of it gets to shore, the strategies and technologies employed in any shoreline cleanup will depend to a significant extent on the often changing properties of the oil. The most important of these properties which influence the effectiveness and the efficiency of cleanup operations include the boiling point; the specific gravity; the flash point; the pour point; the surface tension; the viscosity, and the solubility.

The **Boiling Point** is the temperature at which each hydrocarbon fraction in the crude oil will evaporate. Some lighter fractions, for example, evaporate at temperatures below 20^0 C and on a warm day will rapidly be lost. It is estimated that in the initial twenty-four to forty-eight hours after a spill, approximately 30-40% of the oil evaporates. *After the spill from the "Amoco Cadiz" off the coast of Brittany in 1978, almost one third of the total volume of oil was lost through evaporation.* As the light fractions evaporate, the amount of oil left is reduced, while at the same time becoming heavier and more viscous.

The **Specific Gravity** is a measure of the density of the oil relevant to the density of water, which has a specific gravity of 1.0. The specific gravity of most oils is less than 1.0, and therefore they will float on the surface of the ocean. Although it is very rare for oil to sink, some heavy crude oils and fuel oils, or lighter oils that have lost their more volatile fractions through weathering and evaporation, may have specific gravities greater than 1.0 and will sink below the surface.

The **Flash Point** of the oil is a critical factor from the perspective of the safety of cleanup operations. It is the lowest temperature at which oil vapours will ignite if exposed to an ignition source such as an open flame. This is not a problem in dealing with spills of bunker fuels or weathered crude oils, but it can

be very important if the crude oil is fresh and the air temperatures exceed the boiling points of the lighter fractions. Strong vapours also pose a potential health risk to cleanup crews.

The **Pour Point** is the temperature below which the oil will not flow. If the ambient temperature is below the pour point, the oil will essentially behave as a solid. This property is a very important characteristic of oil in relation to shoreline cleanup, since it determines to a great extent whether oil will penetrate into the shoreline substrate. *During the oil spill from the "Arrow" in Chedabucto Bay, Nova Scotia, in the winter of 1970, because of the cold water and low ambient air temperatures, in many places where the oil came ashore it was almost semi-solid. As temperatures increased during the late spring and summer, the oil liquefied again, causing it to sink deeper into the beach sediments.*

Surface Tension, together with the viscosity, determines the rate of spread of an oil slick. Spilled oil with a low surface tension will spread more quickly than oil with a higher surface tension. The ambient temperature also has an important effect on the surface tension, which decreases with increasing temperature. Surface tension is an important consideration during shoreline cleanup because oils with a low surface tension, such as lighter crude oils, will spread more rapidly over the shoreline, and also penetrate the sediments to a greater extent than oils with a higher surface tension.

Viscosity basically refers to the degree of 'stickiness' of the oil, or to the ease with which the oil will flow. The lower the viscosity, the more fluid the oil. As with surface tension, viscosity decreases with increasing temperature, and oil can more easily penetrate beach sediments.

The **Solubility** of oil in water is generally very low, but it is very important since the more soluble aromatic components of the oil can be extremely toxic to marine organisms.

Types of Shorelines and Oil Behaviour

Once the oil reaches shore, the problem of dealing with it is complicated because of the variety of beaches and coasts that exist. Although the types of shoreline are numerous, in very simple terms, they can be divided into three basic types: rocky coasts, sediment covered shorelines and man-made structures. All three types of shoreline are found in Atlantic Canada.

Rocky Coasts

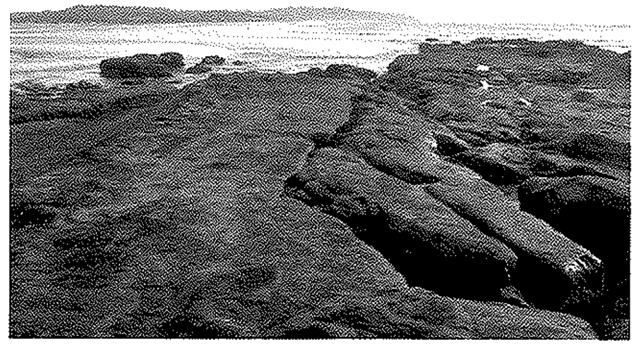
Rocky coasts are generally stable and relatively impenetrable, consisting of cliffs or rock outcrops, as well as intertidal rock platforms.

If wave action is intense on steep shorelines, the reflected waves may keep the oil from coming ashore. If oil does reach the shore, it will generally coat the rocks and may even be splashed by breaking waves onto rocks higher up the shore. If the rocks are wet, oil won't stick to them very well, and will generally refloat as the tide ebbs, but may be redeposited higher on the shore as the tide rises.

If the slope of the rocky shore is steep, the oil may run off leaving only a thin layer on the rocks, but may collect in tide pools and crevices as the tide goes out, particularly if the coastline at the water's edge is low and rocky.

Oil deposited on rocky shorelines is subject to the action of wind and waves, and will usually disperse naturally over a period of time. In general, the length of time that oil will remain on such shores depends on the amount and location of the oil, the openness or exposure of the shoreline, and the degree of wave or ice action.

Intertidal rock platforms are fairly common shoreline features, and, as their name indicates, they are alternately uncovered and covered as the tide ebbs and flows.Tidal pools, crevices and niches are common characteristics of platforms, and oil can be trapped in these pools as well as on the surface of the platforms.

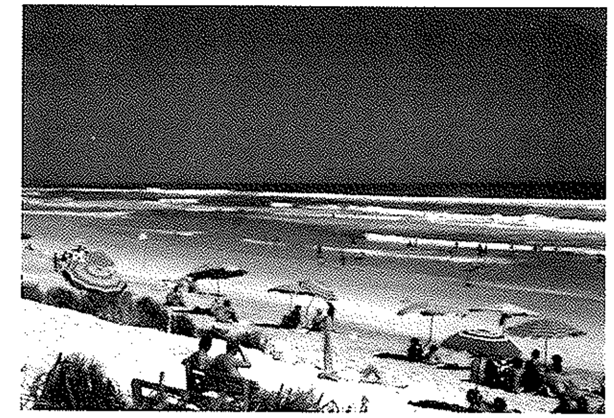


As with shorelines dominated by cliffs and rock outcrops, the oil may be subjected to the same forces of wave and tide, although it may be trapped for longer periods of time in the pools and on the vegetation that often grows in the intertidal zone.

Sediment Covered Shorelines

Sediment covered shorelines include beaches composed of sand; sand and gravel; cobbles, pebbles and shingles; intertidal mud flats, as well as marshes.

The sediments of **sand beaches** tend to be quite mobile, and as a general rule tend to become coarser and more unstable as the wave action intensifies. Coarse sand beaches often have steeper slopes than finer sand beaches, and tend to dry out during low tides. This allows oil on these types of beaches to penetrate to a greater depth than on flatter, fine grained beaches which generally remain wet throughout the tidal cycle.

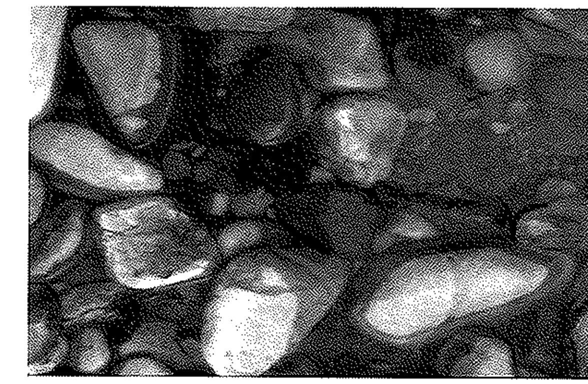


Because oil generally won't adhere to the wetter beach surfaces, it will often be carried by waves and tides to the higher, drier portions of the beach. Sometimes lighter oils will penetrate into beach sands, and when this happens the oil may remain buried for several months.

Because of the adverse natural forces to which sand beaches are often exposed, such as storms and the subsequent wave action, the beaches undergo cycles of erosion and renewal. If oil comes ashore after the beach has been eroded, the subsequent deposition of sand during recovery can bury the oil, which may not resurface until the next period of storm erosion. This type of process often accounts for the discovery of oil on beaches when there has been no obvious oil spill in the vicinity for some time. *Such was the case with the appearance on beaches of oil from the "Arrow" spill in 1970 and the "Kurdistan" in 1979, after beach patrols only days previously had found no oil at all.*

The most common type of beach found along Canada's coastline is the mixed **sand and gravel** beach. While somewhat similar to sand beaches, they are more stable because of the larger size of the beach material, but by the same token, oil can penetrate this type of beach more readily than a sand beach. The degree and rate of natural cleaning of the oil will again depend on the intensity of wave action.

Beaches consisting of **a mixture of cobbles, pebbles and shingle** are common as well, and as expected, the material comprising these beaches is relatively large.



Because of the size of the material, large spaces also exist between the pebbles and cobbles. Oil will accumulate in these spaces, often forming a type of asphalt pavement.

Intertidal mud flats are generally found in sheltered parts of the coastline such as bays and estuaries, where wave action is generally minimal.

The sediments of mud flats are very fine-grained, and as a result of the tight packing of the grains and the position of the flats in the intertidal zone, they are usually waterlogged.

Oil can only penetrate the surface with difficulty, and usually does so only down plant root channels and the burrow holes of animals such as clams and worms. However, because the surface is so level, heavier oils may remain on intertidal mud flats for long periods of time.

Marshes are characteristically flat, vegetated areas found above the normal high water level.

They are located in sheltered environments and grow as vegetation develops on the sediments of the intertidal zone. Muddy creeks and streams channel throughout the marsh, and mud and sand flats often form the seaward edge of the marsh.

The depths of the creeks and streams, as well as strong tidal currents, can make some marsh areas difficult to access.

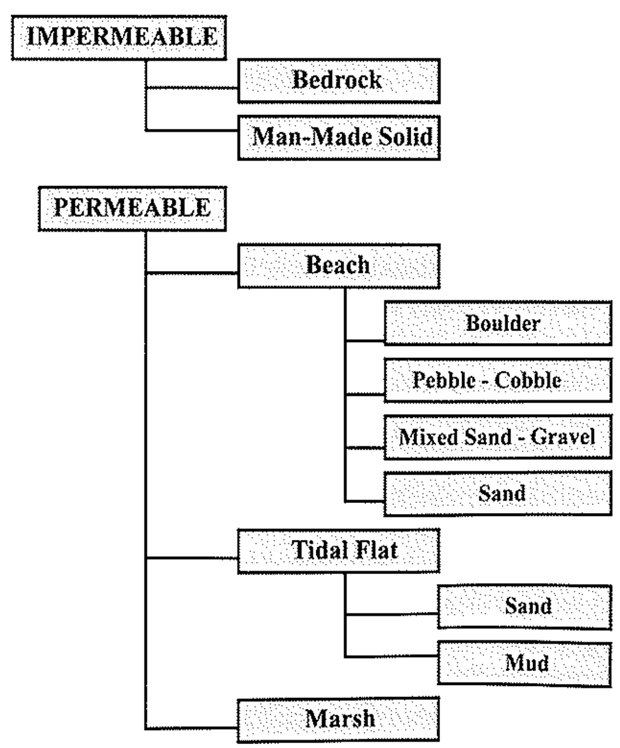
Oil can be deposited along the outer edges of marshes during normal tidal activity, but can be washed further into the upper reaches of the marsh during periods of storm activity or unusually high tides. *Oil was trapped in this way in some areas of the Miguasha Marsh in Quebec, after the spill of Bunker C oil from the "Golden Robin" in the Baie des Chaleurs in 1976.*

Manmade Structures

Manmade structures such as docks, wharves, breakwaters, piers and the myriad other structures of these types are generally made of concrete, wood or metal. For purposes of oil spill cleanup, however, they are generally divided into three types: concrete structures, rock or broken concrete structures and wooden structures. Oil behaves on solid concrete structures much as it does on rock outcrops. On rock or broken concrete structures such as breakwaters, it acts much as it would on cobble or pebble beaches. When oil contacts pilings or piers, although it may flow rather rapidly down the vertical faces, it can leave stains and can also adhere to non-vertical surfaces.

To assist in the selection of appropriate response options, nine shoreline types have been identified in Environment Canada's "Field Guide for the Protection and Cleanup of Oiled Shorelines". These shoreline types are outlined below:

SHORELINE TYPES



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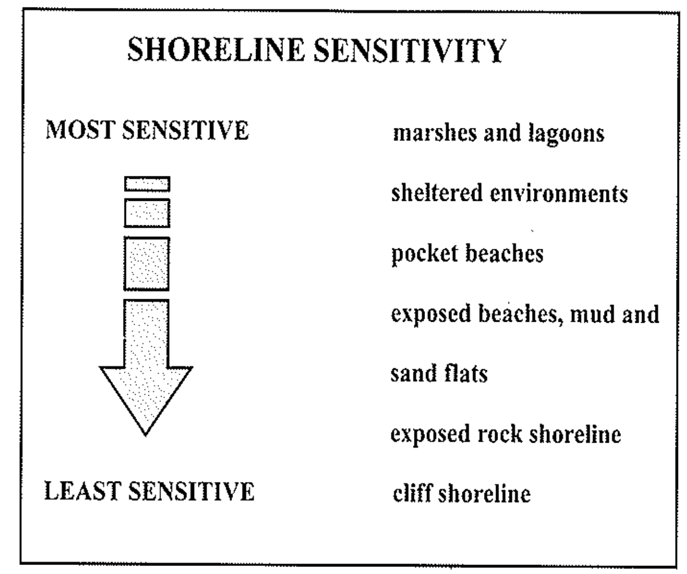
SHORELINE SENSITIVITY

Shoreline sensitivity refers to the potential for the coastline to suffer adverse environmental effects caused by the stranded oil and/or the efforts to remove it. The earliest types of shoreline sensitivity indices were based fairly broadly on the type of shoreline and the amount of wave energy to which it was subjected. This resulted in the kind of index which follows.



Later experience and research has shown, however, that the effects of a spill aren't dependent on the type or character of the shoreline alone, and that many other factors that affect shoreline sensitivity are involved.

Important considerations that were not incorporated in earlier indices included factors such as the location of threatened resources, the times of year these resources would be at risk, the nature of the threat, and the specific human or biological activities carried out along the shoreline. It is obvious that with the increasing number of parameters to be considered, the sensitivity indices become more and more complex. The danger then is that the resulting indices are far too complicated to be of any real value in determining cleanup methods and priorities. What is needed is a relatively simple evaluation matrix that is easily understood and modified if necessary. Such a matrix is shown on the following page. In it, spill effects are defined in terms of whether or not a response should be initiated.

RESPONSE PRIORITY HIERARCHY BASED ON EFFECTS OF SPILL

Absolute
Threat to human health or safety
Primary
Response required for all spills at any time of year
Primary but Seasonal
Response required for all spills but only at certain times of the year
Secondary
Response probably necessary at certain times of year
Tertiary
Response probably not required

An **absolute priority** would, of course, elicit a definite response. Although this type of priority is rarely seen, they do occur, especially when water intakes or drinking water supplies are threatened. *Such a situation occurred during the massive oil spill initiated by Iraq during the Gulf War, when many water intakes had to be immediately protected from the ingress of oil.*

A **primary priority** would be elicited by such things as threats to recreational and aesthetic facilities or facilities of high cultural or natural significance; threats to important or endangered species and/or ecologically important habitat; threats to commercial or subsistence activities for a large portion of the population. A primary seasonal priority would be triggered by all the concerns noted for a primary priority, but they would exist for a part of the year only. At those times of the year when there is no concern, the priority level would drop to the secondary or tertiary level.

If the potential effects on species are expected to be minor or of short-term duration, if the numbers of sensitive species is relatively small, if the economic impact on the affected population is relatively limited, then a **secondary priority** is likely to be assigned. In this case, the need for cleanup countermeasures will depend to a large extent on the time of the year and the urgency of the potential impact, particularly on economic and recreational activities.

If the presence of oil is unlikely to have an adverse effect on either species of concern or habitat, and won't threaten human health or safety or the economic well being of adjacent communities, then a tertiary priority will be assigned and oil spill cleanup countermeasures will in most cases not be initiated.

While the above approach has been used to a large extent in Canada, it must be remembered that there is, and indeed there can be, no one, universally applicable method to develop response priorities. Each spill, each shoreline has its own, unique character and characteristics. The best aid to responsible decision making will be the one that is most flexible and adaptable to the immediate situation facing those responsible for addressing each specific spill.

THE SCAT CONCEPT

When an oil spill occurs, getting accurate information on the status of contaminated coastlines is often difficult, and the information that is obtained may be incomplete, inapplicable, and generally inadequate. In order to solve problems associated with collecting and interpreting data, the concept of the Shoreline Cleanup Assessment Team , or SCAT, was developed.

During the spill from the tanker "Nestucca" off the west coast of Canada in 1989, an attempt was made to gather data in a more systematic and appropriate manner than had been done in previous situations. However, it was not until after the oil spill from the "Exxon Valdez" in Prince William Sound that the approach was refined and the term SCAT was coined.

The SCAT program is implemented after an oil spill and allows the real-time data necessary for an effective response initiative to be collected in a systematic and comprehensive manner. Specific and detailed assessments of the geomorphology of the shore; the type, condition and amount of oil; the environmental resources at risk; and recreational and economic usage are obtained using standardized procedures, definitions and terminology.

The SCAT program provides:

- technical support that can help in decision-making, planning and implementation of response measures
- information and documentation to aid in decision-making
- a data base to support response planning and implementation

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A very important aspect of the SCAT program is to consistently describe and to standardize oil conditions, as well as geological and ecological terms and definitions **before** the field surveys are done. This approach allows information gathered from various surveys with different levels of detail to be compatible.

The SCAT concept is applicable to spills from various sources and of various types and sizes, and can be implemented by the agency responsible for the spill, by the lead government responding agency, or by the team which provides scientific, technical and environmental advice.

SHORELINE PROTECTION

When a spill progresses to the point where it becomes inevitable that oil will reach the coast, there are only a few measures that can still be taken to protect sensitive areas from its impact.

One simple method is to distribute straw, along with other natural sorbents such as peat moss, along the shoreline to absorb the oil as it comes ashore.

In some incidents, for example, chopped straw has been sprinkled on the oil at the water's edge, stirred, raked and removed. Such techniques, however, are very costly in terms of labor, and are not as effective in removing the oil as the many synthetic sorbent batts and pads that now exist. In addition, peat moss and straw can be very difficult to recover because of their consistency. These materials can also be easily transported along the shoreline by the action of tides, wind and waves, and can sink when waterlogged.

Dykes or ditches can be built parallel to the water edge near the high tide line. This approach works particularly well on sandy or fine gravel beaches where backhoes and other types of heavy equipment can be employed. Ditches are often constructed on the seaward side of the dyke to collect oil, which can then be removed using sorbents or suction hoses. Protection methods using dykes and ditches are generally successful only in sheltered areas where wave action is limited.

SHORELINE CLEANUP

Once protection methods have been exhausted and oil has reached the shore, decisions have to be made on strategies for cleaning it up. These decisions will depend on a number of factors, including the physical and biological sensitivity of the shoreline; the economic or recreational use; capacity for natural cleaning; stability of the shoreline; accessibility; type and volume of oil, and the availability and effectiveness of cleanup techniques.

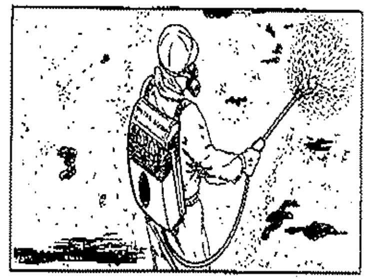
Once a decision has been made that the oil must be cleaned up, the most effective and efficient cleanup methods have to be chosen. The choice is influenced by a number of factors, including some of the same ones that affect the decision to clean or not to clean. These factors include the type and volume of oil and the depth of penetration into the sediments; the nature of the polluted shoreline; the accessibility to the oiled sites; the presence of debris (e.g., driftwood, logs, etc.) and the availability of personnel and equipment.

Because shorelines and oil types and quantities impinging on them vary to such a great extent, it is often very difficult, if not impossible, to assign one specific cleanup method or technique to an entire contaminated coast. The best that can usually be done is to note the kinds of available techniques and the types of shoreline on which they are most effective.

Several methods have been tried, tested and used to clean up oil from beaches. Each of these methods has its advantages and disadvantages depending on the characteristics of the oil and the type of substrate on which it is stranded. Some of the techniques employed are described below.

Washing: Chemical and Hydraulic Dispersion

A number of chemical spill-treating agents have been developed over the years to remove oil. *During the oil spill from the "Torrey Canyon" off the coast of Britain in 1967, tonnes of dispersants were used to remove oil from the sea and shoreline, and in many instances the dispersants used proved to be far more toxic than the oil itself.* Since that time, many dispersants and beach cleaners of relatively low toxicity have been developed, and can be useful in cleaning up certain types of shoreline, if permission has been granted by Environment Canada for their use. It must be remembered, however, that beach cleaners must be used with considerable caution, because even low toxicity products are generally more toxic than the oil itself. In addition, in doing their job, they make the oil more readily available to organisms such as clams, mussels and other filter feeders.



Beach cleaners are generally used to dissolve the coatings on viscous or weathered oil. Once the coating is removed, the oil can be removed by other washing techniques or by natural wave action. Beach cleaners are generally applied at low tide so that as the tide rises, the resultant wave action lifts off the oil, which may then be corralled by booms for removal, soaked up by sorbents, or washed away by mechanical flushing or natural wave action.

Flushing

Flushing using water at varying temperatures and pressures is a fairly common practice to dislodge oil from shorelines. The water temperature and the amount of pressure is adjusted according to the type of sediments to be cleaned.

During the cleanup of oil after the "Exxon Valdez" spill, several flushing techniques were used. One of these involved cold water deluge, where seawater was pumped through a perforated hose at the top of the beach. The oil was carried by the flowing seawater down to the waterline, where it was removed by skimmers or absorbents. During the same spill, cold water washing was used to remove bulk oil and warm water washes were used in areas where cold water washing or manual removal proved ineffective.

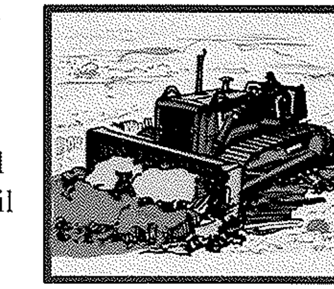
Steam Cleaning and Sandblasting

Steam cleaning and sandblasting are two relatively limited and specialized techniques for removing oil. Both can result in very serious damage to ecological resources, and both are time-consuming and costly. Their use is therefore generally restricted to areas where environmental concerns are minimal and economic interests must be protected.

Mechanical Removal

The guiding principle during all shoreline cleanup programs, and particularly those using mechanical processes, is to remove as little of the uncontaminated beach material as possible, and replace the substrate, where possible, when large amounts are removed.

If oil contamination is heavy and extensive, and if the shoreline conditions allow it, mechanical removal of the oil is more effective and generally more efficient than manual cleaning.



Mechanical removal involves the use of equipment such as graders, backhoes, bulldozers and small tractors to remove oil from contaminated shorelines. Care is required to ensure that heavy equipment does not mix contaminated and uncontaminated shoreline sediments. A variety of vacuum and pumping systems is often used in conjunction with the different types of equipment.

Manual Removal

Manual removal of oil is usually a supplement to mechanical removal. Often, when access to the shore by mechanical equipment is impossible, or where the substrate and physical character of the area prohibit the use of mechanical equipment, manual removal may be the only available cleanup option.

Manual removal is generally applicable to most types of coasts, but can be extremely labour intensive and costly. Manual cleanup is often a significant aspect of the entire cleanup program, particularly in the case of very large oil spills, such as the "Arrow", the "Amoco Cadiz", and the "Kurdistan".

Although manual cleanup is usually the least intrusive from an ecological point of view, it is important to ensure that those conducting the cleanup have enough instruction so that their cleanup efforts have as little adverse effect on the environment as possible.

Mixing and Moving Sediments

After the bulk of the oil has been removed, the remaining, relatively lightly contaminated material may be cleaned by mixing the sediments using a variety of equipment, such as mechanical rakes, harrows and discs. Mixing the sediments allows evaporative and other natural weathering processes to proceed at a more rapid rate, resulting in a more effective cleanup.

To accelerate the cleaning process, oiled material can be pushed or raked down to the intertidal zone in the case of medium to high energy beaches, where the action of waves and tides will act to remove most of the remaining oil.

Burning

At first glance, it would seem that one of the most effective ways to remove oil from shorelines is to burn it on site. This, however, is not the case. Oil is very hard to ignite, particularly when it is thinly spread over a relatively cold surface, and in the event that it is able to be lit, it is extremely difficult to get anything resembling complete combustion. Absorbent materials have been used as 'wicking' agents, but even in the calmest of conditions, complete combustion is impossible. In addition, burning, when it does occur, generally results in a black mass of oily, sooty residue and dense, black clouds of pollutant smoke.

Bioremediation

When oil is spilled, naturally occurring bacteria and fungi will begin almost immediately to act on it to biodegrade it, essentially breaking down the hydrocarbons to carbon dioxide and water. Although this is a fairly basic process, depending on factors such as air and water temperature, oil quantity and type, and weather conditions, it can proceed at a painfully slow pace. To hasten the process, bioremediation methods can be employed. Bioremediation involves the application of nutrients, generally nitrogen and phosphorus, to accelerate the natural biodegradation of oil. This technology has proven to be quite effective in certain instances, particularly when circumstances are relatively favourable. However, if the volumes of oil are large, the oil is thick and weathered, and the temperature is low, the effectiveness of this type of cleanup will be considerably diminished.

Natural Cleaning

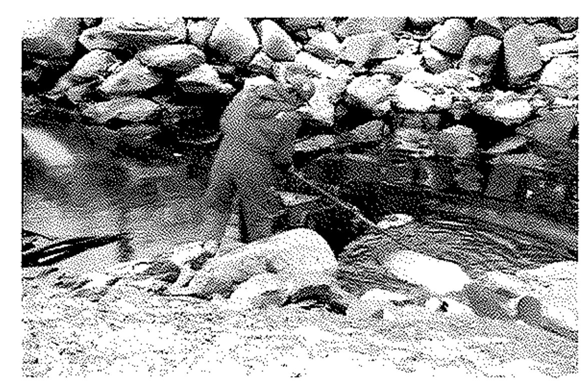
Under certain circumstances, the most effective way to treat oil on the shore is to do nothing and let nature take its course. If it is decided that the oil will not have a significant detrimental economic or environmental effect, or have adverse effects on recreational facilities, natural cleanup may be a practical and effective option.

Natural degradation of oil has been shown to occur on a variety of shores, from those dominated by rocks and cliffs to fairly sheltered coves and bays. *Following the spill of Bunker C oil from the "Arrow", large areas of contaminated shoreline in Chedabucto Bay, both sheltered and exposed, had been cleaned naturally only a few years later.*

CLEANUP TECHNIQUES FOR VARIOUS SHORELINE TYPES

Rocky Shorelines, Boulders and Man-made Structures

When vehicles have access to the shoreline, oil can be removed by skimming, pumping or vacuuming. The free water collected during these processes should be allowed to settle out and then drained off before disposing of the oil. If the circumstances allow it, oil can also be flushed off the rocks or structures, collected at the waters edge and removed.

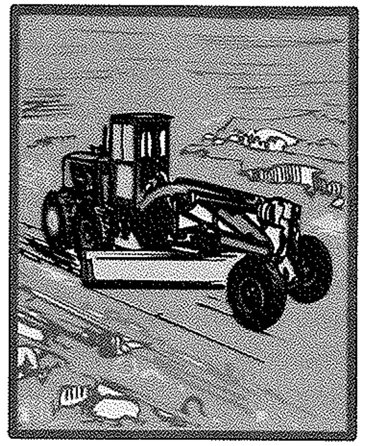


When vehicular access is not possible, the oil can be removed manually, using shovels, buckets, rakes and so on. If the oil is not too viscous, sorbent material may be used and then collected by hand or with rakes or pitchforks and placed in sturdy bags or containers that won't rip or split or spill the oil or debris.

Once the bulk of the oil has been removed, the rest can be left to weather naturally, unless other factors related to economic or recreational or human health issues dictate its removal. In this case, the oil can be removed by washing with water under pressure and at different temperatures. Steam cleaning, surface washing agents and even sandblasting may be effective, and are often used on man-made structured like wharves and slipways. These methods, however, will result in almost certain destruction of any living organisms, as well as potential damage to the rock and boulder surfaces themselves. However, if plants and animals have already been destroyed by the oil, then cleanup using these technique will allow almost immediate recolonization.

Sand beaches

For many types of oiled shoreline it is often recommended that no cleanup take place, and that natural degradation be allowed to proceed. However, this cannot always be done in the case of sandy beaches, which are often regarded as valuable recreational resources. In any case, depending on the time of year, and the intended use of the beach, it is probably best to leave the cleanup for as long as possible. In this way, by the time the cleanup begins, the amount of oil remaining will have been considerably reduced as a result of natural cleaning. On the other hand, if it is summer time and the beach is a popular one, then it is probably essential to clean it as quickly as possible.



Access to recreational beaches is usually easy, and one of the more common methods for cleaning them involves removing the oil covering using scrapers or graders, particularly if the beach is flat and the sand hard packed. Where the surface can handle the weight of heavy equipment, oil can be removed by mechanized graders working in tandem with elevating scrapers. Berms of the oil and sand mixture are formed by the graders, and these are then removed by the elevating scrapers. This is a particularly effective approach if the oil has not penetrated very far into the sand. If traction is very poor and the oil has penetrated quite deep into the sand, front end loaders can be used. Caution has to be exercised, however, to ensure that removal of excessive amounts of beach material is avoided. If too much material is removed, the beaches must often be replenished with uncontaminated sands from a remote source to prevent future erosion.

During the Gulf War, a prototype mechanism, using rotary tillers in combination with high pressure seawater hosing, was used successfully to clean up oiled, sandy intertidal beaches in the Arabian Gulf.

If the oil is light and easily sinks into the sediments, it may be more advisable to let natural flushing and weathering clean the beach rather than attempt to remove large quantities of material to deal with relatively minor amounts of oil.

If the beach can't support heavy machinery, as is the case with coarse sand and sand and gravel beaches, then manual removal is the preferred option. Flushing, low pressure washing or chemical dispersion using beach cleaners could also be used on exposed beaches to flush oil down the beach for collection in trenches or sumps at the waterline.

Manual techniques must also be employed if the distance to the waters edge is too far for pump or vacuum hoses to reach.

In the case of tidal beaches, oil can be collected in trenches or ditches dug parallel to the water's edge, and be collected from the sumps into vacuum trucks and tankers.

Often, after most of the oily contaminant has been removed, it will be necessary to repeatedly plough or rake the still lightly-contaminated beach material down to the tideline to allow wave action to remove the last traces of oil.

As a last resort, lightly-contaminated beach material can be covered with clean sand brought in from non-contaminated areas. The new sand must be of the same consistency and grain size as the contaminated sands, however, since a finer-grained sand could more readily wash away. Dispersants are not used on sand beaches because they cause the oil to penetrate deeper into the beaches and thus complicate removal. *During the spill from the "Jakob Maersk" in Portugal in 1975, dispersants were used in large quantities to flush the oil from the wide beaches near the city of Leixoes in the north of Portugal. It was found, however, that although much of the oil disappeared, it had*

not washed out to sea with the tide, but instead had penetrated to some depth in the sands. Considerable and costly effort then had to be expended in using heavy equipment to turn over the sands to allow the oil to flush out.

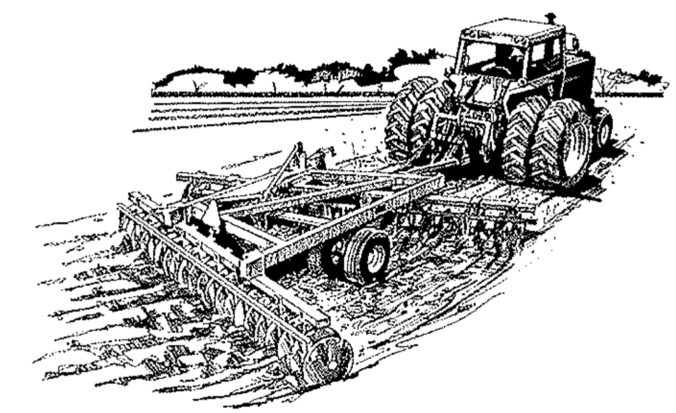
Sand and Gravel Beaches

Sand and gravel beaches offer a poor foundation for heavy machinery. In addition to the poor traction, such equipment has a tendency to mix the oil deeper into the sediment, in effect increasing the cleanup time. Manual cleanup is the preferred and recommended option for sand and gravel coasts, particularly if the oil is only present in small amounts. If the coast is exposed, one effective measure that can be employed is to flush the oil out into pits or trenches dug at the water's edge, and remove it using pumps or vacuum trucks.

Cobble, Pebble and Shingle Beaches

A major problem encountered with beaches of this type is that they almost always have a very poor ability to support heavy equipment. This then often means that the only machines with sufficient traction to be used on cobble, pebble or shingle beaches are bulldozers, and it is inevitable that if bulldozers are used, then large amounts of beach material will be removed in cleaning up the spilled oil. This approach is not recommended, since natural replacement processes for this type of material are extremely slow. In addition, machines will generally create more of a problem by mixing large quantities of the oil down into the beach material. If at all possible, the use of such equipment should be avoided.

The problem with attempting to clean up oil on this type of shoreline is compounded by the fact that the oil naturally seeps down into the many nooks and crevices that exist between the large pieces of sediment material. However, where asphalt type paving may have been formed, bulldozers or other heavy equipment may have to be used to churn up the pavement using discing or ripping fixtures.



If contamination is heavy, much of the oil can be removed by pumping and vacuuming, if possible, or it can be cleaned up by hand.

Flushing is also an appropriate technique, and high pressure hosing will drive oil out of the sediments relatively easily. Any remaining oil can usually be left to weather naturally.

Marshes

When a salt marsh is polluted as the result of an oil spill, cleanup operations can often result in far more extensive damage to the marsh system than the oil itself. The best approach therefore, is often to do nothing and allow the oil to weather naturally. The vegetation in the marsh will generally trap oil, preventing its rapid spread, and studies have shown that the vegetation will generally recover well, particularly from a single oiling.

Cleanup may be necessary, however, if the oil contamination is so heavy that natural cleaning by tidal flushing or biological degradation is too slow and ineffective, or if the contaminated portion of the marsh will act as a reservoir for the oil, allowing it to pollute a much greater area.

The use of wheeled or tracked vehicles can be ruled out almost immediately, as they have practically no utility in a marsh.

Oiled vegetation can be removed manually, although care must be taken to avoid damage to the root systems of the marsh plants. Low pressure flushing can also be used to remove heavy oil, which can then be recovered from collection areas. The small creeks which intersperse the marshes provide natural collection points for flushed oil. Transport of personnel and cleanup operations in the marsh should be conducted from shallow draft boats to avoid damage that might occur from foot traffic. One of the few places where burning may be practically carried out is in marshes, where contaminated vegetation can be successfully burned at certain times of the year.

Intertidal Mud Flats

Intertidal mud flats are generally awash at every tide, and when they are oil covered, each successive tide can lift the oil and transfer it to another location. Unless this presents a problem, however, the best recommendation for a cleanup approach is to take no action at all.

If, however, the situation is such that some treatment must occur, and if access to the oil is possible, and if the substrate can support light machinery and equipment, mechanical scraping can be employed to remove thicker oil and tarry lumps. Low pressure flushing may also be possible, using sorbents and vacuum pumps to collect the oil from pits or trenches.

In general, however, mud flats can hardly support foot traffic, let alone machines, and cleaning such areas can be extremely difficult and hazardous as well. As a result, cleanup is not recommended unless absolutely necessary.

CONCLUSION

When oil comes ashore, what happens to it will depend on a number of factors, including the volume and type of oil spilled, as well as the extent and nature of the affected shoreline. Cleanup options can range from the use of bulldozers to remove oil on cobble beaches, to gently flushing it from marsh vegetation; from sandblasting oil off man-made structures to shovelling it by hand off sandy beaches. In some cases, however, if the recreational and economic interests of humans are not threatened by the presence of oil on the shore, it may be left to weather naturally. Removing the problem from human hands and allowing nature to take its course is often the most practical, effective and environmentally sound solution.

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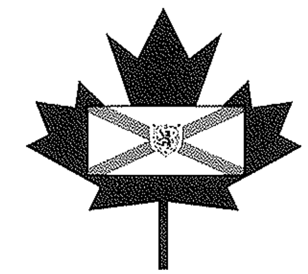

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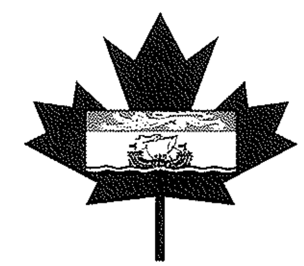

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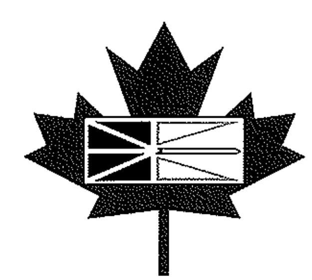

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