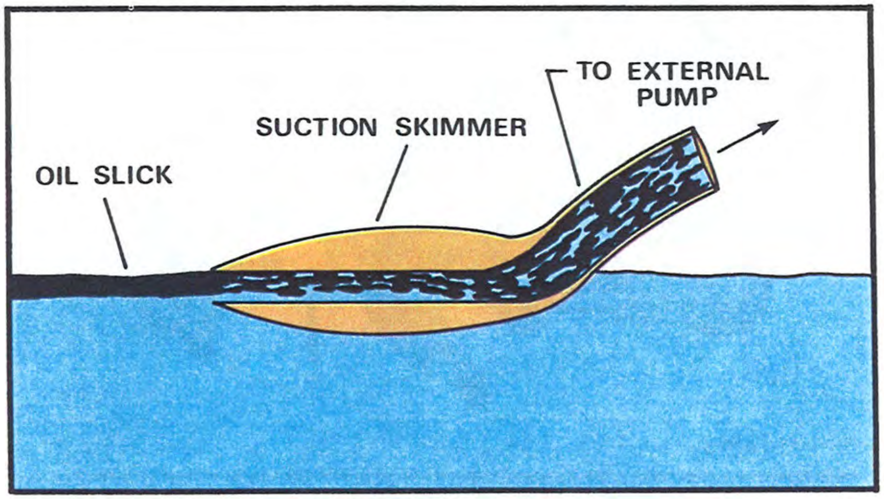
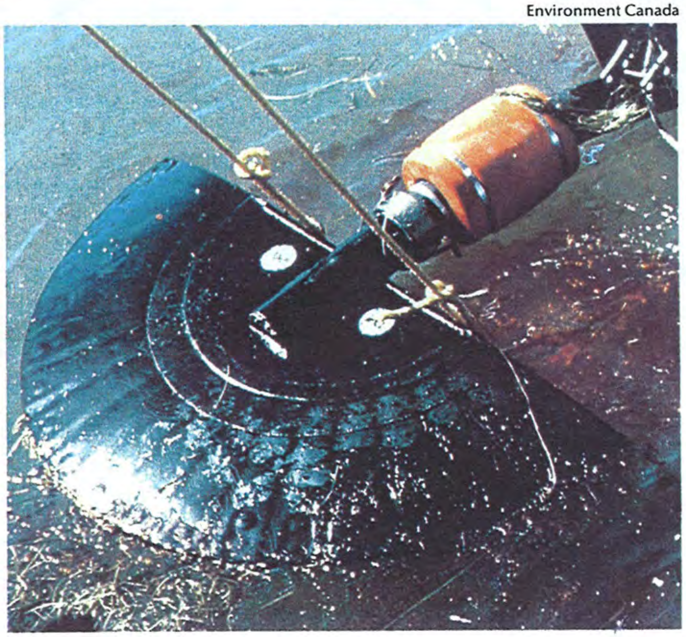
rough open seas by following the wave action while remaining in close contact with the oil slick. However, choppy waves are a persistent problem, and almost always result in air intake and decreased collection efficiency.

Figure 13
OPERATING PRINCIPLE OF SUCTION-TYPE SKIMMERS



Environment Canada



An example of a flexible suction skimmer. Note the tendency to draw floating debris.

Another form of suction recovery is the use of vacuum trucks which are normally employed for other purposes such as the draining of septic tanks. This is often the most readily available oil recovery equipment and can be relatively effective when the slick is concentrated in thick layers. The oil is simply drawn off the water surface by one or more hoses connected to the vacuum truck. However, the greatest shortcoming of the technique is that large quantities of water are recovered at the same time. This water must be allowed to separate from the oil, and is then generally pumped out from the bottom of the truck. Other pumping devices, including compressor and venturi combinations or liquid manure pumps, may be utilized for suction recovery but generally experience the same limitations as conventional vacuum trucks.

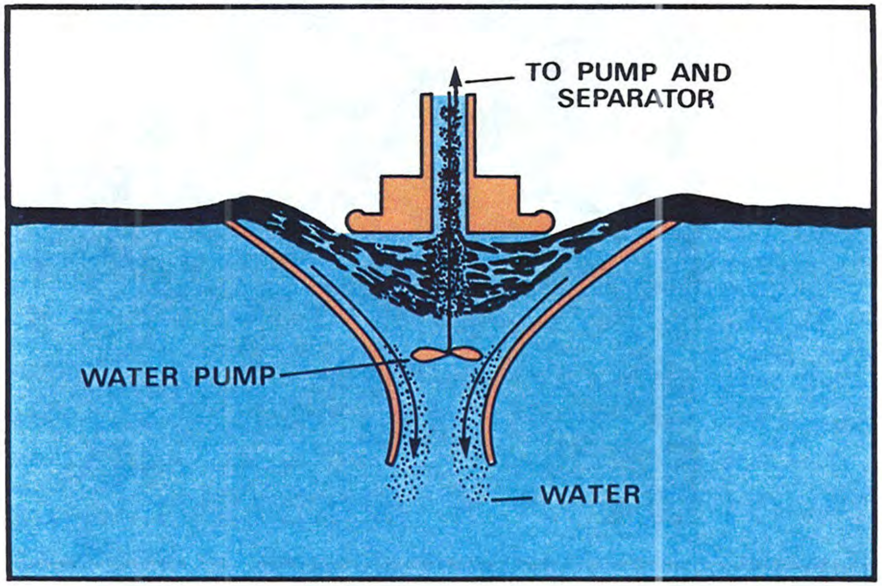
Environment Canada

Use of a vacuum truck to recover oil which is concentrated in thick layers.

Centrifugal Skimmers

This skimmer design operates by the creation of a water vortex, or whirlpool, which draws the oil into a collection area; the oil is subsequently pumped from this area to an oil-water separator for recovery. The basic principle of operation is illustrated in Figure 14. These skimmers are not as susceptible to clogging with debris as weir or suction devices since debris screens can be utilized without adversely affecting oil recovery. However, they do have current and wave limitations similar to most weir-type skimmers and generally do not operate efficiently in waves higher than 60 cm or in currents exceeding 30 cm/sec (0.6 knots).

Figure 14
OPERATING PRINCIPLE OF CENTRIFUGAL (VORTEX)-TYPE SKIMMERS



Environment Canada

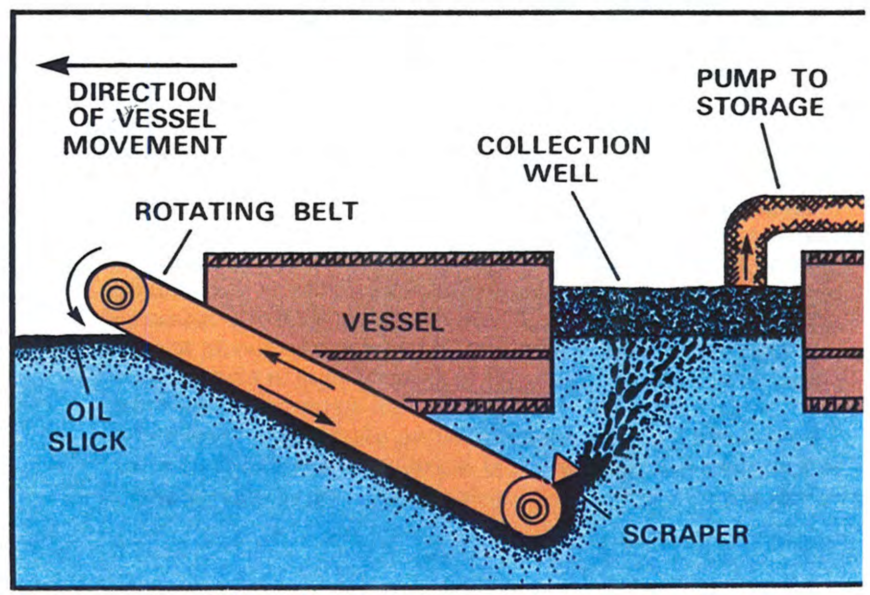
An example of a vessel-mounted centrifugal skimmer incorporating a trash grill.

Submersion Skimmers

This type of skimmer is usually large in comparison to the devices previously described and is typically mounted on or incorporated within a powered vessel. Oil in the path of the skimmer is forced beneath the water surface by a moving belt inclined at an angle to the surface, as indicated in Figure 15. This belt forces the oil downward toward the mouth of a collection well where it rises to the surface due to its buoyancy. Water collected with the oil simply passes under the collection well and out a discharge port. Oil adhering to the belt is removed by a mechanical scraping device located at the collection well opening or within the well itself, and is then pumped to an onboard or adjacent storage facility.

Submersion devices often tend to be more efficient with low viscosity oils and when the slick is relatively thin. This latter characteristic is in direct contrast to most other skimmers, and is related to the design principle. However, the skimmer must be advanced slowly over the water surface to prevent oil from missing the collection well and passing completely under the device. Consequently, this type of skimmer is most efficient with low specific gravity oils which are more buoyant and therefore rise up more quickly into the collection well.

Figure 15
OPERATING PRINCIPLE OF SUBMERSION SKIMMERS



Environment Canada

Submersion skimmers are often most efficient with thin slicks. The spill plate in the foreground is used only for testing of the device.

Submersion skimmers are not seriously hampered by debris in the water, although most models have screens to minimize the amount of debris passed with the oil into the collection well. While waves decrease the collection efficiency of submersion skimmers to a certain extent, the effect is not as great as generally observed with weir, suction and centrifugal devices. Since submersion skimmers are usually large and must be in motion to recover oil, they are not well suited to the cleanup of oil in confined areas or adjacent to containment barriers. However, this type of apparatus can be utilized to recover an uncontained slick, and, in contrast to many other smaller skimmers, the rate of recovery and oil content of the recovered product are both relatively high.

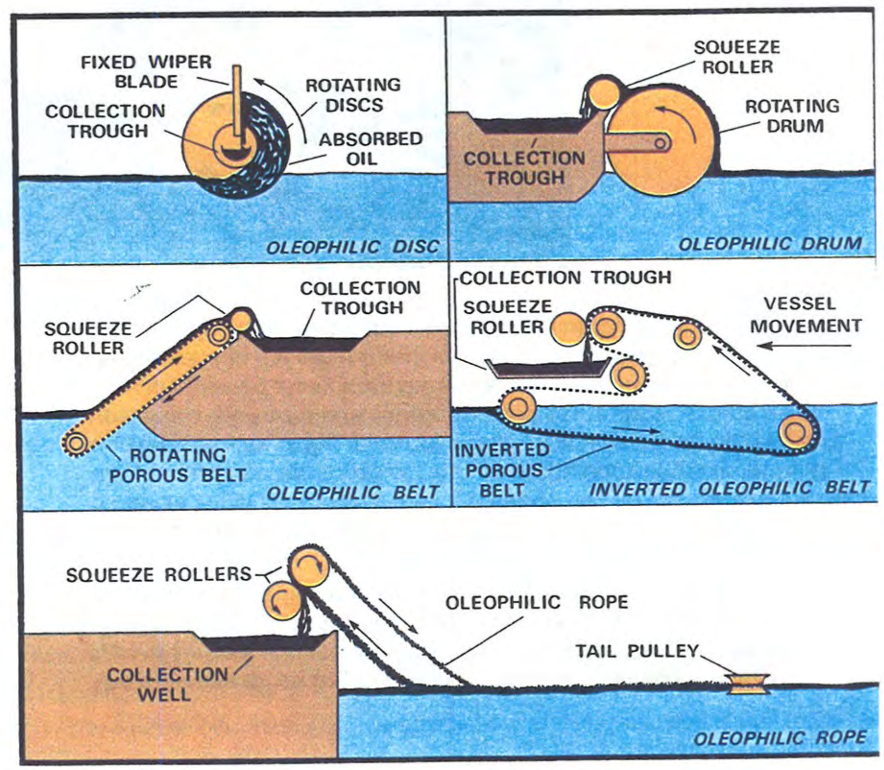
Sorbent Surface (Oleophilic) Skimmers

This generic type of skimmer incorporates a surface to which oil can adhere in order to facilitate its recovery from the water. The sorbent, or "oleophilic," surface can be in the form of a drum, disc, belt or rope which is continuously moved through the oil film (Figure 16). Oil collected on each of these surfaces is removed by a wiper blade or pressure roller, and is subsequently deposited into an on-board container or pumped to storage facilities on a barge or the shore.

Sorbent skimmers range in size and, like submersion devices, achieve high oil-to-water recovery ratios and are most efficient with medium viscosity oils. The sorbent surface varies from metal discs and drums to plastic or treated fabric belts and ropes depending on the manufacturer and the model. However, in general, fabrics and plastics can handle a wider range of hydrocarbons than their metallic counterparts, and, since they do not pick up a large quantity of water, they can continue to operate efficiently with relatively thin oil slicks.

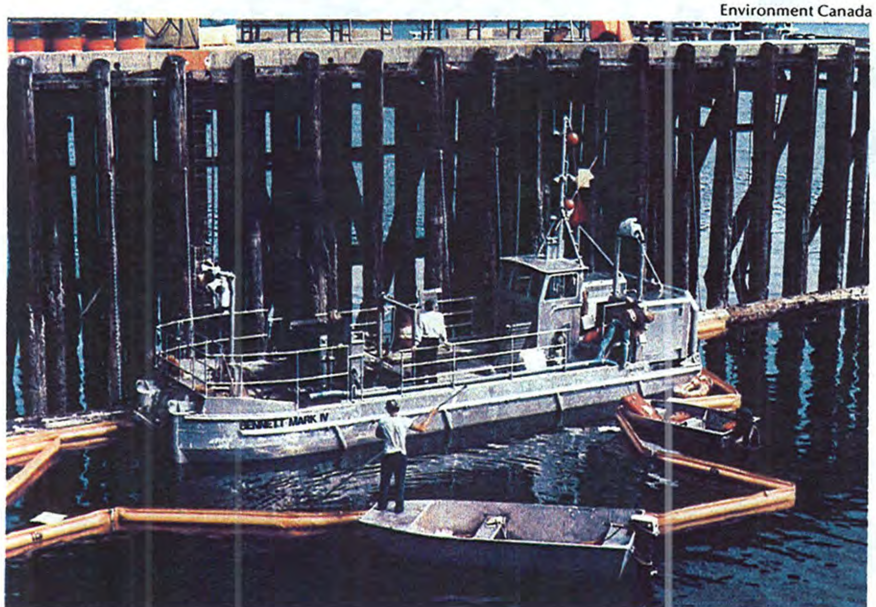
Figure 16

OPERATING PRINCIPLES OF VARIOUS SORBENT SURFACE SKIMMERS



A problem associated with some types of sorbent surface devices is the tendency of the rotating belt or other surface to drive oil away from the skimmer by causing turbulence or setting up pressure waves as it enters the water, particularly when the skimmer is simultaneously moving forward through the slick. This shortcoming can be minimized by decreasing the rotation speed of the sorbent surface, but in so doing, rates of oil recovery are also reduced. Some manufacturers have alleviated this problem to a certain extent by combining the sorbent surface principle with the submersion principle. As will be apparent after examination of Figure 16, the turbulence created by the belt movement on skimmers which incorporate both operating principles is likely to force the oil below the water surface and onto the sorbent surface. Debris may interfere with the recovery efficiency of this generic category of skimmers and in some cases can cause damage to rollers, wringers, and wiper accessories. Nevertheless, sorbent surface skimmers are less susceptible to debris than weir, suction or centrifugal devices. Of all the available skimmer types, this variety is least affected by waves and some models have been known to function efficiently in waves up to 60 cm high. In fact, wave action has been shown to enhance the oil recovery of certain models by increasing the surface area of the sorbent component which is exposed to the oil. Unlike submersion devices, many of these skimmers can be operated from a stationary location, and are most suited to use within containment booms and adjacent to docks.

Environment Canada

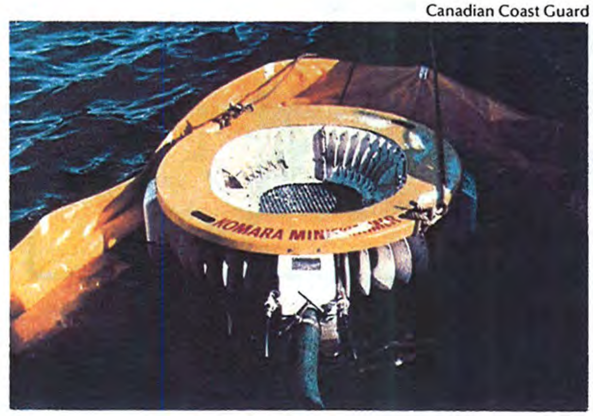


Modern self-powered mechanical skimmer incorporating both submersion and oleophilic belt operating principles.

The recovery efficiency of different viscosity oils varies with the type of sorbent surface used on this class of skimmers. Aluminum discs or drums achieve the highest recovery rates with medium viscosity oils, while fabric surfaces usually work well with a wider range of oils.

In the case of sorbent belt, disc and drum skimmers, efficiency of oil recovery is not only affected by the thickness and viscosity of the oil film, but also by the speed of rotation of the skimming component and the velocity of the recovery vessel. The velocity of the recovery vessel is important since a critical speed exists above which oil is actually pushed away from the sorbent surface in an arc ahead of the vessel. On the other hand, when the belt, drum or disc is rotated too quickly, more water than oil is picked up by the sorbent surface.

Canadian Coast Guard

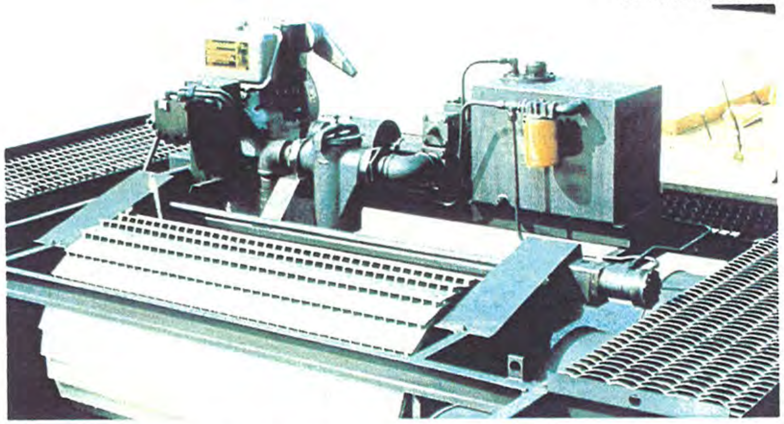


A common example of an oleophilic disc skimmer used within containment boom. Note that numerous discs are incorporated and connected to a common pump.

Environment Canada

Use of an oleophilic rope skimmer in a heavily contaminated dock area.

Environment Canada

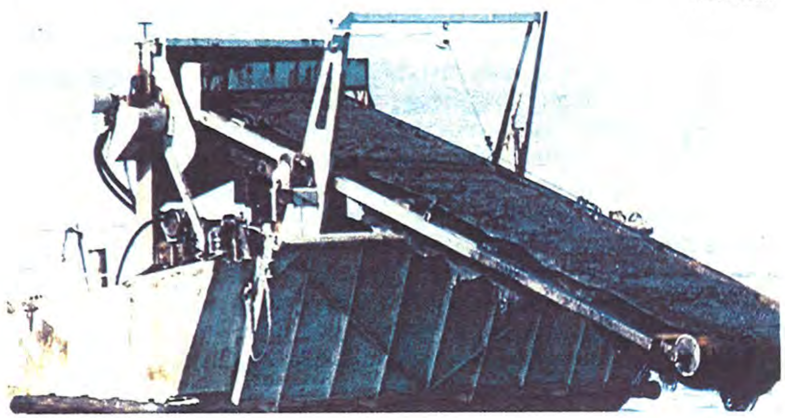


Oleophilic drum-type skimmer.

Environment Canada

Close-up of the synthetic fabric employed on a rotating belt skimmer.

W.C. Austin



Oleophilic belt skimmer mounted on a work barge.

Sorbents

The second major approach for recovery of spilled oil is the use of sorbents. Sorbents are defined as any material which will recover oil through either absorption or adsorption. Absorption occurs when one substance, in this case oil, penetrates into the interior of another; adsorption, on the other hand, occurs when one substance is attracted to and adheres to the surface of another.

Generally speaking, these materials do not play the primary role in oil spill cleanup operations, and are most commonly used for final cleanup of trace amounts of oil or to remove oil from areas which are inaccessible to skimmers. Some sorbents are highly efficient collectors of surface oil, while others tend to release oil before and during handling, and therefore create more cleanup problems than they solve. It should also be emphasized that the use of many types of sorbents prevents operation of mechanical skimmers in oil-contaminated waters; most skimmers are clogged by sorbent materials, and in some instances, indiscriminant use of these materials too soon in a cleanup operation has hampered the efficient recovery of oil.

There are three basic classes of sorbents: (1) natural organic materials such as peat moss, straw, hay and sawdust; (2) mineral-based materials such as vermiculite, perlite and volcanic ash; and, (3) synthetic organic sorbents such as rubber, polyester foam, polystyrene and polyurethane. The latter class of sorbents are most often favoured because of their greater capacity for oil per unit volume and the fact that many are reusable.

The adsorptive capacity of a sorbent material depends on the amount of surface area upon which the oil can adhere; the greater the surface area, the higher the adsorptive capacity. Absorbants, on the other hand, function by capillary action, and therefore the more porous the substance, the greater the opportunity for uptake of oil into its capillaries. However, the absorptive capacity of a material also depends to a large extent on the specific gravity and viscosity of the spilled oil. For example, a material with many open capillaries will generally absorb more light oil than heavy oil since the lighter oil will be drawn further up into the capillary network.

Some sorbents are treated with oleophilic and hydrophobic agents to improve the ability of the material to be preferentially wetted by oil instead of water. Oleophilic compounds are those which attract oil, while hydrophobic agents tend to repel water. This type of treatment also increases the ability of the sorbent to remain afloat once it has absorbed oil. Sawdust, peat moss and cotton, for example, will soak up oil but tend to sink once water saturated and then only intensify the cleanup problem. It is also important that the sorbent material retain the oil when it is lifted off the water; some materials which rapidly absorb oil also allow it to readily drain out again.

As stated earlier, natural organic sorbents include materials such as peat moss, straw, milled corn cobs, wood cellulose fiber and milled cottonseed fibers. In general, natural sorbents absorb three to six times their weight in oil, are nontoxic and relatively nonpersistent in the environment (biodegradable). However, all natural sorbents will absorb water as well as oil and virtually all sink when saturated with water. Indiscriminant use of natural sorbents has resulted in tremendous cleanup problems; in the case of the historic TORREY CANYON spill, 20,000 tons of sawdust and wood shavings were used with good intent, but eventually ended up on the shores and added to the pollution problem. Recovery of large volumes of natural sorbents requires considerable manpower and invariably creates additional problems associated with the need for disposal of the oil-contaminated materials by burning or burial.

Natural sorbents function by virtue of their criss-cross arrangement of fibers rather than capillaries within the material. Oil is trapped in the spaces between fibers and low viscosity oils may drain out again when the sorbents are lifted out of the water. Some natural sorbents such as milled corn cobs are not as fibrous and can actually be recovered by certain mechanical skimmers. Other natural sorbents are available in compressed sheets, minimizing problems associated with removal after the cleanup program has been completed.

The recovery efficiency of inorganic or mineral-based sorbents is slightly better than that of natural sorbents and varies from between four to eight times their own weight. These materials are usually very light and, therefore, tend to be difficult to distribute when windy. Other disadvantages of inorganic sorbents include potential respiratory irritations which may result from inhalation of their dust, persistence in the environment (non-biodegradable) which necessitates complete recovery, and the need to recover the sorbent with dip nets or devices which are not affected by the abrasiveness of the material.

Synthetic organic sorbents are usually in the form of plastic foams or plastic fibers, and offer the advantage of exceptionally high recovery efficiency (Table 6). Examples of common synthetic sorbents include polyurethane foam, urea formaldehyde foam, polyethylene and polypropylene. Some of these sorbents can be re-used after the oil is squeezed out, and they are generally far easier to spread and recover than either natural or mineral sorbents. Synthetic sorbents are available in a variety of configurations such as sheets, booms, and rolls, and most can be burned if re-use is not feasible (see Chapter 8, Separation and Disposal). However, these materials are relatively expensive and, like mineral sorbents, must be completely recovered to avoid persistence in the environment.

Synthetic foam sorbents are the most efficient sorbents available, and as indicated in the above table (i.e. polyurethane) their efficiency is far more independent of oil viscosity than synthetic fibers. Polyurethane also offers the advantage of being producible at the spill site by mixing two liquids which immediately expand to create the sorbent foam. Some synthetic foams, however, also readily absorb water. Fibrous synthetic sorbents, on the other hand, are most effective with viscous oils (Table 6) and have less tendency to absorb water. Care must be exercised when using some synthetic sorbents since slabs which are saturated with oil will occasionally tear as they are removed from the water.

Table 6

TYPICAL OIL CAPACITY OF SELECTED SORBENTS
IN BUNKER C, NO.2 FUEL OIL AND CRUDE OILS
(Grams Oil per Gram Sorbent)

Sorbent	Bunker C	Crude	No. 2 Fuel Oil
Natural Sorbents			
Peat Moss	5	8	7
Straw	4	4	2
Sawdust	3	4	3
Mineral Sorbents			
Perlite/Vermiculite	5	4	3
Synthetic Sorbents			
Polyurethane Foam	73	73	49
Polyethylene Wool	37	24	16
Polyethylene Sheets	19	15	11

Environment Canada

Use of synthetic sorbent sheets to recover oil from a contaminated shoreline area.

Recovery of an oil-soaked natural sorbent.

The quantity of sorbents required and the most suitable method of application depends on the size of the spill. For small spills and final cleanup near the shoreline, sorbents are normally applied by hand, but in the case of some large spills, blowers or other mechanical methods are used to distribute the material. As indicated earlier, a limited number of sorbents can be recovered by skimmers, although more often the use of sorbents precludes the use of skimmers because of the debris-like problems created. In such cases, nets, rakes, forks and pike poles are more commonly used. Sorbents are primarily used near the shore, and may be spread directly onto the oil or placed ahead of the advancing slick.

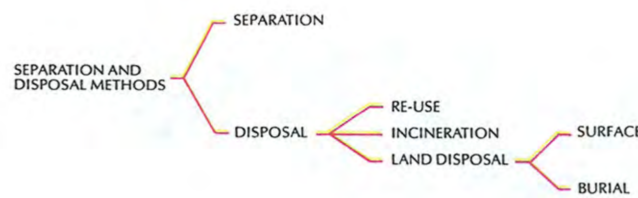
MANUAL RECOVERY

Although extremely labour intensive, manual recovery of oil with buckets, shovels and similar equipment remains a commonly used technique. This approach is frequently taken for small spills which occur in ports and rivers, and continues to play a role in virtually all spills which occur near populated areas. Viscous oils are more readily removed by manual methods than lighter oils which almost invariably require the use of a sorbent for complete recovery. Available manpower and disposal facilities (Chapter 7) are the limiting factors in manual recovery. The use of heavy mechanized equipment in oil spill cleanup is described in Chapter 9, "Shoreline Cleanup and Restoration."

Chapter 7

Separation and Disposal Methods

Two major tasks following the recovery of oil spilled on the water are to separate the oil from the water, and to dispose of this oil along with any remaining sorbent materials and other debris from the cleanup program. Oil spill technology is not well advanced in these areas: consequently, recent industry and government research programs have been directed toward improving separation and disposal methodology. Major topics of discussion in this chapter are illustrated in the following flowchart.



SEPARATION

No skimmer or sorbent material is 100% efficient, so all oil recovery processes produce some mixture of oil and water. The oil must be separated from this mixture for ultimate disposal or re-use by the petroleum industry. Oil separation devices are often incorporated in skimmers in the form of settling tanks or gravity separators. In skimmers of this type, separated oil is transferred to barrels or temporary holding tanks until it can be pumped to shore facilities. As mentioned in Chapter 6, many synthetic sorbents such as polyurethane foam can be pressed or squeezed to remove the absorbed oil; in some cases, the recovered liquid may approach 80% oil content and can be transferred to separators when its quality merits re-refining by the petroleum industry.

One relatively common method of oil separation is the use of 45-gallon steel drums which have been fitted with taps near the bottom. The oil and water mixture is simply poured into the drums and the water allowed to settle before it is removed from the bottom. The disadvantage of this approach is that a large number of drums are required when the volume of recovered oil is high. A more practical approach is the use of 1,000-gallon portable tanks which can be assembled at the spill site; these tanks can also serve as temporary storage facilities until the recovered oil is transported to the disposal site.

Environment Canada

Portable tank for separating water from oil recovered at the site of a spill.

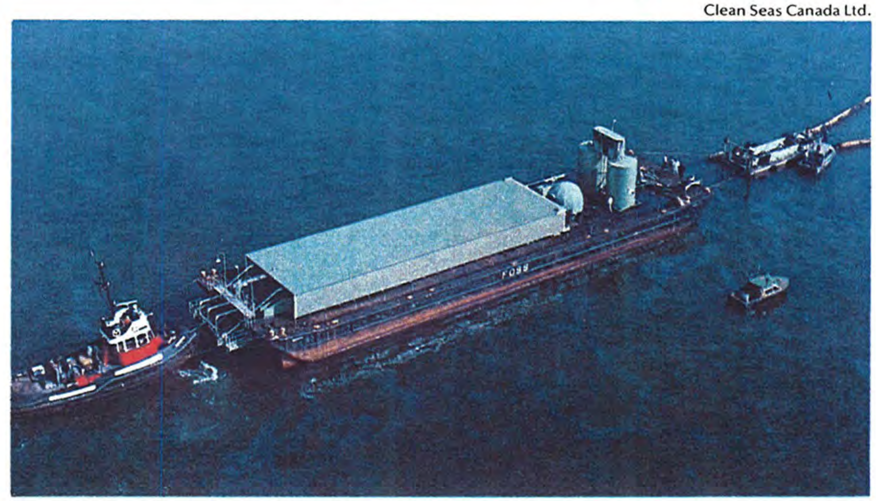
Environment Canada

Heavy oil sludge remaining in a separation tank following removal of water.

DISPOSAL

Persons responsible for oil spill cleanup follow guidelines and regulations for disposal of oil and debris which are established by local, provincial, and federal environmental agencies. Disposal is one of the most difficult problems associated with the cleanup of oil spills. In many cases, the volume of oil-fouled debris may equal that of the total oil recovered. The fate of recovered oil generally depends on its type, degree of contamination with debris, and state of weathering. In some instances, relatively fresh oil that has not been contaminated by significant amounts of water and/or debris may be re-refined.

Clean Seas Canada Ltd.



Recovered oil may be transferred to storage barges and later re-refined.

Incineration is another method of disposing of recovered oil but it must be done with the approval of government regulatory agencies and regional authorities. Incineration of recovered oil should be distinguished from the actual burning of an oil slick on the water surface (Chapter 8), or the *in situ* burning of oil which is stranded in shoreline areas (Chapter 9). In the case of incineration, the oil is actually recovered and then transported to another site for disposal. The main advantages of incineration are its speed and the fact that large quantities of oil can be disposed of at low cost. However, in most areas, the disadvantages of incineration outweigh its advantages. Burning may produce unacceptable levels of air pollution, destroy plants and animals, and leave an unsightly tarry residue; moreover, this disposal technique invariably kills the micro-organisms necessary for the biodegradation of any residues. Another disadvantage of this method is that it often requires the addition of burning promoters such as gasoline in order to maintain combustion.

Environment Canada

The disposal of recovered oil by burning is less difficult on land than at sea.

The most suitable method of incineration depends on the extent to which the recovered oil is contaminated with both water and debris. Relatively clean oil having a low water content is often transported to oil refineries for subsequent disposal in large commercial incinerators. These incinerators are capable of almost completely combusting the oil with minimal air pollution and carbon residue but cannot handle debris. Some satisfactory devices have been designed to incinerate oil containing combustible debris, although research is being continued to improve technology in this area. Oil containing combustible debris has been successfully burned in both pit-type incinerators and rotary kilns. Oil contaminated with incombustible debris such as sand or gravel creates the most difficult disposal problems. To date, the best technique for handling such mixtures has been the use of rotary kilns. However, mixtures of incombustible debris and oil must be continuously agitated to increase oxygen availability, and complete burning of the oil often requires one hour or more. Recent research by Environment Canada and the Petroleum Association for Conservation of the Canadian Environment (PACE) has been directed toward the on-site construction and testing of rotary kilns which utilize readily available components such as steel drums.

W.C. Austin

Burning of oil-contaminated shoreline debris.

Environment Canada

Use of plastic bags for the storage of oil-soaked beach debris prior to disposal.

Environment Canada

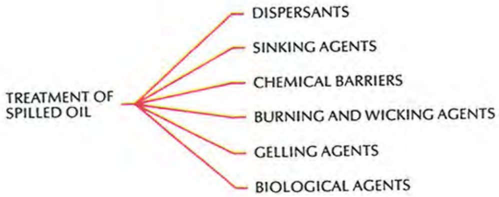
Storage of recovered oil and debris in drums following a major oil spill which occurred on the Inland Sea of Japan in 1974.

Two land disposal strategies which take advantage of natural biodegradation processes tend to be favoured, especially when the total volume of oil is relatively small and contains a high proportion of debris. These disposal methods either involve the spreading of recovered material over the surface of land or its actual burial at an approved site. Both methods are most successful when the oil content of the debris/oil mixture has been reduced by one or more of the separation processes. When the oil and debris mixture is spread over the surface of land, micro-organisms which metabolize hydrocarbons (see Chapter 3), acting with certain bacteria which attack the various debris materials, eventually decompose the vast majority of the oil/debris mixture. Fertilizers may be added to the oi and debris to stimulate microbial growth when conditions required for rapid decomposition are unfavourable. Burial of oil and associated debris has the advantage of removing the material from sight. However, burial must be completed at sanitary land fill sites where the potential danger of hydrocarbons leaching into groundwater (see Chapter 10) or slowly floating to the surface of rain-soaked soil is low.

Chapter 8

Treatment of Spilled Oil

There are an assortment of chemical agents which can be added to oil to facilitate its cleanup or removal from the water surface. However, it should be emphasized from the outset that the use of chemicals in oil spill cleanup programs is not only officially discouraged in most cases, but in many instances is prohibited and may only be considered after all other means fail. Generally speaking, chemicals are only used in oil spill cleanup when the potential damage to biological and physical resources could be greater if they were not used. Common chemical treatments are illustrated in the following flowchart and include: dispersants, sinking agents, herding or surface-active agents, gelling agents, burning and wicking agents, and biological agents.



DISPERSANTS

Dispersants contain chemicals which reduce the surface tension between oil and water and therefore result in the breakup and dispersal of the slick throughout the water column in the form of an oil-in-water emulsion. As discussed in Chapter 3, oil will disperse naturally as it spreads and weathers; chemical dispersants simply accelerate this process. The use of chemical dispersants to increase dispersal of an oil slick is analogous to the use of common household soaps to facilitate removal of dirt adhering to the fibers of clothing, although the mode of action differs in each case. The basic argument in favour of their use is that dispersion of the oil will increase the opportunity for oxidation, biodegradation and other weathering processes, and reduce immediate damage to waterfowl or other wildlife which could be adversely affected by a surface slick. Dispersants are also used to prevent oil from adhering to solid surfaces such as piers.

Older dispersants contained a large proportion of inherently toxic hydrocarbon-based solvents such as kerosene, mineral spirits, and naphtha, which, when applied to an oil slick, increased the volume of hydrocarbon pollutants present in the water. The major organic solvents contained in modern dispersants are alcohols, glycols, and glycol ethers; these substances tend to be somewhat less toxic than the older dispersant constituents. Dispersants also contain various additives to aid in increasing their dispersing ability and these chemicals may further contaminate natural waters; typical additives include sodium phosphates and sodium silicates. One standard measure of the toxicity of chemicals is the acute LC_{50} or the concentration of a contaminant required to kill 50% of a test population over a given time period, usually 96 hours. The dispersants used following the grounding of the TORREY CANYON in 1967 had an acute LC_{50} of approximately 30 parts per million (ppm) with rainbow trout, whereas a concentration of over 1,000 ppm is required to produce the same degree of mortality with modern dispersants. By comparison, the acute LC_{50} (96-hr) of No.2. fuel oil for rainbow trout is approximately 80 ppm.

A variety of equipment such as spray applicators and portable pumps may be used to apply dispersants to the oil slick. And, even in the presence of waves, it is often necessary to agitate the water to facilitate formation of oil-in-water emulsions. Application of these chemicals without thorough mixing in the surface water is a waste of time, manpower, and cleanup funds. The natural action of wind and waves is rarely sufficient to promote formation of oil-in-water emulsions. Dispersants are generally most effective when applied to unweathered oil slicks in relatively warm water, and normally must be applied in a ratio of about 1 part dispersant to 5 to 10 parts oil, depending on the type and viscosity of the oil, the efficiency of the dispersant, and available mixing energy.

Environment Canada

Dispersants should be applied in a manner which maximizes their effectiveness. In this particular application, the volume and surface coverage of the dispersant are difficult to regulate.

Canadian Coast Guard

Correct application of chemical dispersants using a metered spray system as well as a breaker board to supply mixing energy. Some modern dispersants do not require additional agitation.

The use of chemical dispersants is a highly controversial issue which has received considerable attention from government regulatory agencies. Their use is usually considered a last resort in most cleanup programs since dispersion of oil throughout the water column may harm a far greater number and variety of organisms than are affected when the oil is concentrated on the surface. Use of dispersants may be considered in open seas where booms and skimmers are ineffective, and where the oil slick is threatening areas of major biological importance. The advantages of dispersant application include increased rate of oil degradation, less tendency for the oil to form tarry residues, reduced fire hazard with some flammable petroleum products, less contamination of beaches and solid surfaces, and decreased impact of the oil on waterfowl. The disadvantages of dispersants include potential toxic effects of the dispersant to aquatic life, increased exposure of organisms to toxic hydrocarbons in the dispersed oil, and the lack of knowledge regarding the fate of the dispersed oil.

Guidelines on the use and acceptability of oil spill dispersants in Canada have been published by the Environmental Emergency Branch, Environmental Protection Service, Environment Canada. Restrictions contained in Environment Canada, Canadian Coast Guard, and provincial government documents prohibit the use of dispersants in any waters containing major fish populations, or in the breeding or migration areas of fish and other aquatic life which may be damaged or rendered less commercially marketable by exposure to dispersants or chemically dispersed oil. Dispersant use is usually not permitted in coastal areas and is generally avoided once oil has been deposited on sandy beaches or on shorelines with important flora and fauna. All decisions regarding the use of dispersants are made after careful evaluation of the situation and consultation with regulatory agencies.

SINKING AGENTS

Special materials can be spread on the oil slick and oil will be adsorbed to their surface. The combination of oil and the sinking agent is heavier than water and therefore sinks. Common sinking agents include treated sand, brickdust, cement, silicone-treated materials, fly ash, chalk, and special types of clay. However, this disposal technique is no longer favoured by most countries since it is a purely cosmetic approach to oil spill cleanup.

Like dispersants, sinking agents may cause considerable damage to bottom-dwelling organisms, and their use is generally prohibited by government regulatory agencies. Large quantities of sinking agents are required in relation to the size of the slick and it is often difficult to wet the surface of these materials with oil. Once the oil has adsorbed to the material and has sunk from the water surface there is also no guarantee that it will not re-surface, perhaps in other areas which are environmentally more sensitive. In addition, sinking agents are not particularly effective with low viscosity oils or when the oil slick is relatively thick. The displacement of oil from the surface to the bottom may also adversely affect groundfish communities, contaminate bottom fishing gear, and decrease the rate of microbial degradation. Sinking agents clearly have little to recommend their use under any circumstances, and do not play a significant role in oil spill cleanup programs.

CHEMICAL BARRIERS

Chemicals which act as surface tension modifiers were described in Chapter 5. In theory, these chemicals can be used to concentrate the oil slick into thicker layers to facilitate recovery or to deflect oil from sensitive areas. However, they are rarely effective except in extremely calm water and then for only limited periods. As with chemical dispersants, approval of government regulatory agencies must be secured before they can be applied.

BURNING AND WICKING AGENTS

Burning is another way of disposing of oil on water. However, despite the fact that many hydrocarbons are flammable, this is often difficult since the fire must be kept hot enough to continually support combustion and must be supplied with sufficient oxygen. It is virtually impossible to ignite a thin layer of oil on water because it is cooled by the water beneath it.

Burning agents are compounds used to ignite and sustain the combustion of spilled oil, whereas wicking agents increase oxygen availability and insulate the burning oil from the water. Gasoline, light crude oils and various flammable commercial products are typical burning agents, while substances such as straw, wood chips, glass beads and treated silica are used as wicking agents.

In some remote or offshore areas burning may be considered a satisfactory method for disposal of an oil slick; however, the possibility of unacceptable air pollution and safety considerations often prohibit this approach in inland waters. As oil weathers, volatile and lower flash point components are rapidly lost through evaporation (Chapter 3), and, as the oil slick spreads or weathers, it becomes progressively more difficult to ignite. Some investigators report that crude oil slicks less than 3 mm thick will not burn at all, while kerosene, fuel oils or lubricating oils will not burn without a wicking agent.

Environment Canada

Only relatively thick oil slicks will burn at sea.

Although cleanup of oil on the shore is the subject of the following chapter, problems associated with incineration of oil recovered during shoreline cleanup operations are more appropriately addressed here. It is not a simple task to burn oil recovered from the shoreline, even if the fire can be confined to a relatively small area and the resultant air pollution tolerated. As on water, oil on the shore is very difficult to ignite, particularly when spread out in a thin layer on a cold surface. Once ignited, this oil is often difficult to burn completely, even when a flame-thrower is used. Tar lumps and chocolate mousse on the shore create special burning problems. When these materials are burned, there is a tendency for the oil to become much less viscous and to penetrate the sand or gravel of some beaches.

Ignition and combustion can be accelerated by treating the oil with chemical oxidizing agents or by using sorbent materials as a wick. As indicated in the previous chapter, incineration of the oil in rotary kilns or burners is the most satisfactory method of sustaining combustion. A properly designed incinerator may completely burn mixtures of oil, water and combustible debris when air is forced into the side of a covered burner. The safety of personnel and property must be thoroughy considered at all times when approved disposal by incineration is undertaken.

Environment Canada

When approved by regulatory authorities, recovered oil may be treated and burned. In this case, oil and contaminated debris are transferred by conveyor belt to a covered incinerator.

GELLING AGENTS

Gelling agents are chemicals which increase the viscosity of the oil slick and thereby reduce its rate of spread over the water surface. Some gelling agents change oil into a cellular-like foam while others actually coat the oil with a material having the consistency of plastic thread. These chemicals are rarely used since the quantities required to gel an oil are extremely high in relation to the volume of oil, and it takes at least eight hours before the gel is sufficiently strong to allow recovery and subsequent disposal of oil. It has also been estimated that the current cost of gelling oil exceeds four dollars per barrel. For these reasons, gelling agents are generally considered of little practical use in oil spill cleanup programs.

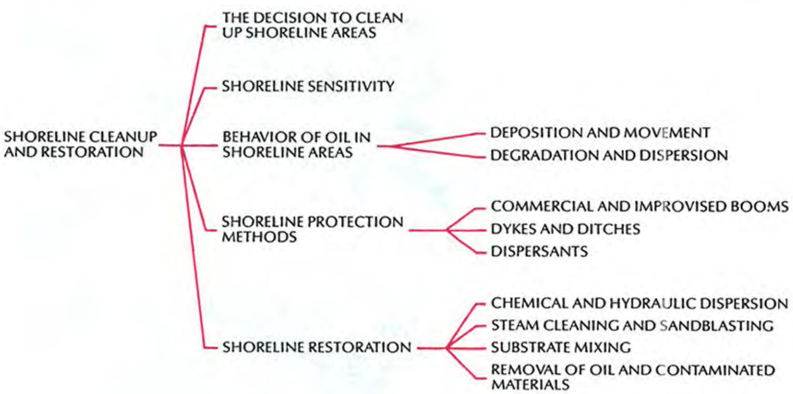
BIOLOGICAL AGENTS

During the previous discussion of the role of microbial degradation in the weathering of oils (Chapter 3), it was emphasized that this process is extremely slow and limited to a large extent by temperature, available nutrients, and dissolved oxygen concentration in surrounding waters. A number of researchers have considered enhancing the rate of microbial degradation through the introduction of additional hydrocarbon-consuming bacteria and/or compounds such as phosphates which will stimulate the growth of bacteria already present in the water column. These techniques have been successfully used in the warm waters of the Gulf of Arabia. However, results of experiments conducted in the colder waters of Canada and the small overall contribution of microbial degradation to the weathering of oil, limit the practicality of using biological agents in this country.

Chapter 9

Shoreline Cleanup and Restoration

It is rare when oil spilled on water can be completely contained and recovered before some of it reaches the shoreline. Cleanup of shoreline areas is considerably more difficult and time consuming than containment and recovery operations on water. It should be emphasized that the physical removal of oil from some types of shoreline may result in ecological and/or physical damage far in excess of that which would occur if oil removal were left to natural processes. The decision to initiate cleanup and restoration activities on oil-contaminated shore areas is based on careful evaluation of socio-economic, aesthetic and ecological factors. Criteria of importance to this decision, shoreline sensitivity, behaviour of oil in shoreline areas, and shoreline protection and restoration methods are discussed in this chapter.



When oil has polluted beaches in a populated region or areas of recreational use, priorities and pressures for cleanup differ from those which may be directed toward removal of oil from remote or uninhabited coastline areas. If a shoreline area is used by the public, the time required for removal of oil by natural processes may be unacceptable and cleanup action may be required despite its possible ecological implications. This is particularly true when sand or gravel beaches are contaminated. The decision to clean a shoreline area also includes consideration of the probable natural rates of dispersion and degradation of oil under the local climatic conditions, as well as the geological and ecological sensitivity of the contaminated shoreline areas. Areas where natural removal of oil may be relatively rapid or where ecological sensitivity is low are typically assigned lower cleanup priorities than areas where the oil may persist for years and biological resources may be adversely affected. Finally, the decision to clean and restore shorelines depends on the effectiveness of the available cleanup equipment and technology in relation to the steepness and composition (sand, cobble, rock) of affected areas. For example, the removal of oil from a flat sand beach clearly poses a different set of problems than cleanup operations on a steep, rocky shore where oil can easily become trapped in small crevices.

Clean Seas Canada Ltd.

Many criteria are considered prior to the initiation of shoreline cleanup and restoration programs. Important factors are the steepness and composition of the contaminated area.

Environment Canada

The presence of debris on the shoreline accentuates the problems of oil spill cleanup.

SHORELINE SENSITIVITY

Shoreline sensitivity is defined as the potential for adverse environmental effects resulting from alteration of normal physical and biological shoreline processes, either by the presence of oil or the activities involved in cleanup and restoration programs. There is little doubt that stranded oil affects all shoreline types to a certain extent; however, the impact of both oil and oil cleanup operations is greatest in the most biologically productive environments. Biologically sensitive shoreline types are generally given the highest priority for both protection and restoration in order to minimize alteration or damage to natural processes. This approach becomes a vicious circle, since on the one hand, sensitive shorelines are the most susceptible to damage by oil, while on the other hand, they are equally sensitive to man's cleanup and restoration activities. Consequently, oil recovery operations must be accomplished in such a way as to minimize additional damage.

The potential biological sensitivity of different shoreline types can be classified as follows:

MOST SENSITIVE	MARSHES AND LAGOONS
↓	SHELTERED ENVIRONMENTS AND POCKET BEACHES
	EXPOSED BEACHES; MUD AND SAND FLATS
LEAST SENSITIVE	EXPOSED ROCK OR CLIFF SHORELINE

The impact of oil on marshes can vary tremendously depending on the season, the type, volume and distribution of oil, as well as with the cleanup techniques employed. On the other hand, rock or cliff shorelines which are constantly exposed to heavy wave action are generally less sensitive and may not require protection or cleanup because of the high rates of natural dispersion and oil degradation.

Environment Canada

Rates of natural dispersion are usually slow if oil is deposited on sheltered pocket beaches. Such areas are often given priority in cleanup operations.

Environment Canada

Steep rocky shorelines exposed to heavy wave action are least sensitive to damage by oil because of high rates of natural dispersion.

BEHAVIOUR OF OIL IN SHORELINE AREAS

When oil reaches the shoreline, the type and extent of contamination are determined by a multitude of factors including: the type of oil, the total volume of oil, the length of time the oil has been in the water (i.e. degree of weathering), the temperature, the time at which the oil washes up on the beach in relation to the daily tidal cycle, the steepness of the beach, and the type of beach substrate (material composition). Some oils which have been on the water for a length of time may be deposited as tar balls, while others may reach the shore in the form of highly viscous slicks. As discussed in Chapter 3, certain types of oil form a water-in-oil emulsion known as chocolate mousse which retains its butter-like consistency when deposited on the shore.

Depending on shoreline topography and the tidal level when the oil first reaches the shore, oil carried by the incoming tide may be deposited in tide pools and other depressions or crevices throughout the area. If the oil arrives at the beach on a particularly high tide, it may remain in confined areas until the next equally high tide. Conversely, oil can be deposited in relatively narrow bands at or near the high tide mark, or can form broad bands as it moves out with the receding tide.

Beach materials vary in their ability to be wetted with incoming oil, and also differ with respect to the depth to which they will allow oil to penetrate. For example, quartz sand is difficult to wet with oil when it is saturated with water, but readily attracts oil when dry. On the other hand, many shell-based sands will adsorb oil whether they are wet or dry. The depth that oil penetrates sand or gravel beaches depends on the viscosity of the oil, the coarseness of the substrate, and many additional factors such as the duration of exposure to oil and the temperature. In the case of sand beaches, contaminated material may be covered by clean sand carried in on incoming tides or during storms. This removes the oil from view but simultaneously prevents further weathering or abrasion until the oil is re-exposed during a later tidal cycle.

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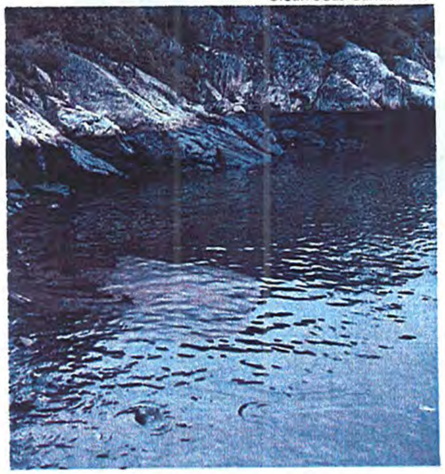


Oil can be deposited in a broad band covering most of the intertidal zone.

As indicated earlier, some shoreline types naturally clean themselves through the processes of degradation, abrasion and dispersion. This natural cleaning capability depends on a number of factors but is primarily related to the amount of wave energy reaching the shore. When wave energy is high, as in the case of open or exposed coastline, significant amounts of oil may be dispersed or spread into thinner layers; oil in these forms weathers more rapidly due to increased opportunity for chemical and microbial degradation. The burial of stranded oil, on the other hand, usually reduces rates of degradation and, under anaerobic conditions (i.e. without oxygen), weathering can cease altogether.

The amount of stranded oil which may be dissipated through evaporation depends on the volume of volatile hydrocarbons remaining in the oil, as well as the temperature and wind conditions on the contaminated beach. Losses of oil associated with chemical and photochemical oxidation processes (see Chapter 3) depend on the availablity of oxygen, the amount of sunlight, and the thickness of oil film. Dissolution of various hydrocarbons may occur when oil stranded on the shoreline is flushed by incoming tides; this form of degradation is accelerated by heavy wave action. Biodegradation by bacteria and other microbial organisms is influenced by oxygen availability, temperature, and the surface area of oil available for attack.

In open coastal environments where wave action is relatively heavy and the shore is predominantly rock, natural dispersion and degradation may remove the bulk of the stranded oil in a few weeks. Conversely, sheltered coastline areas, particularly those characterized by sand substrates, may retain stranded oil for years. A case in point is Chedabucto Bay, Nova Scotia, where oil still persists in some beach areas, eight years after the grounding of the tanker ARROW in 1970.

SHORELINE PROTECTION METHODS

The only way to prevent damage to shoreline areas resulting from spilled oil and cleanup activities is to prevent the oil from reaching the shore in the first place. In many instances, however, it is virtually impossible to protect all shoreline areas from oil contamination, and priorities are assigned to protect those areas considered most sensitive.

Since sheltered coastal environments, marshes and lagoons are most sensitive to damage by oil and usually difficult to restore, protection of these areas is given highest priority. The favoured approach is to deploy containment booms and skimmers at the site of the spill, before the oil threatens sensitive beach areas. Booms and skimmers may be used in conjunction with various sorbents that are broadcast over the slick to reduce its rate of spread to sensitive shoreline areas.

W.C. Austin

Containment booms may be used to protect areas of recreational shoreline.

One method of preventing or minimizing contamination of sensitive shoreline areas is to use improvised booms constructed from straw or other available sorbent material. Bales of straw can be staked at the low tide mark and replaced with fresh sorbent after the tide recedes. Commercially available synthetic sorbent sheets or batts can also be spread on the shoreline to absorb the oil as it washes ashore. In tidal environments this is ideally carried out at the low tide mark so that the oil and sorbent mix as the water level rises. Sorbent materials are removed from the low tide mark as soon as possible to minimize oil loss. Loose sorbent materials are not as useful as a shoreline protection measure since they are readily transported by wind and wave action. Natural sorbents such as peat moss can be spread along the shoreline at the low tide mark but are less efficient than synthetic materials and require considerable manpower to recover. As discussed in Chapter 6, the effectiveness of any sorbent material depends to a great extent on the type of oil and the ambient climatic conditions.

Construction of dykes or ditches parallel to the water line and near the high tide mark is another method for protection of sensitive shorelines. This approach is particularly suited to sand or fine gravel beaches which are accessible to backhoes and other construction equipment. Wet sand taken from the intertidal zone well below the high tide mark is best suited for the construction of dykes. However, the ecological soundness of this measure depends on the relative biological productivity of the excavated sand. This technique is only employed when damage to intertidal organisms which use the excavated sand as habitat will be low in relation to potential damage to organisms which inhabit upper portions of the beach. A major disadvantage of dyke construction is that it does not actually collect the incoming oil unless used in conjunction with sorbent materials. Conversely, pits or ditches excavated for collection of oil serve both needs if the beach sediments are sufficiently fine to minimize oil penetration. Both of these methods of shoreline protection are only successful in relatively sheltered areas with light wave action.

In situations where a shoreline area is considered particularly sensitive to oil, it may be necessary to consider the possible use of dispersants *before* the oil reaches the coastal environment. This decision must weigh the possible deleterious impacts of the dispersant on biological resources, and must also involve considerable communication between the On-Scene-Commander and appropriate regulatory agencies. The use of dispersants may be considered in situations where high waves or strong currents preclude or decrease the effectiveness of containment and recovery devices. Industry and government research teams are also presently examining the suitability of a number of surface treating agents which will prevent any oil which washes ashore from adhering to sediments or rock surfaces. Non-toxic surface treating agents can then be rinsed from the shoreline once the threat of oil disappears.

SHORELINE RESTORATION

The most acceptable methods for cleanup of stranded oil in a shoreline environment and subsequent restoration of the area depend on the type of shoreline affected and the nature of its biological resources. The presence of man-made structures such as jetties, piers and docks require specialized cleanup techniques when excessively contaminated. Since most of the methods for shoreline cleanup and restoration are applicable to more than one beach type, subsequent discussion is directed towards various techniques rather than different beach types. The following cleanup and restoration activities are common to many shoreline cleanup programs: chemical dispersion, hydraulic dispersion, steam cleaning, sandblasting, substrate mixing, and various physical removal methods.

Chemical and Hydraulic Dispersion

Non-toxic or low-toxicity chemical dispersants can play a role in shoreline cleanup when permission is obtained for their use and the shoreline is not biologically sensitive. Dispersants can be sprayed on rock surfaces but are not normally used on sand because they accelerate penetration of stranded oil into the substrate and may create conditions similar to quicksand. Dispersants are sprayed on contaminated areas at low tide, and as the tide rises natural wave action mixes the chemical with the stranded oil to form an oil-in-water emulsion. This emulsion is subsequently flushed from the contaminated beach area with water hoses or through natural wave action.

Environment Canada

Where accessibility permits, barge-mounted high-pressure hoses can increase the efficiency of oil dispersion from contaminated shorelines.

High-pressure water hoses are frequently used to wash oil from coarse sediments, rock surfaces, and man-made structures. However, this method is avoided in areas with cobble beaches since it may wash the oil deeper into the substrate. Damage to flora and fauna on rock shorelines may also result from use of high-pressure hoses, and in many cases loosely attached organisms can be dislodged from rock surfaces. As a result, low-pressure hydraulic dispersion is generally favoured, and has been used with some success to remove oil from rock faces, man-made structures and marshes without causing excessive damage to flora and fauna. Like the use of high-pressure hoses, low-pressure dispersion is avoided in sandy areas because it promotes further penetration of the oil and, in some instances, may wash away the granular beach materials. Oil removed from the beach substrate by either of these methods is typically contained within booms placed parallel to the shore and subsequently recovered.

Canadian Coast Guard

Low-pressure hydraulic dispersion is often used to remove oil from rock faces and heavy debris.

Environment Canada

High-pressure hydraulic dispersion is avoided in areas where it might damage biological resources.

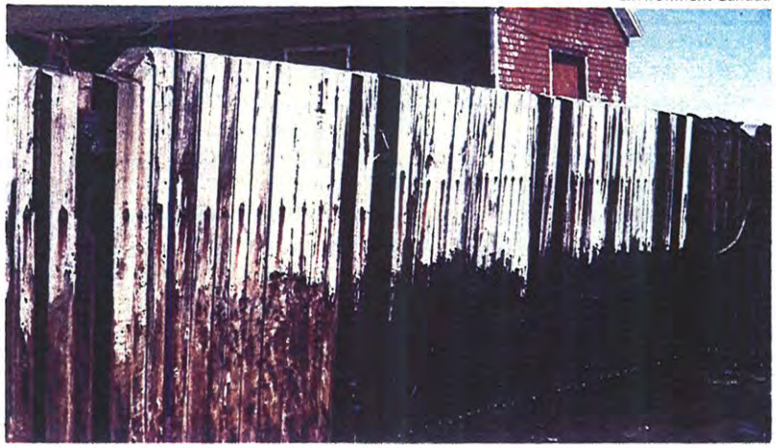
Steam Cleaning and Sandblasting

In some instances, hot-water or steam cleaning has been used for dispersion of stranded oil but this method causes problems similar to those created by the use of high-pressure hoses, and results in even more serious damage to biological resources. Therefore, steam cleaning tends to be restricted to oil removal from man-made structures. Sandblasting is also a satisfactory method of removing oil which has hardened on rock and boulder faces, but it cannot be used in areas where flora and fauna are present. The method is also slow and labour-intensive and for practical purposes tends to be restricted to the cleaning of oil-stained walls and other man-made structures in areas of high aesthetic value.

Environment Canada

Steam hoses are often used to remove oil from man-made structures.

Environment Canada



Traces of oil may remain on some surfaces even after labour-intensive hydraulic dispersion.

Substrate Mixing

On beaches where most of the stranded oil has been removed and only light contamination persists, mixing of the surface sediments with rakes and harrows stimulates evaporation and other weathering processes by exposing a larger surface area of the oil. This method is most effective with low viscosity oils which contain a high proportion of volatile components, particularly when these oils have penetrated the beach substrate and evaporative processes have been retarded. The approach is also most effective when the contaminated sediments are raked into the lower intertidal zone where wave action can accelerate dissolution of water soluble hydrocarbon constituents.

Removal of Oil and Contaminated Materials

On sand beaches, large amounts of oil stranded on the surface can be removed by mechanical graders used in conjunction with elevating scrapers. This is an excellent method of oil removal in areas where the beach surface is hard enough to provide sufficient traction for construction equipment. The most common technique for removal of surface oil is to form windrows of the sand and oil mixture with the grader, and then remove the windrows for disposal or cleaning with an elevating scraper. If graders are not available, elevating scrapers can be used alone; in fact, this is the best approach when traction is poor or oil penetration is less than 2.5 cm. Where traction is very poor or oil penetration exceeds 25 cm, front-end loaders are the only efficient means of removing the contaminated beach material.

Environment Canada

Front-end loaders and other construction equipment play an important role in shoreline cleanup programs.

Several specialized types of equipment have been designed to remove viscous oil or tarry lumps from sand beaches. For example, one approach is the use of tractor-operated sieving devices which pick up the contaminated materials, separate the sand from the oil, and allow the sand to fall back on the beach through screens. However, sieve sizes must be changed for different sizes of sand grains, and the apparatus does not operate efficiently when the sand is wet.

Mechanical removal of oil from coarse sediment (pebble or cobble) beaches is more difficult than oil removal from sandy areas due to the generally greater depth of oil penetration and instability of heavy equipment on this type of surface. Only front-end loaders and bulldozers can operate effectively on this type of beach. Cleanup of pebble or cobble beaches unfortunately involves removal of large volumes of the beach material in relation to the amount of oil recovered, and care must always be exercised to scrape or lift only the contaminated materials. In all cases, the contaminated substrate is cleaned and replaced, or other fill returned to the excavated area in order to minimize erosion of the beach or inundation of backshore areas. It is rarely possible to remove all stranded oil from contaminated pebble-cobble beaches. Once the bulk of the oil has been removed by bulldozers or front-end loaders, the remaining contaminated beach material is usually left in place or transported to lower portions of the beach where natural dispersion and degradation will occur as a result of wave action.

Environment Canada

Manual recovery of oil-soaked shoreline debris is an integral part of virtually all shoreline cleanup and restoration programs.

During all shoreline cleanup programs, as little uncontaminated material as possible is removed to avoid disruption of normal beach processes, and, when large volumes of sand or gravel must be removed, they are generally replaced with materials from backshore areas. For similar reasons, beach cleanup programs are initiated as soon as feasible to avoid excessive oil penetration into the substrate which would then necessitate removal of larger volumes of materials. Manual removal of contaminated material is usually required to supplement mechanical removal methods on most beach types; where mechanical removal is not possible because of limited access, poor traction or substrate type, manual removal, although labour-intensive, may be the only practical approach to cleanup.

When intertidal or marsh vegetation is excessively contaminated with oil and not likely to be cleaned through natural dispersion and degradation processes, it is normally removed with scythes and sickles. This operation is particularly important in marsh areas since oil adhering to vegetation may subsequently contaminate other vegetation when displaced by tidal action. However, cutting of oil-soaked vegetation must be done with considerable care to prevent damage to the root systems of marsh plants, and to avoid trampling of oil into sediments. Transplanting and seeding programs have been initiated following some spills where large portions of marsh vegetation have been inundated with oil and required removal.

Although sorbents have been described in a previous chapter, it is worthy of mention here that they can play a useful role in shoreline cleanup. However, synthetic sorbents are favoured over natural substances because of their greater oil absorption capacity and relative ease of recovery and disposal. In the past, large quantities of peat moss have often been used during shoreline cleanup programs. This practice is no longer generally recommended, however, since this sorbent is not as efficient as synthetic varieties and its recovery from the shore requires excessive labour.

Environment Canada

Sorbent materials may play a useful role in shoreline cleanup programs.

Except in marshes, burning of oil is not a practical approach to its removal since undesirable heavy residues generally persist, air pollution may be intense, and various components of the oil can penetrate the substrate as the burning progresses. Oil in marshes can be successfully burned in the autumn or winter if contaminated vegetation is hand cut and piled for subsequent incineration. In fact, controlled burning is sometimes used for marsh management and can have beneficial effects as long as root systems are protected.

Clean Seas Canada Ltd.

Natural sorbents can be scrubbed into contaminated rock faces to help remove oil trapped in crevices.

W.C. Austin

Natural sorbents such as peat moss, although effective, can accentuate the problem of shoreline restoration unless fully recovered.

A summary of common shoreline cleaning and restoration methods and their suitability for various beach types is provided in Table 7.

Table 7
SHORELINE RESTORATION METHODS

	Chemical Dispersants*	Hydraulic High-Pressure	Hydraulic Low-Pressure	Steam Cleaning	Sandblasting	Mixing	Mechanial Removal	Manual Removal	Sorbents	Burning	Cropping
Rock Surfaces	+	+	✔	+	+	O	O	✔	+	O	+
Man-Made Structures	+	✔	✔	✔	✔	O	O	✔	+	O	O
Unresistant or Unconsolidated Cliffs	O	×	×	×	×	O	×	×	×	O	O
Coarse Sediment Beaches	+	+	+	×	×	+	+	✔	+	×	O
Sand Beaches	+	×	×	×	×	+	✔	✔	✔	×	O
Intertidal Coarse Sediments	+	+	+	+	×	+	+	✔	+	×	O
Intertidal Sand	+	×	×	×	×	×	+	+	+	×	O
Intertidal Mud	+	×	×	×	×	×	×	+	+	×	O
Marshes	×	×	✔	×	×	O	×	✔	+	+	+

*Chemical dispersants are only used in low sensitivity environments and require approval of appropriate government agencies.

✔ Recommended
+ Useful in some instances
× Not Recommended
O Not Applicable

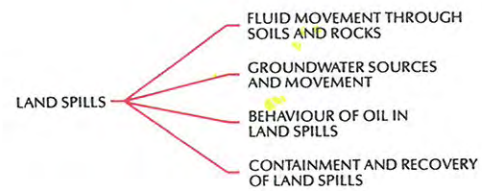
Clean Seas Canada Ltd.

Beach debris is frequently cut and burned when heavily contaminated.

Chapter 10

Land Spills

The vast majority of oil spills in Canada occur on land (see Table 1, Chapter 1) but because they are generally less dramatic than spills in marine or inland waters they receive less attention from the public and press. Pipeline incidents account for the largest proportion of land spills, with storage tank leaks, fueling or transfer spills, vehicle accidents and train derailments contributing lesser amounts to the overall accidental release of oil on land. Most land spills involve small quantities of oil and have less impact on physical and biological resources than spills on water. Land spills normally penetrate only a few centimeters and are either cleaned up immediately or left to degrade through natural processes. However, when large quantities of oil are spilled on land, there is a threat of contaminating ground and surface waters, and cleanup programs are generally initiated as early as possible. This section deals with the behaviour of oil spilled on land and describes the more common methods of containment and recovery.



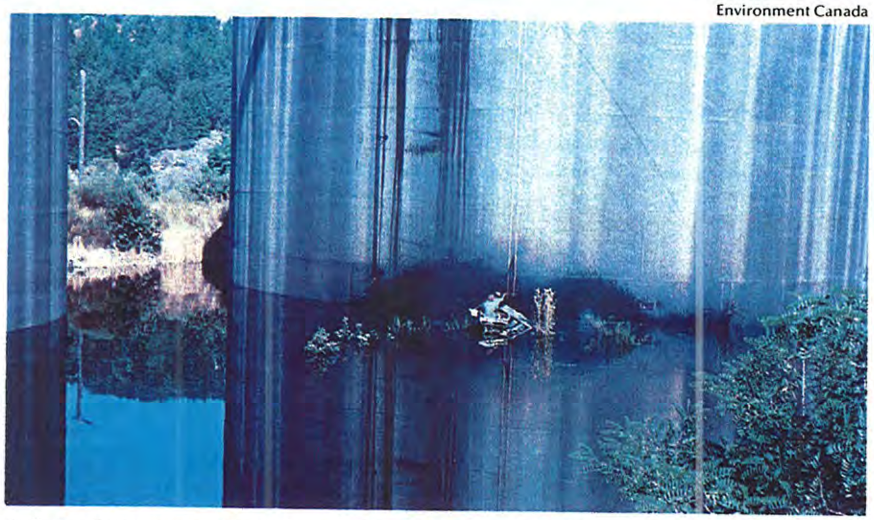
Environment Canada

Pipeline leaks account for the largest proportion of land spills reported in Canada.

Environment Canada

If spilled oil is allowed to penetrate soils and rocks, it may contaminate groundwater supplies.

Environment Canada



A dramatic example of a storage tank rupture which resulted in the inundation of a large area with oil.

FLUID MOVEMENT THROUGH SOILS AND ROCKS

The movement of fluids such as oil through soils and rocks is far more complicated and unpredictable than the spread of oil slicks on water. Unless the geology of an area is well known, the horizontal and vertical movement of oil from the site of a spill and its environmental consequences are extremely difficult to predict. "Soil" is defined as the loose unconsolidated material such as sand, gravel and silt located near the surface, while "rock" is the hard consolidated material (i.e. bedrock) usually found beneath the soil.

Most soils and rocks consist of small fragments or grains, which, when compacted together, incorporate small openings or "pores." If these pores are interconnected, the rock is said to be "permeable" and will allow passage of fluids such as oil and water. Materials such as clay, silt or shale have extremely small pores which are poorly interconnected; these materials allow only limited passage of fluids and are therefore referred to as being "impervious."

Most commonly, soils and rocks are composed of distinct layers produced by successive deposition of different types of material. This layering effect is often seen when large sections of soil and rock are excavated for construction of highways or other structures. These layers are often not parallel to the surface but slope or dip in some direction. This is extremely important in relation to oil spills since this sloping, in addition to the porosities and permeabilities of the different layers, greatly influences the underground movement of fluids, including oil. Oil may also move underground through cracks, fissures and fractures in rock material which is otherwise impervious.

GROUNDWATER SOURCES AND MOVEMENT

The source of most groundwater is precipitation which is absorbed by porous soils and rocks at the surface; loss of water from rivers and streams to the adjacent subsoil also contributes to the groundwater supply. Because of capillary action, the subsoil above the water table is saturated to a greater or lesser extent with water, depending on the geographic region and season. The water table (or groundwater level) usually has an undulating surface that conforms in a general way to the topography of the area. The level of this water table fluctuates seasonally, and is highest during the rainy months of the year.

Groundwater is not stationary but moves in a manner similar to that of a lake with its water flowing to a single outlet. Rates of groundwater movement vary throughout the year and from area to area; this rate can range from only a few centimeters to several meters per day. The rate of flow depends primarily on the permeability of the upper soil and rock layers, and the slope of the water table.

BEHAVIOUR OF OIL IN LAND SPILLS

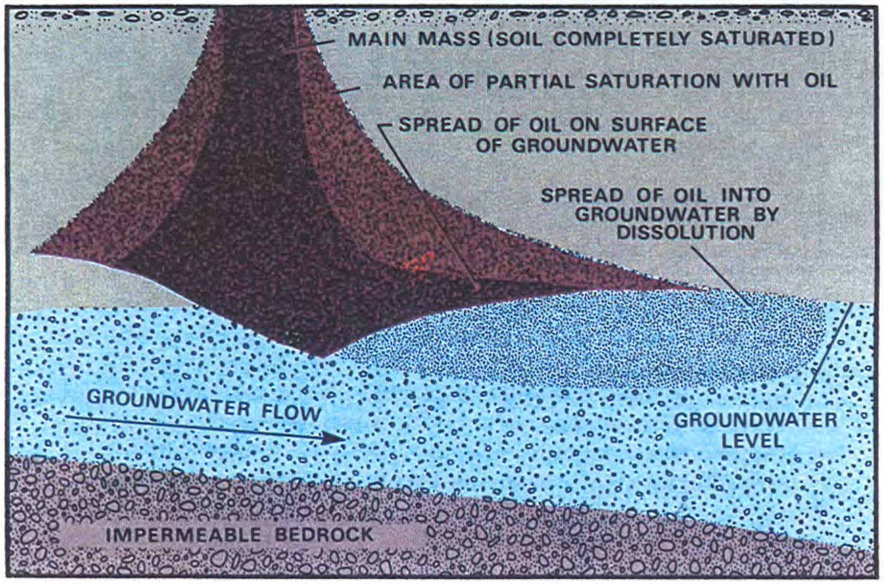
Oil spilled on land will spread over the surface and sink into any permeable soils or rocks. The degree of penetration depends on the type and nature of the surface materials and the type and volume of oil. A low viscosity oil will rapidly penetrate into a dry porous soil such as coarse sand, and at the same time, reduce its rate of spread over the surface. On the other hand, a wet or clay-like soil will tend to resist penetration by spilled oil. In this case, and especially with more viscous oils, the spilled oil will continue to spread horizontally until a much larger surface area is covered. Very viscous oils such as the heavier fuel oils often form a tarry mass when spilled, particularly when the ambient temperature is below their pour point.

In most areas with typical agricultural-type soils, spilled oil will usually saturate the upper 10 to 20 cm of the soil, irrespective of the oil viscosity. Penetration is generally deeper in areas where the oil has formed pools in dry depressions; however, if such depressions contain water, the oil will not penetrate at all. As in the case of spills on water, volatile components of the oil will begin to evaporate immediately, and since the oil does not spread as quickly, the threat of explosion or fire is usually greater. Light oils such as gasoline which spread rapidly over the soil surface also tend to evaporate quickly; consequently, the duration of an explosion risk is short but the actual risk of an explosion is relatively high.

Spilled oil has a tendency to migrate along artificial fills such as pipeline trenches, foundation fills, and utility ducts. Such excavations are often backfilled with material which is more permeable than the soil removed, and therefore offer a migration route of minimum resistance, along which the oil tends to move more rapidly than it would through natural soils. Oil which penetrates into the subsoil will move downward under the influence of gravity. The size and shape of this moving oil mass depends on the nature and structure of the soil as well as the quantity and type of oil. This descending oil mass is often referred to as a "slug" because of its characteristic shape. When the oil at the surface is depleted, the oil slug will continue migrating downwards, leaving behind a funnel of soil which is partially saturated with oil.

Figure 17

MOVEMENT OF OIL IN A POROUS SUBSOIL IN CONTACT WITH GROUNDWATER.



Where the amount of oil spilled is small or the water table is low, the mobile oil will dissipate during its descent, and will leave behind a trail of relatively immobile oil in a roughly vertical column. Subsequent rainfall, percolating through the soil, may cause further downward movement of minor amounts of this residual oil, especially the water soluble components. This situation, however, presents less risk of significant pollution than if the main body of the oil slug reaches the water table. The rate of downward penetration is dependent on the composition of both the oil and soil; a combination of coarse gravel and low viscosity oil will result in a relatively fast seepage rate. Very viscous oils such as heavy fuel oils and some crudes usually do not penetrate the soil to a great depth and downward movement is slow. Migration of the oil slug will continue until it is completely absorbed by the soil, stopped by an impermeable layer, or reaches the groundwater.

As the oil spreads, variations in the permeability of the subsoil may produce changes in its spreading pattern. Spreading rates vary dramatically with time; 40% to 70% of the final extent of spreading usually occurs within 24 hours of the spill, and 60% to 90% in one week. This spreading process can continue for relatively long periods but eventually the carrying capacity of the soil is reached and the spreading process ceases. Any subsequent movement of the oil is generally a result of its displacement by water, and is typically in the direction of the groundwater flow. This oil can eventually reappear in springs, and in such cases may result in contamination of surface waters. The typical movement pattern of oil on groundwater is illustrated in Figure 17.

Environment Canada

Earthen dams may be constructed to contain spilled oil.

CONTAINMENT AND RECOVERY OF LAND SPILLS

Containment of oil spills which occur on land is always undertaken with the proximity of the water table in mind, and usually involves deployment of heavy construction equipment. Bulldozers are typically used for building earthen dykes and containment pits, while backhoes are used for digging trenches to divert oil flow on the surface and expose subsurface oil. Another approach to containing an oil spill on land is to place straw or other sorbent materials in its path. As the sorbent barrier becomes saturated with oil, it is continually replaced.

When oil is spilled on land adjacent to watercourses and drainage

Environment Canada

Water may be pumped into a contaminated area to prevent the oil from penetrating the subsoil.

Environment Canada

Trenches are often excavated to the water table for recovery of oil.

systems, a high priority is given to containment procedures to prevent its spread into these areas. As a precautionary measure, dams may be constructed on smaller ditches and booms deployed on larger rivers. Combinations of sand bags, plastic sheets and sorbents are often used to construct dykes which are designed to prevent the flow of oil into watercourses. This approach may also be used to prevent the spread of oil to areas of extensive vegetation cover or human habitation.

When groundwater is threatened due to the water table being near the surface, every effort is made to prevent downward penetration of the oil. This is usually accomplished by exactly the reverse of containment, allowing or actually promoting the spread of oil into thinner layers so that penetration is reduced. When oil is diverted to temporary containment ditches, water is often pumped into the ditch to prevent oil from penetrating the soil below the ditch.

Environment Canada

Recovery of oil from an excavated trench using a mechanical skimmer.

Environment Canada

Straw sorbent barriers may be used for containment of oil spilled on land.

A variety of methods are used to recover oil spilled on land. Oil lying in pools, trenches, or in specially constructed troughs can be removed with pumps, buckets or similar equipment. On the other hand, if the oil layer is relatively thin, sorbent materials may be used to soak up oil on the surface. When the spill is relatively small and oil has not penetrated to a great depth, recovery may be performed by excavation and disposal of all contaminated material. However, when this approach is undesirable for environmental reasons or the affected area is more extensive, the oil must be separated from the excavated soil and the soil replaced. A common method of accomplishing this is to excavate the material which has become oil soaked and place it in piles around the excavation pit. The pit is then lined with plastic and the contaminated soil slowly washed back into the pit. As the oil comes to the water surface, it is either removed manually or with a mechanical skimmer.

When the oil has only penetrated the soil to a depth of 5 m or less, and is 1 m or more from the water table, the spill is usually not considered particularly serious with respect to groundwater contamination. For this type of spill, the most suitable cleanup technique is excavation of all soil which is visibly contaminated. Oil contaminated material is often simply disposed of at a sanitary land fill site which has been approved by the appropriate government agencies, and the excavated area refilled with clean materials. Alternatively, the contaminated area may be plowed and fertilizers added to accelerate the rate of natural microbial degradation.

A more serious situation exists when the oil is less than 1 m from domestic or agricultural groundwater supplies but still has not penetrated beyond 5 m into the soil. This situation could occur during periods of heavy rainfall when the water table is close to the surface. The most common cleanup technique under this combination of circumstances is excavation of soil to a depth below the water table. The oil is then skimmed or pumped off the surface of the groundwater. During this type of cleanup program, care is taken to avoid disruption of impervious layers since this could result in seepage of the oil to areas below the water table.

A high priority cleanup response is generally required when oil has penetrated the soil to depths greater than 5 m, and is near important groundwater supplies. A common cleanup strategy under this set of circumstances is to flush oil out of the soil by circulating water through the contaminated soil layers. In some instances, a borehole is sunk to a depth just below the water table, and large volumes of water allowed to percolate down through the oil bearing layers. This procedure drives the residual oil from the pores in the soil to the groundwater surface where it can then be pumped through the borehole to a surface recovery site. A similar approach is often taken when the contaminated layers lie more than 5 m from the water table, except that some residual oil may be left within the soil to degrade through natural processes.

When the oil is some distance from groundwater supplies which are not utilized for domestic or agricultural purposes, the favoured approach is to leave the oil in the ground. This oil will eventually biodegrade as a result of microbial activity. However, it is important that local patterns of groundwater distribution be thoroughly understood so that there is no potential for oil to re-enter surface water supplies, including watercourses containing valued fishery resources. Although the degradation process is slow, this approach causes the least disturbance to the soil.

When oil is spilled on soil of agricultural quality, measures may be taken to hasten restoration of the site since microbial degradation of residual traces of oil may require several years. These remedial actions generally involve modification of soil conditions to help provide suitable growth conditions for both plants and micro-organisms. The most effective restoration techniques are addition of nutrients, aeration, maintenance of a neutral soil pH, tillage or mixing to break surface crusts, and, in cases of very wet sites, some form of drainage to remove excess water.

Glossary of Technical Terms

Glossary of Technical Terms

ABSORPTION
Any process by which one substance penetrates the interior of another substance. In the case of oil spill cleanup, this process applies to the uptake of oil by capillaries within certain sorbent materials. (See also: Capillary action.)

ADSORPTION
The process by which one substance is attracted to and adheres to the surface of another substance without actually penetrating its internal structure.

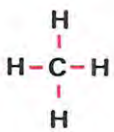
AEROSOL
A system in which liquid or solid particles are distributed in a finely divided state through a gas, usually air. Particles within aerosols are usually less than 1 micron (0.001 mm) in diameter, and are more uniformly distributed than in a spray.

AIR OR WATER STREAMS
A method of oil containment where the force of air or water directed as a stream can be used to divert or contain an oil slick. The method can be used to flush oil from beneath docks or to adjust floating booms once they are in place.

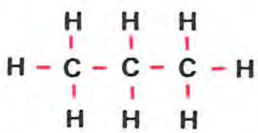
ALCOHOLS
A class of organic chemical compounds characterized by the presence of the hydroxyl (OH: oxygen-hydrogen) group attached to a carbon atom. Alcohols are important solvents, and are used to a certain extent in the preparation of chemical dispersants. (See also: Glycols.)

ALKANES
A class of hydrocarbons (compounds of hydrogen and carbon) characterized by branched or unbranched chains of carbon atoms with attached hydrogen atoms. Alkanes all have the general formula C_nH_{2n+2}, and contain no carbon-carbon double bonds (i.e. they are saturated). Alkanes are also called paraffins and are a major constituent of natural gas and petroleum. Alkanes containing less than 5 carbon atoms per molecule ("n" in above formula is less than 5) are usually gases at room temperature (e.g. methane), those having between 5 to 15 carbon atoms are usually liquids, and straight chain alkanes having more than 15 carbons are solids. Low carbon number alkanes produce anaesthesia and narcosis (stupor; slowed activity) at low concentrations and at high concentrations can cause cell damage and death in a variety of organisms. Higher carbon number alkanes are not generally toxic but have been shown to interfere with normal metabolic processes and communication in some species. The structures of methane, the simplest alkane, propane, and isobutane, a

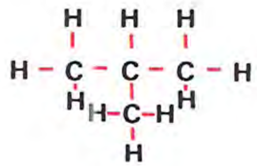
branched alkane, are indicated below. (For other common hydrocarbons, see also: Alkenes, Aromatics and Naphthenes.)



METHANE



PROPANE

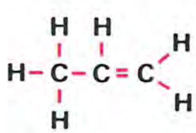


ISOBUTANE

ALKENES

A class of straight or branched chain hydrocarbons similar to alkenes but characterized by the presence of carbon atoms united by double bonds. Alkenes are also called olefins and all have the general formula C_nH_{2n}. Alkenes containing 2 to 4 carbon atoms are gases at room temperature, while those containing 5 or more carbon atoms are usually liquids. Alkenes are not found in crude oils but are often formed in large quantities during the cracking (breaking down of large molecules) of crude oils, and are common in many refined petroleum products such as gasolines. These hydrocarbons are generally more toxic than alkanes but less toxic than aromatics. The structural formulae of ethene, the simplest alkene, and propene, an alkene containing three carbon atoms, are indicated below. (For other classes of hydrocarbons, see also: Alkanes, Aromatics and Naphthenes.)

ETHENE



PROPENE

AMBIENT

Local or surrounding conditions; primarily used in reference to climatic conditions at some point in time, e.g. ambient temperature.

ANAEROBIC

A term used to describe a situation or an area characterized by the lack of oxygen. The term can also be used in reference to organisms such as some bacteria which can survive and grow in the absence of gaseous or dissolved oxygen. For example, many marine sediments are anaerobic below a depth of a few centimeters from the surface, and therefore degradation of oil deposited in such areas is slow and primarily associated with anaerobic types of micro-organisms.

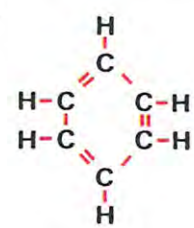
API GRAVITY

A scale developed by the American Petroleum Institute to designate an oil's specific gravity, or the ratio of the weights of equal volumes of oil and pure water. API gravity is dependent on temperature and barometric pressure, and is therefore generally measured at 16°C and one atmosphere pressure. Water with a specific gravity of 1.0 has an API gravity of 10°. A light crude oil may have an API gravity of 40°. Oils with low specific gravities have high API gravities and vice versa. API gravity can be calculated from specific gravity using the following formula. (See also: Specific gravity.)

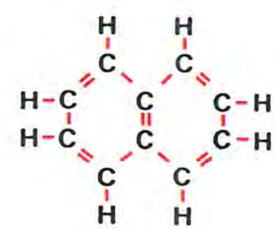
API° = (141.5 / Specific Grav. @ 16°C) - 131.5

AROMATICS

A class of hydrocarbons characterized by rings containing 6 carbon atoms. Benzene is the simplest aromatic and most aromatics are derived from this compound. Aromatics are considered to be the most immediately toxic hydrocarbons found in oil, and are present in virtually all crude oils and petroleum products. Many aromatics are soluble in water to some extent, thereby increasing their danger to aquatic organisms. Certain aromatics are considered long-term poisons and often produce carcinogenic effects. The structural formulae of two common aromatics, benezene and naphthalene, are shown below. (For other classes of hydrocarbons, see also: Alkanes, Alkenes and Naphthenes.)



BENZENE



NAPHTHALENE

ASPHALT

A black or brown hydrocarbon material that ranges in consistency from a heavy liquid to a solid. The most common source of asphalt is the residue left after the fractional distillation of crude oils. Asphalt is primarily used for surfacing roads.

BACKSHORE

The area of the shoreline above the high tide mark. The backshore is only inundated with water during exceptionally strong storms or abnormally high tides accompanied by high winds, and therefore does not support characteristic intertidal flora and fauna. Granular materials for the replacement of oil contaminated beach material excavated during shoreline cleanup programs are frequently taken from backshore areas.

BARREL

A unit of liquid (volumetric) measure for petroleum and petroleum products, equal to 35 Imperial gallons or approximately 160 liters. This measure is used extensively by the petroleum industry.

BARRIER or CONTAINMENT BARRIER

With respect to oil spill cleanup, any non-floating structure which is constructed to contain or divert spilled oil. Barriers are generally improvised and, unlike booms, are usually left in place until the cleanup program is complete. Sorbent materials may be used in the barrier construction to simultaneously recover the spilled oil. Barriers are most frequently used in streams or ditches too shallow for conventional floating booms, and are almost always staked downstream of the spill site.

BIODEGRADATION

The degradation of substances resulting from their use as food energy sources by certain micro-organisms including bacteria, fungi and yeasts. The process with respect to oil degradation is extremely slow and limited to great extent by temperature, nutrients and oxygen availability. Although more than 100 species of micro-organisms have the ability to utilize hydrocarbons as an energy source, no single species can degrade more than 2 or 3 of the many compounds normally found in oil.

BIOLOGICAL AGENT

Micro-organisms (primarily bacteria) added to the water column or soil to increase the rate of biodegradation of spilled oil. Alternatively, nutrients added to the water (in the form of fertilizers) to increase the growth and biodegradation capacity of micro-organisms already present.

BIOLOGICAL PRODUCTIVITY

The rate at which the energy of the sun is transferred to and reflected in growth and/or abundance of plants and animals. It is a measure of the biological richness of a population, community or ecosystem, and is usually expressed as the quantity of carbon stored in tissue per unit time. Certain environments are characterized by higher biological productivity than others; for example, marshes and estuaries are generally more productive than offshore marine waters. The biological productivity of an area is an important consideration in contingency plan design and priorities assigned for oil spill cleanup.

BOILING POINT

The temperature at which a liquid begins to boil; specifically, the temperature at which the vapour pressure of a liquid is equal to the atmospheric or external pressure. The boiling point of crude oils and petroleum products may vary from 30 to 550°C but is of little practical significance in terms of oil spill cleanup. (See also: Flash point.)

BOOM or CONTAINMENT BOOM

A floating mechanical structure which extends above and below the water surface, and is designed to stop or divert the spread or movement of an oil slick. Booms are an integral part of virtually all cleanup programs following oil spills on water.

BOOM FAILURE

Failure of a commercial or improvised boom to contain oil due to excessive winds, waves or currents, or improper deployment. Boom failure may be manifested in oil underflow, oil splashover, or structural breakage. (See also: Sheet breakaway; Droplet breakaway.)

BRINE CHANNELS

Small passages formed in the lower surface of first-year sea ice formed by the exclusion of saline water or salts during rapid freezing. Researchers have found that oil under first year ice will migrate through the brine channels once the spring melting process begins. (See also: First-year ice.)

BUBBLE BARRIER

A containment barrier which takes advantage of the 2-way currents produced when a rising curtain of bubbles reaches the water surface. The system has been used with some success in relatively calm harbours but requires considerable maintenance when the submerged perforated pipes which are used to produce the bubble curtain become covered with redistributed bottom silt.

BULK CARRIER

An ocean-going vessel specifically designed to transport large quantities of a single product such as grain or coal.

BUNKER "B"

A relatively viscous fuel oil (No. 5 fuel) used primarily as a fuel for marine and industrial boilers.

BUNKER "C"

A very viscous fuel oil (No. 6 fuel) used as a fuel for the marine and industrial boilers.

BURNING AGENT

Compounds or materials such as gasoline which are used to ignite and sustain combustion of spilled oil which otherwise will not burn. Burning agents are generally required to burn weathered oils since volatile, low flash point hydrocarbons are rapidly lost through evaporation.

CANADIAN COAST GUARD

An agency within the Department of Transport, responsible for aids to navigation, nautical and pilotage services, and steam ship inspection. The Canadian Coast Guard also has a division which is responsible for cleanup of oil spills in navigable waters.

CAPILLARY ACTION

The process whereby the force of attraction between a solid and a liquid causes the liquid to be drawn into the porous internal structure of the solid. (See also: Absorption.)

CARBON NUMBER

The number of carbon atoms present in a single molecule of a given hydrocarbon. The physical and chemical properties of hydrocarbons tend to vary with the number of carbon atoms, and these properties are frequently described in terms of carbon number ranges for specific classes of hydrocarbons. For example, alkanes with carbon numbers from 1 to 4 are gaseous at ordinary temperatures and pressures.

CATALYST

A substance added to a reacting system (e.g. chemical reaction) which alters the rate of the reaction without itself being consumed. Most catalysts are used to increase the rate of a reaction. For example, the metal vanadium is often present in trace amounts in crude oils and acts as a catalyst to accelerate the rate of chemical oxidation of certain hydrocarbons as the oil weathers. Catalysts (silica, alumina, for example) are also used during the refining of petroleum to increase the rate at which large hydrocarbon molecules are split into smaller ones (catalytic cracking).

CENTRIFUGAL SKIMMER

A mechanical skimmer design which operates by the creation of a water vortex or whirlpool which draws oil into an area within the device where it can subsequently be pumped off.

CHEMICAL BARRIER

Chemicals which act as surface tension modifiers to inhibit the spread of an oil slick on water. When placed on the water surface next to an oil film, these chemicals push away the oil as a result of their surface tension. However, chemical barriers only work with fresh oils and their effect only lasts a few hours. (See also: Surface tension.)

CHEMICAL DISPERSION

With respect to oil spills, this term refers to the creation of oil-in-water emulsions by the use of chemicals made for this purpose. In regard to shoreline cleanup, chemical dispersion is the process of spraying chemical dispersants to remove stranded oil from rocky shoreline areas which are not considered biologically sensitive. Dispersants are usually sprayed on the contaminated surfaces at low tide and allowed to mix with the oil through natural wave action on the incoming tide. This forms an oil-in-water emulsion which is subsequently flushed from the shoreline with water hoses or through natural wave action.

CHOCOLATE MOUSSE

The name given to a water-in-oil emulsion containing 50-80% water. These emulsions are very stable, have a butter-like consistency, and are only formed with a relatively viscous oil in the presence of considerable wave action. (See also: Emulsification; Water-in-oil emulsion.)

CLAY

Soil or sediment particles which are less than 0.004 mm (4 microns) in maximum dimensions. Most clays are produced as a result of the weathering of coarser rock materials. Clay particles are smaller than either sand or silt.

COBBLE BEACH

A beach composed primarily of gravel having a size range from 64 to 256 mm. This type of beach is also referred to as a shingle beach. By comparison, boulder substrates are greater than 256 mm, while pebble substrates range in size from 4 to 64 mm.

CONTAINMENT

The process of preventing the spread of oil beyond the area where it has been spilled in order to minimize pollution and facilitate recovery.

CONTINGENCY PLAN

A plan for action prepared in anticipation of an oil spill. A contingency plan usually consists of guidelines developed for a specific industrial facility or an entire region to increase the effectiveness, efficiency and speed of cleanup operations in the event of an oil spill, and simultaneously protect areas of biological, social and economic importance.

COUNTERMEASURE

An action taken to prevent or control pollution by oil spills.

CRITICAL VELOCITY

The lowest water current velocity which will cause loss of oil under the skirt of a containment boom. Critical velocity varies with specific gravity, viscosity and thickness of the oil slick contained by the boom, as well as the depth of the skirt and position of the boom with respect to the current direction. Critical velocity for most oils in situations where the boom is at right angles to the current is about 0.5 m/sec (1 knot). (See also: Boom failure.)

CRUDE OIL
Petroleum in its natural form before it is subjected to any refining process such as fractional distillation or catalytic cracking.

DETRITUS
Loose material that results from rock disintegration or abrasion. Also, suspended material in the water column including fragments of decomposing flora and fauna, and faecal pellets produced by zooplankton and associated bacterial communites. (See also: Faecal pellets.)

DISPERSANTS or CHEMICAL DISPERSANTS
Chemicals which reduce the surface tension between oil and water, and thereby facilitate the breakup and dispersal of the slick throughout the water column in the form of an oil-in-water emulsion. Chemical dispersants can only be used in areas where adverse biological damage will not occur, and then only when approved for use by government regulatory agencies.

DISPERSION
The distribution of spilled oil into the upper layers of the water column by natural wave action or application of chemical dispersants. In shoreline cleanup and restoration, the removal of stranded oil through wave action (natural dispersion), or application of chemical dispersants, or use of one of various hydraulic dispersion techniques.

DISSOLUTION
The act or process of dissolving one substance in another. Specifically, a process contributing to the weathering of spilled oil whereby certain "slightly" soluble hydrocarbons and various mineral salts present in oil are dissolved in the surrounding water.

DROPLET BREAKAWAY
A type of boom failure resulting from excessive current velocity. In this type of boom failure, the head wave formed upstream of the oil mass contained within a boom becomes unstable and oil droplets are torn off and become entrained in the water flow beneath the boom. (See also: Critical velocity; Head wave; Sheet breakaway.)

EMULSIFICATION:
The process whereby one liquid is dispersed into another liquid in the form of small droplets. In the case of oil, the emulsion can be either oil-in-water or water-in-oil. Both types of emulsions are formed as a result of wave action, although water-in-oil emulsions are more stable and create special cleanup problems. (See also: Oil-in-water emulsion; Water-in-oil emulsion.)

ENVIRONMENTAL PROTECTION SERVICE
A service within Environment Canada which develops and enforces environmental protection regulations, standards, protocols, and other protection and control instruments which are used to implement federal environmental legislation. The EPS includes the Environmental Emergency Branch whose function is to develop and maintain a national state of preparedness in order to cope with accidents (such as oil spills) and to coordinate response to these accidents in close liaison with provincial authorities and industry. This branch also develops and evaluates new countermeasures to deal with environmental accidents.

ENVIRONMENTAL SENSITIVITY
The susceptibility of a local environment or area to any disturbance which might decrease its stability or result in either short or long-term adverse impacts. Environmental sensitivity generally includes physical, biological and socio-economic parameters.

ESTUARY
A partly enclosed coastal body of water in which freshwater (usually originating from a river) is mixed and diluted by seawater. Estuaries are generally considered more biologically productive than either adjacent marine or freshwater environments, and are important areas in the life history of many fish and wildlife resources.

EVAPORATION
The process whereby any substance is converted from a liquid state to become part of the surrounding atmosphere in the form of a vapour. In the case of oil, the rate of evaporation depends on the volatility of various hydrocarbon constituents, temperature, wind and water turbulence, and the spreading rate of the slick. Evaporation is the most important process in the weathering of most oils.

FAECAL PELLETS
Solid or semi-solid excretion products (faeces) which are enclosed within a thin membrane, such as produced by zooplankton and some other invertebrates. If organisms ingest oil which is dispersed in the water column, these faecal pellets may contain oil globules.

FAUNA
Animals in general, or animal life as distinguished from plant life (flora). Usually used in reference to all the animal life characteristic of or inhabiting a particular region or locality.

FIRST-YEAR ICE

In the Arctic, ice formed during the winter of a given year, and not containing residual or polar pack ice from previous years. First-year ice is characterized by the presence of brine channels and is relatively porous in comparison with pack ice. (See also: Brine channels.)

FLASH POINT

The temperature at which vapours produced by a crude oil or petroleum product will ignite when exposed to an ignition source such as an open flame. (See also: Boiling point.)

FLORA

Plants in general, or plant life as distinguished from fauna (animal life). Usually used in reference to all the plant life inhabiting or characteristic of a particular region or locality.

FRACTIONAL DISTILLATION

Separation of a mixture of liquids such as crude oil into components having different boiling points. Fractional distillation is the primary process in the refining of crude oils.

FREEBOARD

The part of a floating boom designed to prevent waves from washing oil over the top. Freeboard is also used to describe the distance from the water surface to the top of the boom. Freeboard is generally also applied to the distance from the deck of a vessel (ship, barge, etc.) to the water line.

FUEL OILS

Refined petroleum products having specific gravities in the range from 0.85 to 0.98 and flash points greater than 55°C. This group of products includes furnace, auto diesel, and stove fuels (No. 2 fuel oils); plant or industrial heating fuels (No. 4 fuels oils); and various bunker fuels (No. 5 and No. 6 fuel oils).

GASOLINES

A mixture of volatile, flammable liquid hydrocarbons used primarily for internal combustion engines, and characterized by a flash point of approximately -40°C and a specific gravity from 0.65 to 0.75.

GELLING AGENTS

Chemicals which increase the viscosity of oil, and, in theory, can be applied to an oil slick to reduce its rate of spread over the water surface. However, gelling agents are rarely used due to their expense, the large volume required and slow action.

GLYCOLS

Any of a class of organic compounds belonging to the alcohol family but having two hydroxyl groups (OH: oxygen-hydrogen) attached to different carbon atoms. The simplest glycol is ethylene glycol, a compound used extensively for automobile antifreeze and contained in many modern chemical dispersants.

GROUNDFISH

Fish species normally found close to the sea bottom throughout the adult phase of their life history. Groundfish feed extensively on bottom fauna and include species such as cod, halibut and turbot.

GROUNDWATER

Water present below the soil surface and occupying voids in the porous subsoil; specifically, the porous layer which is completely saturated with water. The upper surface of the groundwater is referred to as the water table. Contamination of groundwater supplies is a major concern when oil is spilled on land since groundwater supplies springs and wells, and passes into surface water supplies in many areas.

HEAD WAVE

An area of oil concentration which occurs behind and at some distance from containment booms. This area of oil thickening is important to the positioning of mechanical recovery devices (i.e. skimmers), and is the region where the droplet breakaway boom failure phenomenon is initiated when current flow exceeds critical velocity. (See also: Droplet breakaway.)

HYDRAULIC DISPERSION

One of various shoreline cleanup techniques which utilizes a water stream at either low or high pressure to remove stranded oil. These techniques are most suited to removal of oil from coarse sediments, rocks and man-made structures, although care must be taken to avoid damage to intertidal flora and fauna.

HYDROCARBONS

Organic chemical compounds composed only of the elements carbon and hydrogen. Hydrocarbons are the principal constituents of crude oils, natural gas and refined petroleum products, and include four major classes of compounds (alkanes, alkenes, naphthenes, and aromatics) each having characteristic structural arrangements of hydrogen and carbon atoms, as well as different physical and chemical properties.

HYDROPHOBIC AGENT

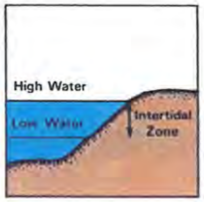
A chemical or material which has the ability to resist wetting by water. Hydrophobic agents are occasionally used in the treatment of synthetic sorbents to decrease the amount of water absorbed and hence increase the volume of oil they can absorb before becoming saturated. (See also: Synthetic organic sorbents.)

IMPROVISED BOOMS

Booms constructed from readily available materials such as railroad ties, logs and telephone poles. Improvised booms may be used as temporary containment structures until more suitable commercial booms arrive at the spill site. They may also be used in conjunction with commercial floating booms to divert oil into areas where the commercial booms are positioned.

INTERTIDAL ZONE

The portion of the shoreline between the low tide mark and high tide mark which is covered by water at some time during daily tidal cycles. The size of the intertidal zone varies with the tidal characteristics of a given region, as well as the steepness of the shoreline. In general, steep, rocky shorelines have smaller intertidal zones than gradually sloping sand or gravel beaches. Since all portions of the intertidal zone are without water cover at some time during each day, flora and fauna capable of withstanding dessication are found throughout this zone. Depending on the tidal level when oil reaches the shoreline, all or a portion of the intertidal zone can be affected by the incoming slick. The most suitable cleanup methods are dictated by the physical characteristics of the intertidal zone, as well as the sensitivity of the affected shoreline. In some instances, the intertidal zone is left to cleanse itself naturally.



JET FUEL

A kerosene or kerosene-based fuel used to power jet aircraft combustion engines. (See also: Kerosene.)

KEROSENE

A flammable oil characterized by a relatively low viscosity, specific gravity of approximately 0.8 and flash point near 55°C. Kerosene lies between the gasolines and fuel oils in terms of major physical properties, and is separated from these products during the fractional distillation of crude oils. Uses for kerosene include fuels for wick lamps, domestic heaters and furnaces; fuel or fuel components for jet aircraft engines; and thinner in paints and insecticide emulsions.

LIGHT ENDS

A term used to describe the low molecular weight, volatile hydrocarbons in crude oil and petroleum products. The light ends are the first compounds recovered from crude oil during the fractional distillation process, and are also the first fractions of spilled oil to be lost through evaporation.

LUBRICATING OILS

Oils used to reduce friction and wear between solid surfaces such as moving machine parts and internal combustion engine components. Petroleum-based lubricating oils (and greases) are refined from crude oil through a variety of processes including vacuum distillation, extraction of specific products with solvents (solvent extraction), removal of waxes with solvents, and treatment with hydrogen in the presence of a catalyst. Most lubricating oils and greases derived from crude oil contain a large proportion of high carbon number alkanes and naphthenes which provide the most favorable lubricating characteristics. The viscosity of a lubricating oil is its most important characteristic since it determines the amount of friction that will be encountered between sliding surfaces and whether a thick enough film can be built up to avoid wear from solid-to-solid contact.

MANUAL RECOVERY

A term used to describe the recovery of oil from contaminated areas by the cleanup work force with the use of buckets, shovels and similar equipment. Manual recovery is extremely labour intensive but plays a role in many oil spill cleanup programs.

METRIC TON (TONNE)

A unit of mass and weight equal to 1,000 kilograms or 2,205 pounds avoirdupois. In Canada, the metric ton is the most widely used measure of oil quantity by weight. There are roughly 7 to 9 barrels (245 to 315 Imperial gallons) of oil per metric ton, depending on the specific gravity of the crude oil or petroleum product.

MICRO-ORGANISMS

Plant or animal life of microscopic or ultramicroscopic size (i.e. not visible to the human eye without the aid of a microscope). Micro-organisms are found in the air, water and soil, and generally include the bacteria, yeasts and fungi. Some micro-organisms are capable of metabolizing hydrocarbons and play a role in the natural degradation of spilled oil.

MINERAL-BASED SORBENT

Any of a number of inorganic, mineral based substances used to recover oil because of their adsorptive or absorptive capacities. Mineral-based sorbents include materials such as vermiculite, perlite or volcanic ash, and recover from 4 to 8 times their weight in oil. (See also: Natural sorbent; Synthetic organic sorbent.)

MINERAL SPIRITS

Flammable petroleum distillates that boil at temperatures lower than kerosene, and are used as solvents and thinners, especially in paints and varnishes. Mineral spirits are the common term for some naphthas. Mineral spirits were used extensively in chemical dispersants made before 1970 but are not used in modern dispersants due to their toxicity. (See also: Naphtha.)

MOLECULAR WEIGHT

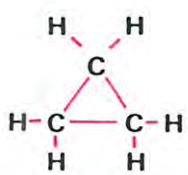
The total mass of any group of atoms which are bound together to act as a single unit or molecule.

NAPHTHA

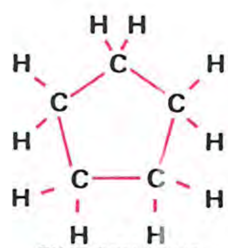
Any of various volatile and often flammable liquid hydrocarbon mixtures used chiefly as solvents and diluents. Naphtha consists mainly of hydrocarbons which have a higher boiling point than gasolines and lower boiling point than kerosene. Naphtha was a principle component of chemical dispersants used prior to 1970.

NAPHTHENES

A class of hydrocarbons with similar physical and chemical properties to alkanes but characterized by the presence of simple closed rings. Like alkanes, naphthenes are also saturated (i.e. they contain no carbon-carbon double bonds), and have the general formula, C_nH_{2n}. Naphthenes are found in both crude oils and refined petroleum products. This class of hydrocarbons are insoluble in water, and generally boil at 10-20°C higher than the corresponding carbon number alkanes. The structural formulae of cyclopropane (the simplest naphthene) and cyclopentane are shown below. (For other classes of hydrocarbons, see also: Alkanes, Alkenes, Aromatics.)



CYCLOPROPANE



CYCLOPENTANE

NATIONAL EMERGENCY EQUIPMENT LOCATOR SYSTEM (NEELS)

A computerized inventory containing the description, location, and "who to contact" information for emergency spill cleanup equipment that is held by NEELS subscribers in Canada and parts of the United States. This system was implemented in 1974 by Environment Canada in co-operation with the Department of Transport, the Petroleum Association for Conservation of the Canadian Environment (PACE), and a private firm, I.P. Sharp Associates Ltd. NEELS can be accessed from the site of a spill through the use of a remote (portable) terminal coupled via telephone to the data base stored in a computer in Toronto, NEELS is also useful in the preparation of contingency plans.

NATURAL ORGANIC SORBENT

Natural materials such as peat moss, straw and sawdust which can be used to recover spilled oil. Natural sorbents generally absorb 3 to 6 times their weight in oil by virtue of the criss-cross arrangement of fibers within the material. However, all natural sorbents will absorb water as well as oil, and virtually all sink when saturated with water. Indiscriminant use of natural sorbents can add to problems of oil spill cleanup, and synthetic sorbents are generally favoured due to their greater capacity for oil and relative ease of recovery. (See also: Mineral-based sorbents; Synthetic organic sorbents.)

OIL SLUG

The name given to a downward moving oil mass which often results when oil is spilled on relatively porous soil. The slug-like shape results from the tendency of the descending oil mass to leave behind a funnel of soil which is partially saturated with oil.

OIL SPILL CONTRACTOR

Private firms which have been formed to provide oil spill cleanup services. These independent contractors often have their own containment and recovery equipment, and may be identified in local and regional contingency plans.

OIL SPILL CO-OPERATIVE

Organizations formed by oil companies operating in a given area for the purpose of pooling equipment and training personnel to combat oil spills.

OIL-IN-WATER EMULSION

An emulsion of oil droplets dispersed in surrounding water, formed as a result of wave action or by a chemical dispersant. Oil-in-water emulsions show a tendency to coalesce and reform an oil slick when the water becomes calm, although the presence of surface active agents in the oil or artificially added in the form of chemical dispersants increases the persistence of this type of emulsion. Natural dispersion of large quantities of oil can follow the formation of oil-in-water emulsions, and weathering processes such as dissolution, oxidation and biodegradation may be accelerated due to the large increase in the surface area of the oil relative to its volume. A diagrammatic illustration of the form of oil-in-water emulsions is provided below. (See also: Emulsification; Water-in-oil emulsion.)

OIL-IN-WATER EMULSION

OLEOPHILIC AGENT

A material or chemical which has the tendency to attract oil. Chemicals of this type may be used to treat sorbent materials in order to increase their oil recovery capacity.

ON-SCENE COMMANDER (OSC)

The overall co-ordinator of an oil spill response team, usually a representative of an oil company, a government official, or an independent oil spill cleanup contractor. The OSC is responsible for on-site strategical decisions and actions throughout each phase of a cleanup operation and maintains close liaison with the appropriate government agencies to obtain support and provide progress reports on each phase of the emergency response.

OXIDATION or ATMOSPHERIC OXIDATION

The chemical combination of compounds such as hydrocarbons with oxygen. Oxidation is a process which contributes to the weathering of oil. However, in comparison to other weathering processes, oxidation is slow since the reaction occurs primarily at the surface, and only a limited amount of oxygen is capable of penetrating the slick or surface oil.

PARAFFIN

A waxy substance obtained from the distillation of crude oils. Paraffin is a complex mixture of higher carbon number alkanes that is resistant to water and water vapour and is chemically inert. The term is sometimes used to refer to alkanes as a class of compounds.

PEBBLE BEACH

A beach substrate composed primarily of gravel having a size range from 4 to 64 mm. Pebble substrates are finer than cobble and coarser than sand, and can allow stranded oil to penetrate to a considerable depth.

POLYETHYLENE

A polymer (substance composed of very large molecules that are multiples of simpler chemical units) of the alkene, ethylene, which takes the form of a lightweight thermoplastic. Polyethylene has high resistance to chemicals, low water absorption and good insulating properties, and can be manufactured in a number of forms. Polyethylene also has high oleophilic properties and has been used with considerable success as a sorbent for oil spill cleanup.

POLYURETHANE

Any of a class of synthetic resinous, fibrous or elastomeric compounds belonging to the family of organic polymers, consisting of large molecules formed by the chemical combination of successive smaller molecules into chains or networks. The best known polyurethanes are the flexible foams used as upholstery material and mattresses, and the rigid foams used as lightweight structural elements including cores for airplane wings. Polyurethane is also the most effective sorbent that can be used for oil spill cleanup and, unlike most synthetic sorbents, efficiently recovers a wide range of different viscosity oils.

POROSITY

A measure of the space in a rock or soil that is not occupied by mineral matter. Porosity is defined as the percentage of total pore space, including all voids, whether or not they are interconnected, in the total volume of rock. The porosity of a rock or soil is determined by the mode of deposition, packing of grains, compaction, grain shape, and grain size. Porosity can also be used to refer to the voids in other materials such as in sorbents.

POUR POINT

The lowest temperature at which a substance, such as oil, will flow under specified conditions. The pour point of crude oils generally varies from -57°C to 32°C; lighter oils with low viscosities have lower pour points. The pour point of an oil is important in terms of impact to the shoreline and subsequent cleanup since free-flowing oils rapidly penetrate most beach substrates, whereas semi-solid oils tend to be deposited on the surface and will only penetrate if the beach material is coarse or the ambient temperature is high.

RECOVERY

In oil spill cleanup, the entire process or any operation contributing to the physical removal of spilled oil from land, water or shoreline environments. General methods of recovery of oil from water are the use of mechanical skimmers, sorbents and manual recovery by the cleanup work force. The main method of recovery of oil spilled on land or shorelines is excavation of contaminated materials.

REMOTE SENSING

The aerial sensing of oil on the water surface. The primary applications of remote sensing are the location of an oil spill prior to its detection by any other means and the monitoring of the movement of an oil slick under adverse climatic conditions and during the night.

RESIDUAL OILS

The oil remaining after fractional distillation during petroleum refining; generally includes the bunker fuel oils.

SANITARY LANDFILL SITE

An approved disposal area where materials including garbage, oil-contaminated debris and highly weathered oil are spread in layers and covered with soil to a depth which will prevent disturbance or leaching of contaminants towards the surface. Sanitary landfill sites should always be located in areas where there is no potential for contamination of groundwater supplies. This method of disposal takes advantage of the ability of some bacteria and other micro-organisms to biodegrade garbage and debris resulting from oil spill cleanup operations.

SEDIMENTS
A general term used to describe or refer to: material in suspension in air or water; the total dissolved and suspended material transported by a stream or river; the unconsolidated sand and gravel deposits of river valleys and coastlines; and materials deposited on the floor of lakes and oceans.

SENSITIVITY MAPS
Maps used by the On-Scene Commander and oil spill response team which designate areas of biological, social and economic importance in a given region. These maps often priorize sensitive areas so that in the event of an extensive spill these areas can be protected or cleaned up first. Sensitivity maps usually contain other information useful to the response team such as the location of shoreline access areas, landing strips, roads, communities, and the composition and steepness of shoreline areas. Maps of this type often form an integral part of local or regional contingency plans.

SHEET BREAKAWAY
A type of current-induced boom failure resulting from the fact that a boom placed in moving water tends to act like a dam. The surface water being held back by the boom is diverted downwards and accelerates in an attempt to keep up with the water flowing directly under the boom skirt, and in so doing simultaneously draws oil from the surface under the boom. As a general rule, sheet breakaway will occur when current velocity exceeds 36 cm/sec, although skirt depth, oil viscosity, specific gravity, slick thickness, and angle or placement of the boom relative to the current direction have a bearing on this form of boom failure.

SHORELINE SENSITIVITY
The susceptibility of a shoreline environment to any disturbance which might decrease its stability or result in short or long-term adverse impacts. Shorelines that are most susceptible to damage from stranded oil are usually equally sensitive to cleanup activities, which may alter physical habitat or disturb associated flora and fauna. The most sensitive shoreline environments are marshes and lagoons, while exposed coastline, subject to heavy wave action, is generally least affected by oil and/or cleanup activities.

SHORELINE TYPE
The average slope or steepness and predominant substrate composition of the intertidal zone of a shoreline area. In any given region, shoreline type may be used to assess the type and abundance of intertidal flora and fauna, protection priorities, and most suitable oil spill cleanup strategies.

SILT
Soil or sediment particles which range in size from 4 to 64 microns. Silt particles are larger than clays (4 microns) but smaller than sand (64 microns to 2 mm).

SINKING AGENT
A material which is spread over the surface of an oil slick to adsorb oil and cause it to sink. Common sinking agents include treated sand, fly ash and special types of clay. However, these materials are rarely used because they provide a purely cosmetic approach to oil spill cleanup and may cause considerable damage to bottom-dwelling organisms.

SKIRT
The portion of a floating boom which lies below the water surface and provides the basic barrier to the spread of an oil slick or the loss of oil beneath the boom.

SLICK
The common term used to describe a film of oil (usually less than 2 microns thick) on the water surface.

SOLUBILITY
The amount of a substance (solute) that will dissolve in a given amount of another substance (solvent). The solubility of oil in water is extremely low. (See also: Dissolution.)

SORBENT
A substance that either adsorbs or absorbs another substance. Specifically, a natural organic, mineral-based or synthetic organic material used to recover small amounts of oil which has been spilled on land or water surfaces or stranded on shorelines.

SORBENT BARRIER
A barrier which is constructed of or includes sorbent materials to simultaneously recover spilled oil during the containment process. Sorbent booms and barriers are only used when the oil slick is relatively thin since their recovery efficiency rapidly decreases once the sorbent is saturated with oil.

SORBENT-SURFACE SKIMMER
A mechanical skimmer which incorporates a rotating, sorbent surface (oleophilic) drum, disc, belt or rope to which oil adheres as the surface is moved continuously through the slick.

SPECIFIC GRAVITY
The ratio of the weight of a substance such as an oil to the weight of an equal volume of water. Buoyancy is intimately related to specific gravity; if a substance has a specific gravity less than that of a fluid, it will float on that fluid. The specific

gravity of most crude oils and refined petroleum products is less than 1.0, and therefore these substances generally float on water. (See also: Surface tension.)

SUBMERSION SKIMMER
A type of mechanical skimmer which incorporates a moving belt inclined at an angle to the water surface in such a way that oil in the path of the device is forced beneath the surface and subsequently rises (due to its buoyancy) into a collection well.

SUBSTRATE
Material or materials which form the base of something. In biology, the base on which an organism lives. Substrate materials include water, soils, and rocks, as well as other plants and animals.

SUCTION SKIMMER
A type of mechanical skimmer which incorporates an enlarged intake device at the end of a vacuum hose to increase the surface area over which suction of an external pump is exerted.

SURFACE ACTIVE AGENTS
Chemicals which when added to a fluid alter the forces of surface tension between adjacent molecules. Surface active agents generally decrease the surface tension of a fluid such as an oil, and are used to facilitate its dispersion throughout the water column, or prevent it from adhering to solid surfaces such as pilings, wharfs and rocks on the shore. (See also: Surface tension.)

SURFACE TENSION
The force of attraction between the surface molecules of liquid. Surface tension affects the rate at which spilled oil will spread over a land or water surface, or into the ground. Oils with low specific gravities are often characterized by low surface tensions and therefore faster spreading rates. (See also: Specific gravity.)

SYNTHETIC ORGANIC SORBENT
One of several organic polymers, generally in the form of plastic foams or plastic fibers, used to recover spilled oil. Synthetic organic sorbents have higher recovery capacities than either natural organic sorbents (e.g. peat moss) or mineral-based sorbents (e.g. vermiculite), and many of these materials can be re-used after the oil is squeezed out. Examples of common synthetic sorbents include polyurethane foam, polyethylene and polypropylene. (See also: Mineral-based sorbent; Natural organic sorbent.)

TAR
A black or brown hydrocarbon material that ranges in consistency from a heavy liquid to a solid. The most common source of tar is the residue left after fractional distillation of crude oil.

TAR BALLS
Compact semi-solid or solid masses of highly weathered oil formed through the aggregation of viscous, high carbon number hydrocarbons with debris present in the water column. Tar balls generally sink to the sea bottom but may be deposited on shorelines where they tend to resist further weathering.

TENSION MEMBER
The part of a floating containment boom which carries the load placed on the barrier by wind, wave and current forces. Tension members are commonly constructed from wire cable due to its strength and stretch resistance.

TIDE POOLS
Permanent depressions in the substrate of intertidal zones which always contain water but are periodically flushed with successive incoming tides. Tide pools are most frequently located near the high tide mark and often contain abundant flora and fauna which can be adversely affected when spilled oil becomes stranded in these areas.

TOXICITY
The capability of a poisonous compound (toxin) to produce deleterious effects in organisms such as alteration of behavioral patterns or biological productivity (sublethal toxicity), or, in some cases, death (lethal or acute toxicity). The toxic capability of a compound is frequently measured by its "acute LC_{50}" with a standard test organism such as rainbow trout. The acute LC_{50} of a toxic chemical is the concentration which will result in death in 50% of the test organisms over a given time period, usually 96 hours. The most immediately toxic compounds in crude oils or refined petroleum products are the aromatics such as benzene. (See also: Aromatics.)

ULTRAVIOLET RADIATION
The portion of the electromagnetic spectrum emitted by the sun which is adjacent to the violet end of the visible light range. Often called "black light," ultraviolet light is invisible to the human eye, but when it falls on certain surfaces, it causes them to fluoresce, or emit visible light. Ultraviolet light is responsible for the photo-oxidation of certain compounds including hydrocarbons, although this process is limited to a large extent by the low penetration ability (in water, air or soil) of this short wavelength form of energy. (See also: Photo-oxidation.)

VISCOSITY
The property of a fluid (gas or liquid) by which it resists a change in shape, or movement. Viscosity denotes opposition

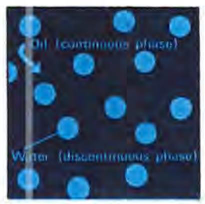
to flow, and may be thought of as internal friction between the molecules in a fluid. Tar, for example, is very viscous as compared to gasoline. The viscosity of liquids decreases rapidly with an increase in temperature. In oil spill cleanup, the viscosity of an oil is important in terms of its ability to penetrate shoreline substrates, as well as its ability to be handled by most conventional pumps. Viscosity increases as oil weathers since low molecular weight, volatile fractions (light ends) are lost most rapidly. (See also: Light ends; Volatility.)

VOLATILITY

The tendency of a solid or liquid substance to pass into the vapour state. Many low carbon number hydrocarbons are extremely volatile and readily pass into a vapour state when spilled. For example, gasolines contain a high proportion of volatile constituents which pose considerable short-term risk of fire or explosion when spilled. On the other hand, bunker fuels contain few volatile hydrocarbons since these have been removed during the fractional distillation refining process.

WATER-IN-OIL EMULSION

A type of emulsion where droplets of water are dispersed throughout oil, formed when water is mixed with a relatively viscous oil by wave action. In contrast to oil-in-water emulsions, this type of emulsion is extremely stable, and may persist for months or years after a spill, particularly when deposited in shoreline areas. Water-in-oil emulsions containing 50-80% water are most common, have a grease-like consistency, and are generally referred to as "chocolate mousse." (See also: Chocolate mousse; Emulsification; Oil-in-water emulsion.)



WATER-IN-OIL EMULSION

WATER TABLE

The fluctuating upper level of the water saturated zone (groundwater) located below the soil surface. (See also: Groundwater.)

WAX

Any of a class of pliable substances of plant, animal, mineral, or synthetic origin. Waxes generally consist of long-chain organic compounds. Waxes are included in the residue formed following the refining of crude oil.

WEATHERING

The alteration of the physical and chemical properties of spilled oil through a series of natural processes which begin when the spill occurs and continue indefinitely while the oil remains in the environment. Major processes which contribute to weathering include: evaporation, dissolution, oxidation, emulsification, and microbial degradation.

WEIR SKIMMER

A type of skimmer which employs the force of gravity to drain oil from the water surface. Basic components include a weir or dam, a holding tank, and an external pump. As oil on the water surface falls over the weir or is forced over by currents into the holding tank it is continuously removed by the pump.

WICKING AGENT

Substances such as straw, wood chips, glass beads and treated silica which are used to increase oxygen availability and provide insulation between oil and water during the disposal of spilled oil by burning. (See also: Burning agent.)

Information on Oil Spills

Further information on oils spills can be obtained by contacting:

Environmental Emergency Branch
Environmental Impact Control Directorate
Environmental Protection Service
Ottawa, Ontario
K1A 1C8

The Environmental Protection Service also has five regional spill coordinators and these individuals may also be contacted for information:

	Jurisdiction
Regional Environmental Emergency Coordinator Environmental Protection Service Atlantic Region Environment Canada Bank of Montreal Tower 5151 George Street Halifax, Nova Scotia B3J 1M5	Nova Scotia New Brunswick Prince Edward Island Newfoundland
Regional Environmental Emergency Coordinator Environmental Protection Service Quebec Region Environment Canada 2020 University Street Montreal, Quebec H3A 2A5	Quebec
Regional Environmental Emergency Coordinator Environmental Protection Service Ontario Region Environment Canada 2nd Floor 135 St. Clair Avenue W. Toronto, Ontario M4V 1P5	Ontario
Regional Environmental Emergency Coordinator Environmental Protection Service Environmental Conservation Branch Northwest Region Environment Canada 8th Floor 9942 - 108 Street Edmonton, Alberta T5K 2J5	Alberta Saskatchewan Manitoba Northwest Territories
Regional Environmental Emergency Coordinator Environmental Protection Service Pacific Region Environment Canada Kapilano 100 - Park Royal West Vancouver, British Columbia V7T 1A2	British Columbia Yukon Territory