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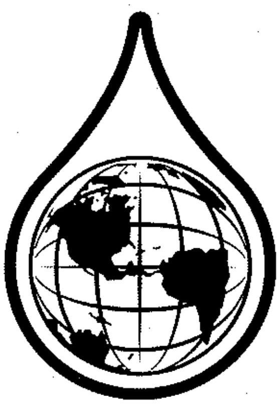
Information Bulletin



Offshore Oil Spill Cleanup

A discussion of the methods by which oil can be cleaned up at sea.

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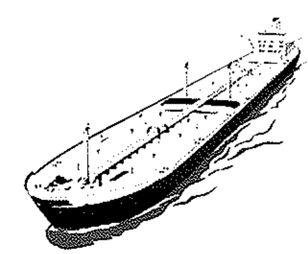
INTRODUCTION

Oil can enter the marine environment from any number of different routes and for a variety of different reasons. In the offshore, the major sources of oil are tanker accidents and blowouts from oil and gas exploration and production facilities. It is worth noting, however, that oil from these two sources constitutes only about 15 percent of the total amount of oil entering the ocean.

It is difficult to accurately estimate the amount of oil spilled into the ocean annually from tanker spills. Most of the spills (up to 75%) occur during loading and unloading operations in port. These spills, though numerous, are usually small in volume. On the other hand, tanker accidents and oil well blowouts happen infrequently but are usually catastrophic in nature and can result in spills of massive size.



It is estimated that 3.2 billion tonnes of oil are produced every year and that movement of oil from the oil field to the consumer may require 10 to 15 transfers between numerous modes of marine and land based transportation (eg. tankers, pipelines, trains, trucks) and storage facilities (temporary tanks, permanent tank farms, underground storage tanks, household heating tanks). Accidents and spillage can occur from any one of these sources which can lead to an input of oil to the oceans, depending upon the location and nature of the spill.

STRATEGIES FOR OFFSHORE OIL CLEANUP OPERATIONS

When an oil spill occurs offshore, a number of options are available to those charged with the responsibility for responding to it. There are four main strategies that are currently employed: Containment and Recovery; Chemical Treatment; In Situ Burning, and Monitoring (often referred to as the Do Nothing Option). In most cases, more than one strategy is used depending on the location and size of the spill; the type of oil spilled; the weather and the sea state, and the phase of the cleanup operation.

CONTAINMENT AND RECOVERY

Responders may try to corral as much of the oil as possible and remove it from the sea surface. In this approach, floating barriers, called booms, are deployed to contain the oil slick, and the oil is then collected using skimmers (which remove oil and water from the surface and then separate the oil); vacuum hoses (which suck the oil from the surface), or sorbents (which soak up the floating oil). These technologies remove the oil mainly by mechanical means. Containing and recovering oil spilled at sea can be a very expensive option, requires significant logistical support, is weather dependent and results in large volumes of contaminated material which must be adequately disposed of. It is, however, the only approach which actually removes the oil from the environment.

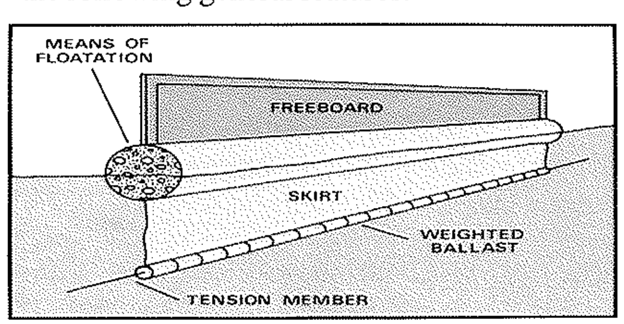
There are some obvious constraints to the use of containment and recovery techniques in cleaning up oil spills offshore. The operation has to be mounted very close to the source of the spill so that the spread of oil can be minimized. The weather conditions have to be almost ideal as booms are most effective in calm seas. The oil has to be of a type which is amenable to mechanical recovery, with heavier, more viscous oils being easiest to contain and recover.

Containment - Oil Booms

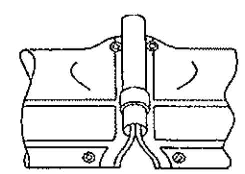
Oil booms can be used to contain oil, thus preventing the spread of the slick and confining the oil close to the area where it was discharged. The purpose of containment booming is to localize the spill and minimize pollution, and also to concentrate the oil into thick layers to facilitate removal. Booms can also be used as barricades to exclude oil from sensitive structures and areas, and to deflect oil from entrances to harbours, rivers and other environmentally or economically sensitive areas. For safety reasons, it is not advisable to boom highly flammable oil products like gasoline.

Boom Characteristics

Many types of booms are commercially available and many others can be constructed as and when needed. The designs vary considerably depending upon the particular application and oil type, but all booms have the following general features:



1. a fabric skirt, made of a flexible material, which floats below the surface to reduce the escape of oil under the boom. Some common materials used in boom skirts are polyester, nylon, or fiberglass fabric coated with rubber or vinyl; metal and glass cloths laminated with vinyl; uncovered fabrics such as canvas or polyester, and plastic films such as ethylene vinyl acetate or polyethylene.
2. a tension member, such as a piece of metal cable, which extends along the entire length of the boom. This tension member is stronger than the fabric and prevents it from tearing under the stress of wind, waves and currents.
3. some type of ballast or weight attached to the bottom of the fabric to keep the boom vertical in the water.
4. flotation material, either rigid or flexible, such as inflatable air chambers or styrofoam.
5. freeboard (fabric above the water line) to prevent oil from washing over the top of the boom.
6. end connectors used to connect sections of boom together.



The most important characteristic of a boom is its oil containment or deflection capability. The boom's performance is affected by wind, waves and currents. It must be capable of conforming to the wave profile and maintaining its freeboard, and still have sufficient structural strength to withstand the stresses caused by the wind and the motion of the waves. Although wind and wave action are important factors in boom design, water currents are the usual reason for boom failure. Booms are only effective when used in areas where the velocity of water movement is less than 1 knot (0.5 meters per second) and this represents a severe limitation to performance. In areas where the velocity of water movement exceeds 1 knot, oil can escape in a number of different ways:

it can splash over the top of the boom; it can flow down the face of the boom and escape underneath, and low viscosity oils can form droplets which also escape under the boom. Because a boom acts as a sort of a dam, holding back the surface water, it commonly fails when this constrained surface water seeks another, unimpeded route and is driven downward and under the boom, taking the surface oil slick with it.

Boom Types

The two basic types of commercial booms in common use today are distinguished by their construction characteristics. A number of improvised booms can also be used for specific purposes.

Curtain Booms

Curtain booms have flexible skirts which are free to move independently of the floats. Centerline flotation is provided by air, inert gas, solid foam bars, flexible foam rolls, or granulated foam in a plastic cylinder. Curtain booms with air flotation devices take up very little storage space when the chamber is deflated, whereas the solid flotation types, although much more durable, are considerably more bulky. Curtain booms generally rise up and down quite effectively with wave motion; can withstand moderate surface water velocities before allowing oil to escape, and are reasonably easy to clean.

Fence Booms

These booms use a rigid or semi-solid material as a vertical screen against oil floating on the water. They are buoyed by external floats mounted on the side of the boom. Fence booms are quite easy to handle and are very durable, but they are bulky to store and are very difficult to clean.

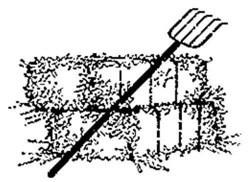
Improvised or Special Purpose Booms

Netting Systems - Conventional fishing nets have been used to contain and recover solid tar balls. This technique has also been expanded to the use of nets to collect relatively viscous oils. Nets offer distinct advantages over the more solid, commercially available booms since they have an open structure and offer low resistance to surface water flow. This should make it possible to operate in faster currents and at higher towing speeds than with conventional booms. Large scale field trials with nets have shown some promise but there are limitations, especially when the mesh becomes blocked with oil. In these cases the net behaves just like a solid boom.

Sorbent Booms - These booms are made from a tube of netting or some other fabric filled with an absorbent material. They are often constructed from 'at hand' materials such as bales of straw sandwiched between plastic netting. They are simple but often effective means of reducing the amount of oil reaching the shore. Some of these need extra flotation devices to prevent them from sinking once they become saturated with oil and water. In areas of low current velocity where there is only a thin film of oil, sorbent booms are particularly effective.

Fire Booms - As the name implies, these are special purpose booms made to contain oil which is to be burned in place. Obviously, these booms must be able to withstand high temperatures, and they are usually constructed of fire resistant materials like ceramic textile and stainless steel mesh.

Custom Made Booms - Locally available materials can be used to construct effective oil barriers. For example, wood, bamboo, oil drums, hoses and rubber tires can be used to make floating booms, and fishing nets or wire mesh filled with straw can be used to make sorbent booms.



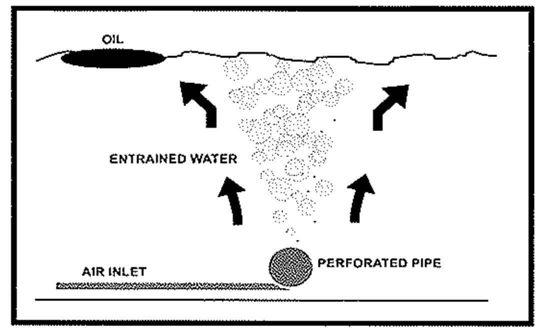
Booming Techniques

There are basically four different ways a boom can be used in offshore oil spill response, depending on the type of oil, the weather conditions, the type of boom available and the resources at risk.

In **Exclusion booming,** booms are deployed across the mouths of harbours, marinas, inlets and the entrances to facilities such as these to exclude, as their name implies, the entrance of oil or around a sensitive area to prevent the oil from contaminating that area. Sheltered areas, particularly marshlands, are often most sensitive to the impacts of oil spills, and are usually those areas given highest priority for protection.

Oil can be prevented from entering the channels and streams leading into marshes by either damming the waterways or by using permeable booms or barriers. Such booms are especially useful because they allow the water to flow through while the sorbent material removes the oil. In addition, they are able to move in synchrony with the movement of the tide while at the same time conforming to the shape of the channel or stream.

Another exclusion booming technique utilizes a rising curtain of air bubbles generated from a perforated pipe which is positioned below the water surface. When the bubbles rise to the surface, they entrain water which then spreads in two directions when it reaches the surface. The oil slick cannot cross this two-way current barrier. The bubble barrier system is most suitable in calm waters and is sometimes used to protect harbours where currents are relatively low and where conventional booms would hinder the movement of ships.



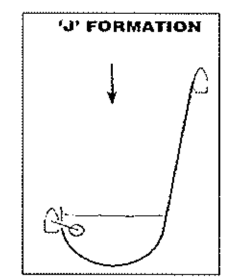
Diversion booming can be employed in areas in front of sensitive zones such as marshes to divert the oil onto less sensitive areas like sand beaches, where the cleanup is relatively easier and less costly in both economic and environmental terms. In addition these booms can be employed to divert or deflect the oil from water intakes.

Diversion of oil from water intakes along the shores of Saudi Arabia using booms met with great success during the cleanup of oil spilled by Iraqi forces. During the oil spill from the Exxon Valdez in the Gulf of Alaska in 1989, massive booming and skimming operations were employed to protect fish hatcheries and salmon streams.

In some instances, diversion booms are deployed at an angle to the approaching oil, thus diverting the oil to a collection device. This method is mainly used on rivers and streams, since a small amount of current is necessary for it to work effectively. In these circumstances, one end of the boom is usually anchored to the shoreline and the other to the bottom of the river or to a stationery vessel. Diversion booming must

take into account the velocity of the river flow. The boom must be angled properly to avoid damage from the force of the water and to prevent the oil from escaping under the boom.

In **Containment / Collection** booming, a boom is deployed in a U or a J shape in front of the approaching oil. The ends of the boom are anchored or secured on vessels and often recovery devices are deployed at the same time in the pocket created by the shape of the boom. Alternatively, the collected oil can be towed to a more sheltered location for recovery. This technique is most often used in unsheltered water with booms specially designed for the offshore.



Sorbent booms are most often employed in relatively calm conditions. In this technique, the booms are deployed along the shoreline to keep oil from spreading up into higher regions of the beach.

Recovery - Skimmers and Sorbents

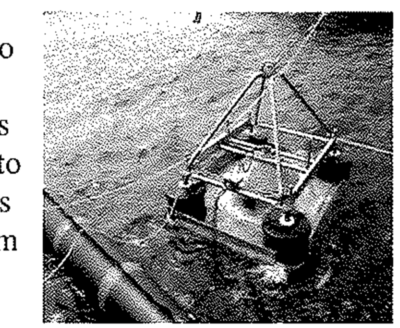
Once the oil has been contained, every effort must be made to recover as much of it as possible and as quickly as possible, using skimmers or sorbents.

Skimmers are mechanical devices designed to remove oil from the surface of the water without changing the physical or chemical properties of the recovered oil. Four basic types of skimmers are commercially available: floating weirs, suction units, vortex units, and adhesion units, with the suction and floating types being more versatile and commonly used.

Skimmers perform best when the oil slick is relatively thick and the sea is calm with little or no wave action. The presence of debris, like seaweed or driftwood in either the oil or the water will severely hinder the performance of the skimmer. In offshore applications, skimmers are most effective when used in conjunction with a boom which contains and concentrates the oil slick, thus enhancing skimmer performance.

Floating Weir Skimmers

When a floating weir skimmer is used, oil and water flow over the top of a weir or dam into a collection chamber. The height of the weir is set so that it is as close to the oil/water interface as possible, and a minimum amount of water is collected with the oil.



The oil is pumped out of the collection chamber. It is then either treated by gravity separation and/or recovered directly, depending upon the amount of entrained water.

The presence of debris in the water severely restricts the efficiency of weir skimmers since it builds up around the edge and must be manually removed. Wave action also disrupts the recovery of oil by weir skimmers. As the skimmer rocks with the waves, the suction line moves up and down, taking in air at some times and the water beneath the oil layer at others.

Suction Skimmers

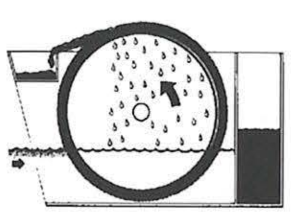
A Suction skimmer floats on the surface and is simply an enlarged suction hose positioned at the oil/water interface. The enlargement increases the area over which the suction is exerted, thus making this type of device extremely versatile and effective for a range of oil types. As with weir skimmers, suction skimmers are adversely affected by any floating debris. Floating material pulled in through the suction head to the suction hose causes clogging and disrupts the recovery operation. As well, choppy wave conditions result in the intake of air to the suction device and a resultant loss in collection efficiency.

Vortex Skimmers

These units operate by creating a water vortex or whirlpool which entrains oil from the surface of the water into a collection area beneath the surface. The oil/water mixture is then pumped to an oil water separator where the water is separated and the oil is recovered. These devices are not as susceptible to clogging by debris as some of the others since a screen can be effectively used to prevent debris from entering the hoses. They are, however, subject to the same types of performance limitations when wave heights exceed 60 cm. or currents exceed 0.6 knots (30 cm/second).

Adhesion Units

Adhesion skimmers incorporate oleophilic (oil loving) belts, drums, discs or synthetic ropes and operate on the principle that oil will adhere to the surface of the skimming device and water will not. The oleophilic belt, drum or disc is drawn through an oil slick or revolves in it, the oil is adsorbed onto the oleophilic surfaces and, as the unit is



drawn out of the water the oil is recovered by squeezing or scraping the oil soaked surfaces. The recovered oil is then pumped to a holding tank and later recovered. Of all the commercially available skimmers, this one is least susceptible to the adverse effects of choppy seas. Debris may interfere with the efficiency of these units if the oil removal areas are damaged, but they are far less prone to disruption by floating debris than all other types.

Sorbents

A common method of collecting spilled oil is the use of sorbents. Oil will cling to the surface of some materials (adsorption) and will be soaked up by others (absorption). Sorbents may be natural products (peat moss, straw, hay, sawdust, reeds); mineral based products (perlite, vermiculite, mineral wool, volcanic ash and zinc stearate-coated talc), or manufactured products (synthetic rubber, polyester foam, polystyrene and polyurethane). The most effective sorbents have high oil and low water sorption capacity and remain buoyant even after accumulating oil.

Sorbents are spread directly onto an oil slick or are placed ahead of an advancing slick. They are applied in a number of different

ways and are available as mats, slabs, cubes, shavings or powders. For maximum effectiveness, the sorbent should be mixed with the oil, but in actual spill conditions, wind and waves may accomplish the required mixing without the aid of added manual or mechanical techniques.

Sorbents offer some distinct advantages in oil spill cleanup. When used offshore, sorbents can greatly assist a boom in containing a slick, and can, on their own, help to contain a slick and limit its spread.

There are, however, some disadvantages to the use of sorbents. They are very bulky and a problem to store and transport; their use entails a considerable amount of physical labour to dispense; they will clog some skimmers and pumps during mechanical recovery operations, and they significantly increase the volume of material requiring disposal.

After the "Torrey Canyon" spill off the coast of Britain in 1967, 20,000 tons of sawdust and wood shavings were spread over the floating oil. The material was blown onto the coast of Brittany where the whole agglomeration had to be removed almost entirely by hand. The sorbents in this case only increased the amount of material which had to be collected and disposed of.

CHEMICAL TREATMENT

Dispersants are sometimes used to break up the oil and enhance its dissolution into the water column. Other chemicals which could be used to treat an oil spill include emulsion breakers, which break down water/oil mixtures (mousse) that develop as the oil weathers; gelling agents, which increase the viscosity of the oil slick and reduce its rate of spreading; herders or collection agents, which affect the surface tension of the oil and cause it to herd to a collection point; viscoelastic additives or solidifying agents, which convert oil to a solid form facilitating its recovery by manual means or in nets; biological agents, which increase the rate of natural degradation; burning agents, which make it possible to ignite the oil; neutralizing agents, which react chemically with the oil to form less harmful substances, and sinking agents, which adsorb oil to their surfaces, making a heavier than water mixture which sinks. Sinking agents are not recommended in water depths less than 100 meters.

It is obvious then, that a variety of chemicals can be added to an oil slick at sea to break it up, to sink it, to gel or solidify it or to dissolve it into the water column. The use of chemicals to treat oil spills is a controversial issue. It is basically the deliberate addition of a chemical which may lead to increased ecological damage. The decision to use chemicals to treat an oil spill must be made in full consultation with the regulatory authorities and must involve an assessment of the resources at risk. The decision inevitably involves some compromises. For example, the potential benefits from the use of dispersants to protect coastal amenities may have to be weighed against the potential disadvantages of tainting of the fish stock in the area.

Of all the chemicals which could potentially be used to treat an oil spill, the ones most commonly used in the offshore are dispersants.

Environment Canada expends considerable research effort to determine the effectiveness and toxicity of a range of dispersants. The

Department has also developed guidelines on toxicity testing of dispersants and dispersant use. To be acceptable for use in Canada, a dispersant must be non-toxic in approved tests and must be demonstrated to be effective.

Dispersants

Chemical dispersants when applied to an oil slick reduce the surface tension between the oil and the water, and allow the slick to spread over a much wider surface area than it normally would. This permits the natural processes of oxidation (reaction with the oxygen in the air to form more soluble compounds than the parent oil); dispersion (formation of oil droplets in the water column through wind and wave action), and biodegradation (breakdown of the oil by microorganisms in the water column) to occur more quickly. In effect, these chemicals disperse the oil on and into the water so that the natural weathering processes are enhanced and the oil is more quickly degraded and removed from the environment.

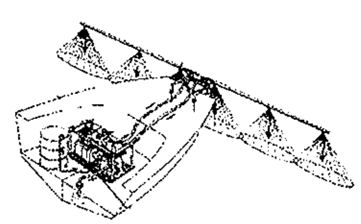
The major components of dispersants are the surfactant or Surface Active Agent (SAA), the solvent and the stabilizer.

Surfactant/Surface Active Agent (SAA) - SAAs are compounds which have an affinity for both oil and water and they are the major active components of dispersants. Household soaps are SAAs and they facilitate the removal of dirt from clothes in much the same way as dispersants facilitate the removal of oil from the water surface. By altering the interface between the dirt and the fabric, soap allows the mixing action of the washing machine to lift the dirt and disperse it in the wash water. In much the same way, dispersants alter the interface between the oil and the water and allow the natural forces of wind and waves to disperse the oil over the water surface and into the water column.

Solvents - Most of the SAAs which are effective on oil are viscous or solid materials, and must be dissolved in some type of solvent for ease of handling. The solvent may also serve other purposes including depressing the freezing point of the mixture so it can be used in low temperatures; enabling more rapid dissolution of the mixture in the oil, and allowing the optimum concentration of SAA to be achieved in the mixture prior to use. The solvent usually comprises the bulk of the dispersant product and may be a petroleum hydrocarbon, an alcohol or another hydroxy compound, or water.

Stabilizers - Stabilizers are added to dispersant products to adjust the pH, to inhibit corrosion, to increase stability in hard water; to fix the emulsion once it is formed and to adjust the color and appearance of the product.

Dispersants are usually applied by spraying, using back pack units or fire hoses and pumps normally available on offshore vessels. In some cases, dispersants are sprayed from specialized spray gear mounted on vessels or from spray booms mounted on fixed wing aircraft or helicopters.

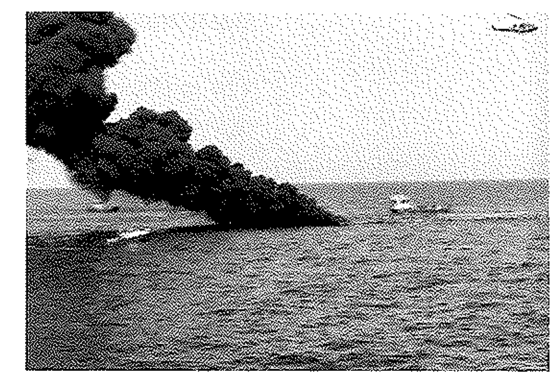


Agitation is necessary for adequate mixing, and the action of wind and waves in the offshore may be sufficient to mix the chemical and the oil. If not, then a boat's propellers or a board towed through the slick may be required to achieve the desired results.

Environmental Emergencies Section
Atlantic Region

IN-SITU BURNING

Some spills which occur in open waters where no danger is posed to drilling rigs, ships, or the shoreline can be burned in-situ. To be successful, this strategy must be initiated as soon as possible after the spill, before the lighter, more volatile components evaporate. Fire booms are routinely used to contain the burning oil, but obviously some air pollution is inevitable. **In-situ Burning** can be very effective in removing large volumes of oil from the sea surface, but the conditions must be favourable.



The cleanup of oil spills by burning seems to offer a practical and permanent solution. Theoretically, all of the oil could be consumed in the fire, and if conditions are closely controlled, the damage to the environment could be minimized. For spills on open water, historical evidence suggests that in situ burning could be an effective countermeasure. There have been several tanker accidents (*the grounding of the "Jacob Maersk" off the coast of Portugal*) where the oil **accidentally** caught fire. In these cases, most of the oil was consumed without spreading and contaminating large areas.

In-situ burning does, indeed, hold a great deal of promise but there are some severe limitations. After a very short period of time, an oil slick is very difficult to ignite because the more volatile components rapidly evaporate. Also, as the slick spreads, it becomes thinner and begins to emulsify with the seawater, making ignition even more difficult. Even if ignition is achieved, the slick constantly loses heat to the water, making sustained combustion very unlikely.

Considerable experimentation has been conducted to overcome these difficulties, however, and in-situ burning is viable in some cases.

Burning or priming agents, such as gasoline, have been used to ignite oil spills and have been shown to successfully sustain combustion. Wicking agents such as straw have also been successfully used to promote combustion of oil at sea. The theory is that by soaking into the wicking agent, the oil is raised above the water surface and the cooling effect of the sea is diminished, thus allowing sustained combustion.

Experience has shown, though, that burning of unconfined oil slicks is extremely difficult unless the oil is more than 2 millimeters thick. Therefore, more recent attempts to burn oil in-situ have employed fireproof boom to contain and concentrate the slick while it burns.

In 1988, the first open ocean test oil burn was conducted off the coast of Norway, when 12 barrels of crude oil were successfully ignited and fully burned in thirty minutes. During the Exxon Valdez spill in 1989, an *estimated 400 to 800 barrels were burned in 75 minutes and in 1993, in two separate experiments off the coast of Newfoundland 400 barrels of crude oil were burned with a reported efficiency of greater than 99 percent.*

Research continues into this promising method of dealing with oil spills at sea and it is expected to be a viable and practical technique in some offshore spill situations.

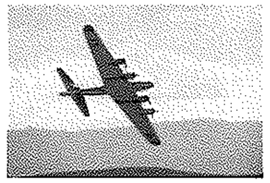
DO NOTHING

Although the **Monitoring** or "**Do Nothing**" strategy is not often employed, and even though it may seem difficult to justify, it may be the most appropriate in some circumstances. If nothing is done, an oil spill will weather naturally and eventually degrade. With turbulence created by wind and waves the oil slick will break up and disperse; the lighter components will evaporate into the atmosphere and dissolve into the water column, and the action of sunlight and oxygen in the air will facilitate chemical breakdown of the parent oil. With the passage of time, naturally occurring microorganisms will degrade the oil in the water column and other marine organisms will assist in removing the remnants of the dispersed oil.

In these cases, the movement of the oil slick should be closely monitored while natural biological and physical processes disperse and degrade the oil. Crude oils, particularly lighter ones, if spilled a considerable distance offshore, are unlikely to cause significant environmental damage unless the oil is spilled close to concentrations of vulnerable seabirds. In most cases, such oils will dissipate before reaching shore.

During the weathering period, the probable movement or trajectory of the oil slick can be predicted if the wind speed and prevailing currents are available. Floating oil will move in the direction of the wind at about 3 percent of the wind speed. Superimposed on this wind-induced movement is the strength and the direction of the surface current. Simple calculations can then be performed to predict the ultimate fate of the oil slick.

Oil spills can also be tracked by aerial surveillance and/or remote sensing techniques if it is felt that sensitive resources could be at risk in the projected path of the slick.



CONCLUSION

When oil is spilled at sea, there are a number of response options available, none of which are 100 percent effective. In fact, there are severe limitations to the effectiveness of most offshore cleanup equipment. Booms and skimmers do not operate efficiently in high wind or waves, and chemical treatment always involves a compromise, the protection of one resource while risking another.

In-situ burning has been successfully tested but only under very controlled conditions. However, with the development of fire resistant booms and more effective wicking agents, this method may indeed have some important applications in the future.

While the Monitoring or "Do Nothing" option may be difficult to justify, it is viable and should not be dismissed out of hand.

Our ability to deal with spills of oil on the open ocean has improved in recent years. However, even with new technologies and approaches, the effective cleanup of these spills is still determined to a significant extent by the vagaries of nature. Fortunately, in these instances where weather conditions are limiting, nature appears to be quite capable of effectively cleaning itself.

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