IPIECA

International Association of Oil & Gas Producers

Oil spills: inland response

Good practice guidelines for incident management and emergency response personnel

IPIECA

The global oil and gas industry association for environmental and social issues

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Preface

This publication is part of the IPIECA-IOGP Good Practice Guide Series which summarizes current views on good practice for a range of oil spill preparedness and response topics. The series aims to help align industry practices and activities, inform stakeholders, and serve as a communication tool to promote awareness and education.

The series updates and replaces the well-established IPIECA 'Oil Spill Report Series' published between 1990 and 2008. It covers topics that are broadly applicable both to exploration and production, as well as shipping and transportation activities.

The revisions are being undertaken by the IOGP-IPIECA Oil Spill Response Joint Industry Project (JIP). The JIP was established in 2011 to implement learning opportunities in respect of oil spill preparedness and response following the April 2010 well control incident in the Gulf of Mexico.

The original IPIECA Report Series will be progressively withdrawn upon publication of the various titles in this new Good Practice Guide Series during 2014–2015.

Note on good practice

'Good practice' in the context of the JIP is a statement of internationally-recognized guidelines, practices and procedures that will enable the oil and gas industry to deliver acceptable health, safety and environmental performance.

Good practice for a particular subject will change over time in the light of advances in technology, practical experience and scientific understanding, as well as changes in the political and social environment.

Contents

Introduction

Most large, well-known spills have occurred in the marine environment; however, inland spills outnumber marine spills. Many of the classic spill response techniques were originally developed for use in offshore and coastal spill settings. While some basic principles of oil spill response are the same no matter where oil is spilled, techniques for inland spill response operations require some degree of adaptation. The objective of this Good Practice Guide is to present an overview of inland oil spill response, identifying similarities to marine response and highlighting unique issues pertinent to inland spills.

This guide addresses the response phase of inland incidents, where actions are undertaken to ensure safety, minimize the immediate spread and threat of a spill and deploy techniques to clean-up spilled oil. Its principal focus is on spills in the aquatic environment, although some additional information on adjacent terrestrial environments is also included. It does not address the possible remediation actions which may be considered where oil has contaminated the ground.

Inland aquatic environments in this guide encompass freshwater rivers and streams, lakes and ponds, wetlands and estuarine water bodies and their associated shores and banksides.

Excluding the infrequent large spill events, more oil is spilled on inland habitats than on marine coastal or offshore habitats. Inland spills most frequently involve refined products, though almost half of the largest inland spills involve crude oil. In general, more inland spills originate from fixed facilities than from transportation, though pipeline breaks have caused many of the largest inland spills.

This guide begins with a description of the weathering, fate and effects of spilled oil. The socio-economic effects of inland spills are also described, followed by a discussion of response management issues and response techniques.

Oil fate and weathering

Crude oils are composed of a large number of individual chemical compounds. Almost all of these are hydrocarbons, composed of only hydrogen and carbon. Hydrocarbons can be classified by molecular weight or carbon chain length, and the majority of hydrocarbons in crude oil contain from 5 to 35 carbon atoms.

Hydrocarbon categories include:
- paraffins (alkanes)—consisting of saturated carbon chains with no double bonds;
- olefins (alkenes)—consisting of carbon chains with at least one double bond;
- naphthenes (cycloalkanes)—consisting of carbon rings, with up to four rings in one compound; and
- aromatics—consisting of one or more unsaturated carbon rings with alternating double bonds.

The relative proportions of these chemical compounds differ between crude oils, and are responsible for the range of physical properties that crude oils exhibit. The majority of hydrocarbons in most crude oils are alkanes and cycloalkanes, and these can range from volatile liquids to non-volatile liquids or solids (waxes) depending on their size (number of carbon atoms) and the prevailing temperature. Oil products represent different oil fractions derived from refining crude oil.

The light, single-ring aromatic compounds are the most toxic compounds in oil and consist of benzene, toluene, ethylbenzene and xylenes (BTEX). Aromatics with two or more rings are called polycyclic aromatic hydrocarbons (PAHs) and many are also toxic. Examples include naphthalene (two rings), anthracene (three rings) and benzo(a)pyrene (five rings). The extremely large aromatics are called asphaltenes. These compounds can have sulphur, oxygen and nitrogen derivatives in the mixture and may also have low levels of metals.

Weathering processes

Spilled oil is affected by natural processes that transform the oil (weather) and modify its fate and behaviour. The weathering processes affecting oil in aquatic environments are summarized below.

Movement

Liquid oil spreads out over the water to form very thin slicks with an average thickness of about 0.1 mm, although these can range from as high as 1–2 mm for thick oil to as low as 0.1 µm for sheens in open waters. Low-density oils spread faster than heavier oils, which means lighter, refined products will spread faster than most crude oils. Depending on the location and spill volume, spreading may be constrained by available surface area. Wind and water flows may fragment the oil as it spreads, and fast flowing rivers may move oil downstream relatively quickly. Smaller inland water bodies result in rapid oil stranding, and their size makes it easier to locate and track oil.

Evaporation

The smaller, lighter hydrocarbons (typically with less than 12 carbon atoms) are likely to vaporize under ambient conditions. The process is temperature dependent, and large percentages of gasoline, light crude oils and light fuel oils can evaporate in the first hours and days of a spill. The heavy hydrocarbon components in crude oils and heavy fuel oils have a low potential for evaporation, so the amounts lost to evaporation during a spill can be small. Initially, in a spill with light to medium crude oils or refined products, the vapour concentrations can be so high that health and fire hazards may result. Any remaining oil after evaporation is more viscous, which can complicate response efforts.

Dissolution

Some hydrocarbons dissolve in water. However, less than 1% of crude oil will dissolve and many of the hydrocarbons that do dissolve are the light aromatics and polar compounds containing oxygen, sulphur or nitrogen. These compounds are also highly volatile and therefore tend to evaporate rather than remain in the water. The solubility of oil is greater in fresh water compared to the sea, and increases with higher concentrations of dissolved organic matter.

Natural dispersion

Wave and current energy causes the oil to form into small droplets in a water body. Most of these droplets are large enough to quickly resurface. It is therefore typical for only a small percentage of oil to remain naturally dispersed, although there have been a few cases of marine spills during major storms with very high winds and waves where virtually 100% of the spilled oil dispersed naturally. Inland lakes rarely experience these conditions.

Emulsification

Naturally dispersed oil droplets that return to the surface can trap water in the surface oil slick to form a water-in-oil emulsion. Emulsification greatly increases a spilled oil's viscosity and thereby complicates recovery efforts. Emulsified oils are also less affected by other weathering processes such as evaporation, dispersion and biodegradation. An emulsion may consist of up to 80% water, and the apparent volume of the oil pollution can increase by 4–5 times. The formation of stable (persistent) emulsions requires heavy components such as asphaltenes and resins. Many lighter refined products (gasoline and light fuel oils), therefore, will either not emulsify or will form unstable emulsions. Emulsification is a major weathering process affecting marine spills of crude and heavy fuel oils because the mixing energy in the ocean is extremely effective in incorporating water into oil. Emulsification is less likely in fresh water, even for spills of heavier oils, because significant mixing energy often does not persist long enough to generate the stable emulsions seen at sea.

Photo-oxidation

Sunlight oxidizes oil. This process occurs with less than 1% of spilled oil and is what makes heavily weathered black oil turn greyish over time. The process makes the oxidized compounds more soluble.

Sedimentation

Oil can adhere to solids in the water. In waters with high silt content, spilled oil can bind to the suspended sediments, becoming neutrally buoyant in a water body and/or sinking to the bottom. Very fine particles, especially clays, can bind with oil and provide a platform for microbes to biodegrade the oil. Sedimentation can be significant for oil spills during flooding events when waters contain high levels of suspended solids; some spills have seen dramatic decreases in surface oil due to this process.

Biodegradation

Microbes use spilled oil as food and degrade the compounds to simpler hydrocarbons and, ultimately, to carbon dioxide and water. This process requires nutrients (primarily nitrogen and phosphorus) and oxygen. The very large hydrocarbons (such as asphaltenes) found in heavier oils degrade very slowly or not at all. Biodegradation in quiescent freshwater bodies with low oxygen replacement rates may cause oxygen depletion, slowing subsequent oil breakdown.

Sinking

Fresh oils are typically less dense than water, and will therefore float on the surface. However, the weathering processes tend to increase the density of the oil and lead to situations where the oil may sink. This is most likely to occur with very heavy oils, whose initial density is relatively high; sinking is also more likely in fresh water, which is less dense than seawater.

Terrestrial spills

Inland oil spills can come into contact with soils and groundwater as well as surface water bodies. On the ground surface some weathering processes, such as evaporation, are active while others, such as emulsification and dispersion, are non-existent. Spreading does occur, but the degree is highly dependent on the topography and surface roughness. The amount of biodegradation is dependent on moisture and nutrient levels. Underground spills contaminating soil and groundwater undergo little weathering. Oxygen levels are usually limiting and biodegradation proceeds slowly. The oil does adhere to the soil, but other weathering processes are virtually non-existent. This guide does not address contaminated soil and groundwater remediation.

Inland aquatic environments

For the purposes of this guide, inland aquatic environments or habitats encompass:

- freshwater rivers and streams, lakes and ponds, and wetlands;
- estuarine water bodies and shorelines; and
- shore or riverbank habitats including bedrock, man-made structures, sand, mixed sand and gravel, vegetated shores and mud.

Large inland water bodies, such as the North American Great Lakes and Lake Victoria in Africa, have waves and currents. However, compared to oceans, the currents are usually weak, and waves fluctuate with local wind conditions with no oceanic swell. Tides are low or non-existent, and water level fluctuations may be driven by water inputs and evaporation rates. Shores are usually narrower than marine beaches. Smaller lakes and ponds may have limited flushing rates and also be subject to variations in water levels due to seasonal effects and/or flooding. If water exchange rates are low, high nutrient levels and low oxygen levels can occur which can affect the biodegradation rates of the spilled oil. Lakes in higher latitudes can be subject to winter icing. Even large lakes can freeze over substantially, and ice cover along the shore is common.

Large rivers can have variable flow rates; these may be seasonally high which may lead to substantial flood events. River flows near the coast can be subject to tides and have varying salinity in estuaries. Some rivers have multiple channels with mid-channel islands, and some have controlled flow due to the construction of locks and dams. Sediment loads can be quite high. There will be floodplains of varying widths with associated wetlands and backwaters.

Small rivers and streams can be shallow, with flow characteristics ranging from fast currents with falls and rapids to slow winding channels. All can freeze over during winter in colder climates. The channels can contain varying amounts of debris and sediment load.

Heavy rains caused a spill that led to the oiling of vegetation in the resulting flood.

U.S. EPA OSC website

Ecological effects

Exposure of the environment to oil can lead to several types of effects. There are two key concepts to consider: vulnerability (able to be exposed) and sensitivity (reactivity to exposure). It is the sensitivity of exposed habitats and organisms that dominates considerations of the environmental effects of a spill. Habitat characteristics which influence sensitivity include:

- species diversity and abundance;
- climate extremes and types of precipitation; and
- the amount of water circulation and flushing.

Exposure to oil can have two types of effects on animals and plants:

1. Many compounds in oil are acutely (short-term and lethal) or chronically (long-term and sub-lethal) toxic, and exposure to sufficient concentrations for a long enough duration can cause sickness or death in plants and animals. Toxicity from ingestion and inhalation mostly results from the BTEX and PAH compounds because they are more soluble in water, especially the BTEX compounds. Light crude oils and petroleum products (gasoline, kerosene, diesel and No. 2 fuel oil) contain more of these compounds and are therefore more toxic than heavier oils that contain fewer of these compounds. These aromatic compounds are also the most easily weathered compounds in oil, and as spilled oil weathers, it becomes less toxic as a result. The PAHs persist in the environment longer than the BTEX compounds, and much longer-term toxicity results from their presence.
2. Physical smothering can occur if plants and animals become coated in thick layers of oil. Physical smothering is more likely with heavier crude and fuel oils, especially if they become emulsified, because of their greater viscosity and adhesion potential. These heavier oils can persist for long periods of time and cause longer-term environmental disruption, but their toxicity is minimal.

There can be indirect effects from the above through alterations in species abundance and diversity after a spill. For example, removal of grazing animals within a habitat due to toxicity or smothering by oil may allow a subsequent increase in vegetation until ecological balance is restored. Aggressive or invasive clean-up actions can also alter habitats. Care needs to be taken when choosing response techniques to ensure that the overall result is beneficial compared to taking no action.

Impacts on inland and marine habitats are judged by the relative severity of the impact and speed of recovery.

Habitat recovery is dependent on the:

- degree and persistence of oiling;
- characteristics and weathering of an oil;
- circumstances of a spill (especially the weather); and
- response techniques and tactics.

The recovery of species is dependent on:

- rates of reproduction; and
- the rate of recolonization from adjacent habitats.

The effects of oil on various classes of organisms are summarized below. Generally, organisms can accumulate hydrocarbons from surrounding water and air, and by the ingestion of food and contaminated sediment. The concentrations of hydrocarbons which may be found within organisms is a reflection of the physiochemical properties of the hydrocarbon, environmental conditions, characteristics of the exposed organisms, and the food chain.

- **Bacteria:** While some oils can be initially toxic to bacteria, many bacteria use oil as a food source and, consequently, remove spills from the environment. In agricultural areas, and urban or suburban areas with high run-off, nutrient levels from fertilizers are likely to be high, which increases the potential for eutrophication and plummeting levels of dissolved oxygen even without a spill.

- **Algae:** Freshwater and estuarine algae are affected by exposure to the lighter weight, acutely toxic volatile compounds in many oils, but algal populations usually recover very quickly. The acutely toxic effects decline quickly as the toxic components weather. An increase in cyanobacteria (which fix nitrogen) provides nutrients to spur new algal growth. Microorganisms (zooplankton) which feed on algae are usually suppressed by the toxicity of spilled oil, and the subsequent lower predation rate helps algae to repopulate.

- **Invertebrates:** These animals can be subject to acute and chronic toxic effects from exposure to spilled oil. Sub-lethal (chronic) effects include impaired growth and reproduction. After a spill, the invertebrate population density and diversity can be significantly altered and population changes can indirectly affect the survival of organisms higher up the food chain.

- **Fish:** Unlike marine species in the open ocean, which can avoid a slick, freshwater fish may be unable to avoid spilled oil in a smaller water body. Fish kills have occurred after spills in constrained fresh waters, and can be a direct result of hydrocarbon toxicity or may occur indirectly due to low dissolved oxygen. Fish can accumulate hydrocarbons in their tissues but can also metabolize them; short-term exposures may therefore result in few long-term effects.

- **Amphibians:** The permeable skin of amphibians makes them more at risk than reptiles to oiling. The greatest risk to these animals is from smothering by physical coating, and toxicity due to ingestion of the oil.

- **Mammals and birds:** These animals are similarly susceptible to physical coating by oil, and to ingestion of oil through preening and consumption of oiled prey and plants. Physical coating of oil can severely affect the ability of fur and feathers to insulate an animal, resulting in hypothermia and possibly death. These injuries are often highly visible during a spill response and can lead to much public concern. Some species may smell the oil and avoid it.

- **Vegetation:** Oiling can affect more than just the plants themselves. Animals that live among the plants can become exposed to the oil by interacting with the plants. The oil on plants can remobilize during changes in water level or rain events, or can be transferred by animals and cause additional exposure effects.

Sensitivity

Habitat sensitivity to oil takes into account several factors, including: the potential for natural removal processes; biological productivity and the ability to recover following oiling; socio-economic use of the habitat; and the ease of oil removal. These factors can be used to rank the overall sensitivity of habitats as part of an Environmental Sensitivity Index (ESI). Use of an ESI is common for marine habitats, and has been used for freshwater shores.

An ESI typically uses a scale from 1–10 to indicate increasing sensitivity. An example is provided in Table 1.

Table 1 *ESI scale*

ESI	Shore type
1A	Exposed rocky cliffs
1B	Exposed solid walls
2	Shelving bedrock shores
3	Eroding scarps in unconsolidated sediments
4	Sand beaches
5	Mixed sand and gravel beaches
6A	Gravel beaches
6B	Riprap structures
7	Exposed tidal flats
8A	Sheltered rocky shores
8B	Sheltered, solid, man-made structures
9A	Sheltered vegetated low banks/bluffs
9B	Sheltered sand/mud flats
10A	Freshwater marshes (herbaceous vegetation)
10B	Freshwater swamps (woody vegetation)

Ecologists differentiate between types of freshwater wetlands, which include marshes, swamps, bogs and fens. To response personnel, these differences often have low relevance. Inland wetlands (ESI 10A and 10B) consist of marshes, bogs, fens and swamps. In any of these habitats, the water can be stagnant, oxygen levels can be low, and nutrient levels can be high. Low oxygen levels, uncommon in marine wetlands because of tidal water exchange, can make it much more difficult for spilled oil to degrade aerobically. The soft sediment that comprises these wetlands brings specific challenges to response techniques, as there is heightened risk of clean-up activities exacerbating damage.

Socio-economic effects

Drinking water and industrial water abstraction

A major concern for inland spills is the potential for contamination of drinking water supplies and industrial water abstraction sources. The three main routes for exposure are:

- oil spilled directly into surface waters that serve as water supplies and sources;
- oil-contaminated run-off from roadways, which flows to wetlands or spills directly to wetlands that serve as recharge areas for groundwater supplies; and
- spilled oil that penetrates soils and migrates down to groundwater.

Municipal drinking water intakes, cooling water intakes for industrial power plants and other industrial or agricultural water abstraction points can utilize surface water. Protecting these water intakes is often a major objective of inland spill response.

A major water intake protection effort occurred in January 1988 when a storage tank containing about 3.9 million US gallons (14,800 m^3) of diesel oil collapsed in Pennsylvania, USA. About 750,000 gallons of spilled fuel reached the Monongahela River approximately 25 miles upstream of Pittsburgh. The oil mixed into the water column as it passed over dams, and the cold temperatures and significant ice cover limited the amount of evaporation. As the oil travelled 200 river miles along the Monongahela and Ohio Rivers, drinking water intakes were closed (some for a week), and both large and small communities found alternative water sources until the oil concentrations in the river decreased to safe levels. A robust effort to track the oil movement, coupled with an outreach programme to alert communities to the threat of contamination, contributed to the ability to protect communities.

Traffic disruption

Many inland spills are relatively small and occur on or adjacent to roads or railways. In recognition of the priority placed on open roadways, the response to a truck rollover is usually to quickly establish safe conditions, clear the roadway, and reopen it to traffic. Many local fire departments are experienced in responding to truck rollovers or train derailments that spill fuel and/or refined products or, more rarely, crude oil. If gasoline is spilled, fire departments may first apply firefighting foam to suppress volatile hydrocarbon vapours and limit the potential for a fire.


U.S. EPA OSC website

The urgency to reopen roadways often results in flushing the spilled oil and any foam to the side of the road or into a storm drain as part of clearing the roadway. Firefighting foam contains a surfactant that can disperse the oil into water. If this mixture of oil and foam flows to a stream or river, it could unintentionally cause pollution itself and spread oil over a larger area. If possible, responders should limit run-off or recover these liquids to avoid the possibility of further contamination.

Above: an overturned road tanker causing disruption to a highway.

Traffic disruption is also a common consequence of transporting responders, support personnel and equipment to a spill location. Road access may be restricted to facilitate responder access, secure a site, provide temporary storage and establish staging areas.

Relocation of the community

When an oil spill occurs on water near a residential neighbourhood, residents and others in the vicinity could be relocated for health and safety reasons, e.g. the potential impact on water supplies. Caring for these community members' immediate needs for food, water and shelter can be a significant response effort. Property that is oiled can be difficult and time consuming to clean.

Local health departments can be engaged by response teams to help identify acceptable levels of hydrocarbon vapours in residential dwellings or commercial/industrial facilities, and to determine when they can be re-opened.


Kansas wing of the Civil Air Patrol

NOAA

Response management

The basic principles of incident management are the same for all spills:

- current and future actions are proposed based on an incident assessment within the framework of contingency plans;
- response objectives and actions are set and approved by those in command;
- field crews are directed by operations personnel; and
- logistical and financial activities are performed to support the operations.

These response activities take place regardless of incident complexity, whether a large formal organization is created or a small group of responders handles a spill.

In many countries, government agencies lead and coordinate the response to a spill, and the government expects the spiller to compensate them for their efforts and to provide support. Management of an incident is often carried out by a government official from a regulatory, law enforcement or military organization. In some countries, the spiller is required to respond at their own expense and under the direction of government officials. Ideally, everyone involved works together in a coordinated and unified effort to limit the ecological and socio-economic effects.

Since the majority of inland spills are relatively small, the scale of most inland response operations is also proportionately small, and such operations are usually handled by small teams on site. One notable difference between managing inland spills versus marine spills is that the initial responders are often from local municipalities, i.e. from fire and law enforcement agencies. For spills resulting from vehicle rollovers, these local agencies often conduct the whole response without any assistance from external resources (such as regional, provincial, state or national response organizations). However, a larger incident will often quickly overwhelm local capabilities and expertise, and local officials may be supplemented or even replaced by external responders. Regional and national agencies responsible for inland spill response may differ from those responsible for marine spills.

Inland spills can occur at varied locations—along a highway, railroad, river or pipeline—virtually everywhere oil is produced, used or transported. Response organizations need to be prepared to cover large geographic areas with a greater variety of habitats than offshore:

- Many inland spills occur at fixed facilities, so contingency planning will be specific to a location. Scenarios can be developed, detailed contingency plans written, suitable response capability can be procured or identified, communities can be engaged and exercises can be performed that specifically address potential incidents for that facility.
- Transportation-related spills are more difficult to predict and plan for. Pipelines, railways and roadways represent a route over which spills can occur. Contingency planning will need to encompass greater geographic areas in a manner suitable to provide response resources.
- Response resources tend to be concentrated at or near to major facilities or ports and responders may be a considerable distance from a potential spill site.

The probability of inland spills occurring near populated areas is relatively high, and impacts on the public can occur immediately. Public demands for a quick, robust response can be intense and can outstrip local governments' resources.

- For smaller spills, simple containment (keeping the oil from spreading or from reaching flowing water) is the overriding initial goal, and simple construction equipment (bulldozers, front-end loaders, etc.) are often more than adequate to contain the spill. Vacuum trucks can be used to suck up the oil, and these are usually available because they are used for other purposes.

- Specialized spill response equipment, such as containment booms and skimmers, may be located hours away from the spill site, resulting in a potential for considerable delays in initiating a comprehensive response.

Care should be taken when considering the use of oil spill trajectory models as part of an inland response. Most spill trajectory models were developed for forecasting the fate and transport of spills on open waters (ocean or inland seas) and are not appropriate for spills on rivers, streams and lakes, or on land. Simple calculations tracking the progress of a slick downriver as a function of the water current do not account for loss by sinking or stranding as oil encounters the river banks, especially at bends. Models can be applied to rivers to predict the timing and extent of the oiling downstream, but their resolution may not yield reliable results.

The process of setting response priorities using shoreline clean-up and assessment techniques applies to both marine and inland habitats. Assessment methodologies may have to be expanded because of the greater number of shore types encountered during an inland spill, and as tidal influences are replaced by possible fluctuations due to varied water flows.

An oil spill response operation is conducted around a private residence.

U.S. EPA OSC website

Safety and health issues

The safety of response teams and the community affected is the top priority during an oil spill response. Hazards to responders include physical ones (such as slips, trips and falls) and chemical hazards (such as spilled oil). Four dominant factors that influence the degree of hazard to responders are:

- the properties and composition of the spilled oil;
- environmental circumstances at the time of a spill and during the response;
- the location and types of tasks (including duration); and
- measures to minimize exposures.

Evaporation can produce high levels of flammable gases, and the risk of igniting a fire is a serious consideration, particularly for spills of light crude oils and light refined products (especially gasoline). An early task during spill response is often to monitor for explosive limits of volatile hydrocarbons, as crude oils and gasoline can often contain high levels of light aromatics.

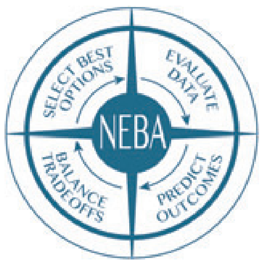
The public (and responders) near oil spills can be exposed to volatile compounds evaporating from the oil. Chemicals of concern are the light aromatics, plus hydrogen sulphide and other mercaptans (organic sulphides). The light aromatics evaporate readily, are acutely toxic and can cause cancer in the case of prolonged exposure at high doses. The light aromatics are so volatile that hazardous levels usually only last for a few hours, except at very low temperatures and in still air conditions. Heavier fuel oils, however, contain much lower concentrations of light aromatics, therefore spills of these oil types rarely cause hazardous levels in the atmosphere.

Hydrogen sulphide and other sulphur compounds are not carcinogenic but they are highly acutely toxic. The human nose can detect these compounds at very low levels. Sulphur compounds cause irritation well before toxic levels are reached. However, since our ability to detect odours is quickly deadened, spilled oils with sulphur compounds should be approached carefully. Sulphide levels in crude oils vary widely. Some crudes pose few problems, but the ones that do can present serious health issues even with concentrations at non-toxic levels, due to their highly irritating effects (e.g. headaches and nausea etc.).

Further information and details on managing safety and on how responders are protected from potential hazards is provided in the IPIECA-IOGP Good Practice Guide entitled *Oil spill responder health and safety* (IPIECA-IOGP, 2012).

Net environmental benefit analysis (NEBA)

Net environmental benefit analysis (NEBA) is a process used by the response community for making the best choice of response options to minimize the impacts of oil spills on people and the environment—see the IPIECA-IOGP Good Practice Guide on NEBA (IPIECA-IOGP, 2015). It involves consideration and judgment to compare the likely outcomes of using different oil spill response techniques alongside recommendations as to the preferred tactics from experienced response/NEBA practitioners. NEBA typically involves the steps shown in Table 2 on page 16, which should be carried out prior to an oil spill as an integral part of contingency planning.



The NEBA process

Table 2 *Typical steps involved in the NEBA process*

NEBA step	Description
Evaluate data	The first stage is to consider where the oil may be spilled and where it could move to in aquatic environments. It is also useful to know how an oil will 'weather' as it moves. This requires spill scenarios to be developed and is part of evaluating the available data.
Predict outcomes	The next stage is to assess what is likely to be affected by the spilled oil if no response is undertaken. This may include both ecological and socio-economic resources.
Balance trade-offs	The efficiency and feasibility of the response toolkit should be reviewed. This covers the response techniques, the practicalities of their utilization and how much oil they can recover or treat. Previous experience can help to assess which oil spill response techniques are likely to be effective. Pragmatic, operational considerations should form an important part of the NEBA process, as applied to all feasible response techniques.
Select best options	The process concludes with the adoption of response technique(s) within contingency plans that minimize potential spills' impacts on the environment and promote the most rapid recovery and restoration of the affected area.

The simple NEBA example below raises the question of whether or not to use in-situ burning (see pages 22–23) in an oiled wetland:

- The oil may be pooled in substantial amounts, so it would be easily ignitable. Yet, burning would create unaesthetic black smoke, and combustion would damage and/or destroy the oiled vegetation above the surface water level.
- Traditional manual/mechanical clean-up operations could destroy the same vegetation (e.g. after oiled sediment and oiled vegetation removal). Equipment operations and responders could unintentionally push or trample oil down towards root systems where the effects of the oil exposure could create long-term damage.
- What is the degree of oiling and the forecast recovery potential for the oiled wetland?
- What is the predicted oil removal efficiency of the response options?
- How unique is this habitat and what is the seasonal sensitivity of these plants?
- Both the in-situ burning and mechanical recovery options (see the following section on *Response techniques*) need to be evaluated against each other, and also against the additional option of no clean-up with monitoring of the natural recovery of the wetland.

These NEBA considerations can be assessed beforehand and incorporated into contingency planning. This planning then facilitates effective decision making, with equipment and personnel identified, staging areas selected and priority protection needs in place. NEBA considerations are also applicable during a specific incident to guide the process of assessing the spill circumstances and response options, and estimating the potential outcomes.

Response techniques

The suite of response techniques appropriate to inland spills is not the same as for marine spills. The larger mechanical recovery equipment (e.g. ocean booms and skimmers) used on marine spills are generally inappropriate for use on the smaller water bodies encountered inland. However, smaller-scale mechanical recovery equipment, as typically used nearshore in coastal spills, will be suitable for many inland water bodies. If the use of booms is considered, it should be noted that there are specific deployment tactics for their use in fast flowing waters. For oil stranded on freshwater shores, manual recovery of the oil is likely to be the dominant approach in many countries. The use of dispersants is typically limited to marine waters deeper than a specific minimum depth and beyond a specified distance from the coastline, where dilution can quickly mitigate the impact of dispersed oil and facilitate biodegradation; furthermore, dispersants are not usually formulated for use in fresh water and, as such, are much less effective in a fresh water context. This technique is therefore not normally considered for an inland response. Controlled (in-situ) burning, however, may be suitable for use in a wide variety of inland habitats.

Oiled wildlife response procedures and processes are almost identical for both inland and marine spills. Oiled animals in inland spills may include domesticated livestock or pets.

Oiled waste must be collected, stored and disposed of in accordance with applicable government regulations. The principles of waste minimization and segregation apply. In contrast to offshore spills:

- liquids recovered from spills at fixed facilities may be recycled back into storage tanks at the facilities; and
- contaminated soils may be removed or remediated in place.

Oil from smaller spills is often recovered using sorbents, and relatively large amounts of oily solid waste may be generated for disposal. Most countries have regulations that treat these wastes as hazardous, requiring greater levels of analysis and care in handling.

Isolating sites for safety reasons and keeping the public away from the clean-up crews and the oil may be difficult if the oil is on, or adjacent to, their land or property. Participation in the decision-making process by the public and their elected local representatives can be intense and can easily divert response leadership from the operational aspects of cleaning up the oil. Challenges facing the incident management team can include relocating families, supplying drinking water, reopening roads, and handling claims for damages and lost income.

Containment and recovery

Containing spilled oil and then manually or mechanically recovering it is by far the most common inland response technique. The concepts are simple and many operations do not require special equipment—an important factor when a spill might occur at a considerable distance from a stockpile of specialized response equipment. Containment is used to prevent the spilled oil from spreading and to concentrate it in quantities that can be more easily recovered. The types of equipment used range from local construction materials and earthmoving equipment to smaller versions of the booms and skimmers used offshore in marine spills.

Near right: piles of soil used to contain spilled gasoline.

Far right: sorbents being used to contain oil for recovery.

U.S. EPA OSC website

U.S. EPA OSC website

Most aquatic inland oil spills originate as spills on land. Responders initially want to keep the oil from flowing into surface waters and from penetrating into the ground. If spills are on impenetrable surfaces, responders will construct berms or other barriers to keep the oil contained. Sorbent booms have been used for the same purpose on small spills. Drains for storm water runoff are often protected by blocking them off with specially designed covers or by placing sheets of plastic over them weighted down with sand piles or sandbags.

Small streams and ditches are often dammed with local construction materials such as clay and gravel. This is especially useful when containment booms are not readily available or cannot be deployed because the stream is too narrow, or the current is too fast or the depth too shallow. Underflow dams use pipes installed through the dam to allow water to pass while retaining surface oil for collection. In deep streams, pipes just need to be placed at the bottom of the stream bed to allow the water to pass. Care must be taken to provide enough capacity for the flow of water, otherwise the dams may be washed away. For shallower streams where the constructed dam raises the water level, the pipes, or at least some of them, may be angled with the high ends on the downstream side of the dam providing a means to regulate the water level. Increased runoff due to rain or snow melt can overwhelm the flow-through capacity of these temporary

Near right: underflow dams with angled pipes to raise the water level and allow surface oil to be retained for collection.

Far right: underflow weirs using plywood sheets.

BP

U.S. EPA OSC website

dams, hence it is advisable to monitor the weather to ensure dams are appropriately constructed, maintained and able to retain their integrity. Locations for these dams should be chosen so that water does not spill out of the stream onto adjacent terrain and result in unintended exposures upstream of the dam.

Sheets of plywood can be used effectively to block culverts, ditches and very small streams. These need to be cut into the stream bank and secured. If there is flow in the stream or ditch, they can be raised off the bottom to create a simple underflow dam. Some wooden dams can be pre-constructed and inserted where needed or they can be built on-site. They will often have a centre section which can be raised and lowered to control the water level and trap oil. As with the other damming techniques, the function of these structures needs to be monitored for flow changes and maintained for structural integrity.

Below: booms used to exclude oil from side channels.

Hansen 2001

Containment booms are designed to control the oil floating on water. Booms of different sizes are readily available for a variety of conditions. Small booms are usually used on rivers and streams because they possess relatively low freeboard and are easier to handle.

The physics of water flowing under a containment boom is such that very low water velocities (even below one knot or 0.5 metres per second) can cause oil to become entrained in the water flowing underneath a boom. As a result, containment booms are usually deployed at an angle to the water current direction so that the effective water velocity is reduced and no oil is lost. However, even sharply angled booms will fail to hold back oil in currents greater than three knots (1.5 metres per second). When current speed and direction varies due to estuarine tidal cycles, flood events and other normal water variations, it can be challenging to deploy containment booms that will continue to hold back flowing oil. The forces exerted on containment booms by flowing water are high, and a skilled crew is required for successful deployment of a boom (or booms) in the proper configuration, and for regular boom

Below left: booms used to divert oil to a collection point.

Below right: a deflector is used to position the boom at the desired angle.

Hansen and Coe, 2001

Hansen and Coe, 2001

maintenance. In some instances, such as floods, it may not be practical to deploy booms due to worker safety considerations. Deployed booms should be monitored periodically to ensure proper function and adjusted as required.

Booms can be deployed to exclude oil from sensitive resources or to divert the oil to a collection point. For example, deflection booming may be used to deflect oil away from relatively small but particularly sensitive areas such as a water intakes. Multiple booms can be cascaded down a watercourse to achieve these aims. Booms need to be anchored to hold them in place. Deploying long sections of boom in a proper configuration with anchors and ropes can be difficult and time-consuming. Boom deflectors have been developed that use the force of the flowing water to hold a boom in place.

Below: a vacuum truck used in conjunction with a drum skimmer to recover the spilled oil.

BP

For some incidents on large rivers, where it has proven difficult to deploy a boom effectively, barges have been driven onto the river bank to act as barriers. Oil can still entrain beneath the barges and they may need to be angled into the current, as with a containment boom.

Recovery of spilled oil can be as simple as using vacuum trucks. Vacuum trucks are best used when connected to an oil skimmer or other recovery device, though they can be used alone when oil is accessible and pooled to larger thicknesses. However, an open suction hose on a vacuum truck can recover large volumes of water; this recovered water can significantly increase waste handling requirements and associated disposal costs.

Below left: oleophilic (oil-loving) drum skimmer.

Below right: oleophilic rope mop in heavy debris.

The most common skimmers are the oleophilic types in which oil is adsorbed onto the skimmer surface with reduced water recovery. Of these, drum and disc skimmers are very popular and rope mops are desirable in locations with heavy debris. For simple suction operations, suction head skimmers that lay flat can be used to limit the amount of water recovered. Response stockpiles typically contain the types of skimmers most likely to be effective on the oils and in the conditions found in the local area.

NOAA

NOAA

Oil trapped on quiescent water can be physically herded to a skimming location by spraying water. The intent is to push oil towards containment booms and skimmers. Care must be taken not to mix the oil into the water column where it may come into contact with, and attach to, sediments and thereby become more difficult to remove.

Spills on snow and ice

Locating oil beneath snow and ice can be challenging, and boring holes through the ice may be the only viable technique to find it. Remote sensing technologies to find the oil beneath the ice have been researched and a number of new promising techniques have been identified but none have yet made it into the response community.

Once located, oil in moving water under ice can be recovered by cutting slots in the ice or by inserting plywood sheets into the ice at appropriate angles to divert the oil (analogous to containment booms) to where it can be recovered. Chainsaws can be used to cut into the ice, and the safety risks when using these saws in adverse conditions while wearing bulky cold-weather protective clothing should be addressed.

Oil spilled on top of ice can penetrate the ice through cracks and require a much more thorough clean-up.

Below: a slot cut into ice allowing oil to rise and flow to a collection point.

Oskins, 2004

Sorbents

Sorbents (materials that can absorb or adsorb oil) are frequently used for collecting oil on hard surfaces. For small spills, they may be the only recovery method needed. Oil spilled on roads can be very slippery and must be removed before the road can be reopened. Often, mineral particulates (such as sand, vermiculite, clay mixtures) are used because they are inexpensive and can be easily applied and then collected.

The use of straw bales and other sorbent barriers is a viable recovery technique, especially if only natural materials are available. Wire mesh fencing can be installed across narrow, slow moving waterways to support and anchor sorbent materials placed on the upstram side to contain and absorb floating oil while the water continues to flow through the barrier. These barriers will not stop the flow of high levels of oil but can adsorb light quantities of oil. While straw is most commonly used, other sorbent materials can also be substituted. A major operational challenge is the recovery, handling and disposal of the oiled sorbent. Burning at the site is sometimes an option.

Workers recover sorbent material that has been used to clean an oiled road.

U.S. EPA OSC website


U.S. EPA OSC website


U.S. EPA OSC website

Above left: straw used to hold back and absorb low quantities of oil.

Above right: oiled straw is disposed of by burning on site.

Traditional synthetic sorbents are often used to help contain and recover oil. They may be placed outside drains and along containment booms to adsorb small amounts of oil. They can be overused and create a recovery and waste disposal problem when it might have been better to use a skimmer or in-situ burning. Used, oily sorbents create waste and usually have to be disposed of as hazardous waste. The logistics of moving them to the spill site, using them, recovering them and then removing them from the site need to be considered in advance.

Solidifiers

Solidifiers are products which mix with, and immobilize, oil. They consist of dry, granular polymers that partially melt when contacting petroleum oils, and which act to bind or encapsulate oil. Heavy, viscous oils and emulsified oils do not react well due to poor penetration and mixing. Manufacturers often recommend that they be broadcast over spilled oil as powders. These powders can be difficult to recover on water but can be easier to deploy and recover for small spills on land or hard surfaces.

Solidifiers can also be placed in disposable booms, pillows, sausages, etc., and deployed and recovered like sorbents. They create stronger bonds with oil than sorbents and will not leak oil as sorbents may do. They can remove oil sheens from water. There may be regulations restricting the use of solidifiers, particularly those in loose powder form.

In-situ controlled burning

There have been numerous cases of spilled oil accidentally catching fire and damaging facilities and vessels. However, deliberate burns have succeeded in limiting the spread of the spilled oil, rapidly removing oil from water, snow or ice surface and thereby mitigating its consequences from a NEBA perspective. Inland burning has been successfully and routinely used in North America.

In-situ burning is usually considered when access is limited or when it is necessary to remove the oil quickly. Mechanical equipment may not be able to access a spill site if, for example, the terrain is too steep, too forested or water-logged. While mechanical clean-up can take considerable time, controlled burns can remove large amounts of oil in a few hours. This saved time may be critical if heavy rains are forecast that could flush oil to wider or more sensitive areas. Another consideration is waste disposal. If large amounts of waste will be generated and/or there are no convenient disposal sites available, in-situ burning may be the best option to remove the oil.

Wetlands and other sensitive environments are highly susceptible to damage by the intrusive actions of clean-up workers. Wet conditions may prevent equipment from accessing the site and can make responders' actions more damaging, but the moisture will protect plant roots and soil from the heat of a burn.

Minnesota Pollution Control Agency

In-situ controlled burning in a peat bog; the white powder is fire retardant.

When considering the use of a controlled burn, the following should be borne in mind:

- **Safety:** responders and the public should be protected from any risk of spreading fire. Often local fire departments are present to wet surrounding vegetation to protect against the fire spreading beyond the spilled oil.
- **Ignition:** simple and safe methods are preferred. Flares, flare guns, torches and propane burners have been used successfully.
- **Moisture:** many ecosystems are tolerant of the heat from fires because fire is part of their life cycle (e.g. wetlands). However, heat from burning oil may be more intense than even these plants can tolerate. High moisture levels are therefore desirable, in particular to protect roots from heat stress and to limit the risk of the fire spreading beyond the oiled area.
- **Season:** in higher latitudes, winter burning often creates little environmental damage because many plants are dormant and could be covered in snow. Burns in late summer conditions can cause stress to plants as they are still building food reserves.
- **Weather conditions:** unpredictable weather can produce safety-related hazards at a controlled burn. Low, steady winds with no threatening storms or weather fronts are preferred because such conditions reduce the risk of the fire spreading. Atmospheric temperature inversions can trap the smoke plume and are not desirable because they restrict the dispersion of the smoke.
- **Residue collection:** some unburned oil or oily residue is almost always left after burning. If quantities are sufficient, the unburned oil could be collected and burned. Residues from crude oil burns can have varying consistencies from tarry to brittle; this residue needs to be collected. On water, oils subject to intense burns may create residues that sink after they cool, and it may be unacceptable to leave these behind.

Below left: snow and ice protects this wetland from oil exposure and aids fire control.

Below right: a large smoke plume rises from a wetland burn.

NOAA

Michel, 2002

Shoreline clean-up/treatment

Shore assessment

Oiled shore assessment surveys—also known as Shoreline Clean-up Assessment Technique (SCAT) surveys—are a critical component of a response operation. The information gathered by the survey teams is used by the response managers to set objectives, priorities, constraints and end points, all of which are essential in supporting the planning, decision making and implementation of an effective shore response programme.

Oiled shore assessment surveys of inland aquatic environments are carried out to:
- define and document the scale and character of shoreline oiling;
- identify and document the shoreline type and riverine or lacustrine character within the affected area;
- develop recommendations for treatment end points and treatment techniques which provide a net environmental benefit based on sound science;
- provide support throughout the treatment programme so that shore clean-up operations personnel understand the expectations and concerns of the response managers;
- provide a process for closure once treatment has been completed; and
- involve appropriate representatives to ensure consensus throughout the shoreline response programme.

Further details on how SCAT surveys are developed and implemented are provided in the IPIECA-IOGP Good Practice Guide entitled *Oiled Shoreline Assessment (SCAT) Surveys* (IPIECA-IOGP, 2014). The principles of SCAT can be applied equally to coastal or freshwater incidents. In order to facilitate standardization or a systematic approach to assessment and capturing field data, a series of forms for recording data on inland habitats have been produced (ORG, 2014).

For successful implementation of SCAT, a team of dedicated personnel is needed who are familiar with its aims and terminology. This team should be fully integrated within an incident management team to ensure that their data are utilized to support the decision making process.

Response options

Techniques for cleaning oiled river banks and shores share similarities with marine shorelines (for more information on the latter see the IPIECA-IOGP Good Practice Guide on oiled shoreline clean-up techniques (IPIECA-IOGP, 2015a)). The term ‘cleaning’, in this context, is applied broadly and includes various water flushing options, manual and mechanical oil removal, and the removal of oiled vegetation and oiled debris; it may or may not remove all of the oil from the shoreline. The scale of response operations may be different for smaller inland spills, with the techniques requiring adjustment according to the specific circumstances of a spill.

While tides and waves typically dominate marine shoreline-oil interaction, it is waves in lakes, and water flow in streams and rivers that dominate freshwater shoreline-oil interactions. The tendency for freshwater systems to be more confined than marine environments leads to less dilution of oil in water, and less spreading. As a result, oil concentrations can be greater in freshwater habitats.

HDR

Removing oil from a wetland contaminated with heavy fuel oil—planking is used to reduce trampling.

Many inland habitats have been transformed by human activity, including urban and suburban construction, the development of commercial and industrial facilities, and agricultural terraforming. As a result, the original landscape may have disappeared or been substantially altered. These factors can result in less concern being shown for the ecological sensitivity of such habitats to oil exposure, and more aggressive clean-up techniques may be considered acceptable.

While marine shorelines are classified based on tidal zone, inland habitats are classified as follows:

- Lake shores are classified based on swash zone from wave action. The swash zones are analogous to marine tidal zones, and include the supra-wash, upper swash, lower swash and submerged zone (down to where rooted plants stop growing).
- River bank zones are classified based on water levels, and include the over-bank (flood plain), upper bank, lower bank, and mid-stream (exposed bars or shoals in the channel).

Marine tidal effects typically create wider shorelines than the swash zones do on freshwater shores. In a freshwater setting, a one-metre wide shoreline would be considered wide, whereas in a marine setting it would be considered narrow. Freshwater shores include various mud, clay, and other sediment banks and vegetated shorelines.

Water level variations in the marine environment are often predictable (e.g. those caused by tides) while variations in freshwater levels can be unpredictable (e.g. those caused by storm events and runoff from precipitation). These unpredictable changes in water levels can dramatically affect clean-up operations as well as the natural oil removal. Small streams and shallow water may become oiled across the whole channel, resulting in the need to clean the entire bottom of the water course from bank to bank. The ecological effects from this spreading of oil must be balanced against potential damage from manual and mechanical removal and the option of leaving some oil behind to degrade naturally.

Table 3 *A summary of the relative effects of physical response techniques for use in freshwater habitats and shorelines in the absence of spilled oil*

Physical response method	Water environment				Shoreline habitat							
	Open water	Small lakes/ponds	Large rivers	Small rivers/streams	Bedrock	Man-made	Sand	Vegetated shores	Sand and gravel	Gravel	Mud	Wetlands
Natural Recovery	–	–	–	–	–	–	–	–	–	–	–	–
Booming	L	L	L	L	–	–	–	–	–	–	–	–
Skimming	L	L	L	L	–	–	–	–	–	–	–	–
Barriers/berms	–	–	–	H	–	–	–	–	–	–	–	–
Physical herding	L	L	L	L	–	–	–	–	–	–	–	–
Manual oil removal/cleaning	L	H	L	M	L	L	L	H	M	M	H	H
Mechanical removal	L	H	H	H	–	M	M	H	M	M	H	H
Sorbents	L	L	L	L	L	L	L	L	L	L	M	M
Vacuum	L	L	L	L	L	L	L	M	L	L	H	M
Debris removal	–	L	L	L	L	L	L	L	L	L	M	M
Sediment reworking	–	H	–	H	–	–	M	H	M	M	H	H
Vegetation removal	L	H	M	H	–	–	–	H	–	–	–	H
In-situ burning	L	M	L	M	L	L	M	M	M	M	H	M
Flooding	–	–	–	–	L	L	L	L	M	L	L	L
Low-pressure, cold-water flushing	–	–	–	–	L	L	M	L	L	M	H	L
High-pressure, cold-water flushing	–	–	–	–	L	L	H	H	H	H	H	H
Low-pressure, hot-water flushing	–	–	–	–	M	L	H	H	M	M	H	H
High-pressure, hot-water flushing	–	–	–	–	M	L	H	H	H	H	H	H
Steam cleaning	–	–	–	–	M	L	H	H	M	M	H	H
Sand blasting	–	–	–	–	H	M	–	–	–	–	–	–

L = Low   M = Moderate   H= High

From API-NOAA, 1994

All cleaning techniques can be intrusive and can damage habitats, even in the absence of oil. It is best to identify preferred techniques in advance when preparing contingency plans, and guidance is available to help make these judgments for freshwater habitats and associated shorelines. During a response, an informal and rapid NEBA (see page 15) can be used to confirm that appropriate decisions are made regarding the choice of response options, thereby ensuring that such actions are operationally feasible, effective and least intrusive to the environment. A summary of the relative effects of physical response techniques for use in freshwater habitats and shorelines in the absence of spilled oil is provided in Table 3 on page 26.

Surface washing or shore cleaning agents

Shore cleaning agents are products which increase the ease or efficiency of oil removal when flushed with water. The oil is washed, or mobilized, off a hard surface, corralled by booms and collected by skimmers or sorbents. These products are designed to be used on very heavy oils on hard substrates that cannot be cleaned by water flushing alone, and their use is not an initial response technique. They do not work well on porous habitats like sand shore and marshes.

Many cleaning products are sold for the purpose of surface washing, some of which are also suitable for household use. However, only a few have low aquatic toxicity and avoid causing the

a) Oiled riprap with sorbent boom at water's edge.
b) Spraying shoreline cleaner.
c) Flushing after soak time.
d) Cleaned riprap.

removed oil to disperse. Because these agents are good cleaners, some are used to clean oiled response equipment at decontamination facilities.

There is a long history of their use by local responders, such as fire departments, for removing oil quickly from roads and other hard surfaces. Their priority is to quickly reopen paved areas for safe public use. However, care should also be taken to constrain the further spread of mobilized or dispersed oil.

The best products are those that have low aquatic toxicity while remaining effective. They often require soak time to interact well with the oil before being flushed with water. As a result, they cannot be successfully used if waves or rain are present because the water will wash the product off the oiled surface before it has time to interact with, and mobilize, the oil.

Biodegradation

Although not a technique for spill response to limit the spread of oil and recover it, subsequent longer-term clean-up activities may include bioremediation tasks. Microbes that degrade oil exist everywhere and need adequate oxygen and nutrients, primarily nitrogen and phosphorus, to promote their growth. In quiescent inland waters with limited flow, such as some wetlands, swamps, and ponds and lakes, a major influx of hydrocarbons can be overwhelming to microbes and nutrients may become limiting. Microbial degradation of spilled hydrocarbons is easier and faster if oil components are soluble in water. However, this is atypical since most oil components are not very soluble in water, or may be insoluble. The more soluble components are the lighter-weight compounds found in refined products, very light crude oils and ethanol fuels.

If soluble components (e.g. refined products) are available to microbes in large quantities, their rapid growth could deplete the dissolved oxygen supply in smaller water bodies and cause hypoxia, slowing down their growth and affecting other aquatic species. Extreme reductions in dissolved oxygen can lead to fish deaths. Studies have shown that the addition of fertilizers accelerates the rate of degradation if nutrients are lacking; however, this can also lead to eutrophication, thereby increasing the potential for hypoxia.

Biodegradation is not a new response technology. It occurs naturally, regardless of whether it is enhanced by the addition of nutrients. The rate of biodegradation depends on four key factors: nutrients; oxygen; ambient temperatures; and the local degree of oiling. Light oiling can be degraded within weeks or a growing season. Because it may take months to degrade thick layers of stranded oil, this is not regarded as a response technique, but rather a process that can be relied upon after the majority of the oil has been removed by other clean-up techniques.

It can be a challenge to reach agreement on the end points of clean-up activities, as stakeholders may have the initial perception that removing all oil through clean-up activities is required and appropriate. However, the ability for the natural process of biodegradation to break down the majority of oil compounds is an important consideration in the framework of NEBA and should be factored into the analysis alongside the potential harm of other clean-up operations.

Sunken oil

There are specific challenges to be faced where very dense oils sink in fresh waters. The identification of sunken oil may be difficult as it is likely to be hidden from view. Initial predictions of depositional areas can be made by studying the water body (bathymetry) and its surface water hydrology to determine where natural areas of deposition may occur (for example, the pools of a meander in a river or around the edges of a lake, or depressions in the stream bed). This would be followed by probing or surveying for oil. In some cases changes in temperature or seasonal factors may lead to sheens appearing, which could provide indicators of sunken oil. The use of sorbent snares (pom poms) or sorbent pads fastened to a weight and dragged along the bottom can also be useful in locating the presence of sunken oil.

Clean-up actions may include agitating or aerating the river or lake bed to encourage the release of oil, with subsequent recovery of released oil as it reaches the surface. Dredging of oiled sediment may also be considered. In all cases the treatment of sunken oil is likely to be a long-term project extending beyond the emergency phase of an incident.

U.S. EPA

Pumping water into river sediment to release sunken oil and flush it to the surface.

Summary

Spills to inland environments are typically much smaller in volume but more frequent than spills to marine waters and their shorelines. Inland spills do not garner the degree of broad public and media attention compared to large offshore spills.

The response to oil spills in inland aquatic environments shares similar principles to a marine spill response, but there are significant differences. Inland spills, even small ones, often directly affect the public in a more intimate manner than similar-sized marine spills. They are also more likely to involve oil products, and raise immediate safety concerns due not only to their potential proximity to communities but because of specific fears about toxic vapours and fire risks. Spills may occur near homes and businesses, along highways, and in cities and towns. This proximity can, and often should, drive response priorities, including:

- preventing the exposure to oil of drinking water supplies;
- monitoring hydrocarbon vapours and smoke plumes for responder and public health and safety, and securing operational exclusion zones;
- preventing exposure to oil of livestock and pets; and
- limiting the disruption of waterborne traffic, and arranging the temporary relocation of residents and closure of businesses, as necessary.

Response activities, especially for smaller spills, may be conducted and/or supervised solely by the local authorities. A response to small inland spills can be achieved by relatively few responders and can often be completed more quickly than marine spills, as smaller geographic areas may be affected. Where potential inland oil spills originate from fixed facilities or other assets, it is feasible to engage in detailed contingency planning based on realistic spill scenarios, leading to improved communication and coordination during a response.

The industry has evaluated inland spills and associated response operations, and has developed guidance for response techniques which account for oil type and habitat sensitivity. This guidance aims to inform the selection of response options which are both effective and provide a net environmental benefit.

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IPIECA

IPIECA is the global oil and gas industry association for environmental and social issues. It develops, shares and promotes good practices and knowledge to help the industry improve its environmental and social performance; and is the industry's principal channel of communication with the United Nations. Through its member led working groups and executive leadership, IPIECA brings together the collective expertise of oil and gas companies and associations. Its unique position within the industry enables its members to respond effectively to key environmental and social issues.

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IOGP International Association of Oil & Gas Producers

IOGP represents the upstream oil and gas industry before international organizations including the International Maritime Organization, the United Nations Environment Programme (UNEP) Regional Seas Conventions and other groups under the UN umbrella. At the regional level, IOGP is the industry representative to the European Commission and Parliament and the OSPAR Commission for the North East Atlantic. Equally important is IOGP's role in promulgating best practices, particularly in the areas of health, safety, the environment and social responsibility.

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