



Introduction

In addition to the costs incurred in cleaning up oil spills, serious financial losses are sometimes experienced by economic sectors that rely on clean seawater and clean coastal areas. Typically, the greatest economic impacts are felt in commercial fisheries and tourism, although a great number of other sectors can be affected, such as power plants, shipping, salt production or seawater desalination. This paper considers some of the effects of oil spills on a variety of coastal industries and social activities and considers measures which might reduce their impact. Given their particular importance, the effects of oil spills on fisheries and mariculture are considered in a separate Technical Information Paper.

Tourism

Tourism is a key economic sector in most populated coastal areas of the world that can be disrupted by the presence of oil in the water or on the shore, with the most serious consequences likely to arise just before or during the main tourist season (*Figure 1*). Disruption of traditional coastal activities such as bathing, boating, angling and diving can have a consequent effect for hotels, restaurants and bar owners, as well as sailing schools, camp sites, caravan parks and the many other businesses and individuals who gain their livelihood from tourism. Restaurants serving seafood may additionally experience losses due to reductions in supplies, while those businesses supplying hotels and restaurants may also experience reduced incomes unless they are able to make up losses elsewhere. Much depends on the extent to which such businesses are dependent on the coastline affected.

Some holidaymakers may decide to cancel bookings in the area affected and transfer their holidays to alternative locations. The repercussions of visitors curtailing or cancelling their stay may go beyond losses to commercial businesses, for example, by reduced receipts from car parks operated by local authorities and national parks. Losses may also be incurred by road, rail and sea transport companies that routinely transport holidaymakers to the coastal areas affected.

Affected beaches may have to be closed during clean-up. On beaches that remain open, in addition to the oil itself, the presence of workers and equipment may cause a nuisance. The movement of trucks and heavy machinery to and from affected shorelines may cause further disruption to the local population and may lead to secondary contamination in areas further inland if oil on vehicle tyres is not addressed.

In heavy weather, oil can be carried inshore by airborne spray from waves breaking against a quayside or a rocky shore. Buildings, cars and caravans along a seafront or close to the shore can become spotted with oil and require cleaning and, in some cases, repainting. The cleaning of private shorelines, for example those associated with holiday homes, presents a particular difficulty if the owners are absent and their permission is required to access the shoreline.



▲ *Figure 1: Oil spills can lead to severe disruption for the tourist industry.*

During an incident, some businesses may be able to find alternative sources of income, for example, by providing food and lodging for those involved in the incident. However, secondary contamination of hotel carpets and fixtures may occur from workers attending the spill, if due care is not taken. A wreck close to the shore can attract substantial numbers of spectators bringing with them the possibility that some businesses – cafés, restaurants, parking, etc – may be able to make up some of their losses.

The physical disturbance to coastal areas and recreational pursuits from a single oil spill is usually comparatively short-lived. Once shorelines are clean, normal trade and activity would be expected to resume, although media attention may cause disproportionate damage to the image of the local tourist industry, aggravating economic losses by contributing to a public perception of prolonged and wide-scale pollution. This could result, for example, in bookings being lost even by hotels and other businesses well outside the affected area. The degradation of the 'brand image' of a region may call for targeted regional advertising campaigns and other promotional activities to counteract negative publicity generated by the spill and restore public confidence.

Aquariums and recreational facilities

Many coastal facilities, such as aquariums, seawater swimming pools and thalassotherapy centres, require a continuous supply of fresh seawater. The water is usually screened to remove debris and sometimes passed through filter beds composed of sand, crushed shells or other materials. While these can provide protection against gross contamination, soluble components of the oil may still get into the water supply, particularly if crude oils or light refined products are spilled.

Operators of these facilities may be able to mitigate the damage from oil in a number of ways. With sufficient warning, the animals in an aquarium might be transported to alternative facilities, but this requires specialist transport and is likely to expose the animals to extreme levels of stress. Depending on the volumes of water required and the degree of oil exposure, filter beds may be constructed using sorbent materials to remove the oil. Alternatively, the water intakes may be closed and water in the system re-circulated with clean seawater brought in by road. In all cases, a balance will be required between potential damage caused by the mitigation activity and that caused by the oil. In addition to the costs of such preventive measures, it is likely that aquariums and other facilities will either be closed or suffer reduced attendance figures for the duration of the incident.

Marinas and fishing harbours

Marinas and fishing vessel harbours are usually enclosed by sea defences to protect moored vessels against adverse sea conditions. The sea defences are often provided by rock armour or tetrapods. If oiled, these can be difficult to clean and, as the oil can penetrate deeply into the structure, they may become a source of secondary pollution. In many instances, a narrow entrance to the marina or harbour allows vessels access to the sea and, with sufficient notice, this could be protected from floating oil by deployment of booms.



▲ Figure 2: Successful booming of marina entrances can be compromised if the boom is damaged by vessels entering or leaving.

However, if conditions allow fishing to continue, protection of fishing harbours may be compromised by the passage of vessels entering and leaving the harbour, if not appropriately managed (Figure 2).

Vessel cleaning

Once oil has entered a marina or fishing harbour, the hulls of a significant number of vessels, mooring lines and berths can become oiled (Figure 3). Oil stains on vessel hulls are typically limited to a band around the waterline. Hulls can usually be cleaned while still in the water if undertaken with minimal delay. Inducing a list in the vessel, thereby exposing the waterline, may allow oil to be removed with rags and one of a range of proprietary vessel cleaning products stocked by yacht chandlers. To avoid secondary pollution, run-off should be recovered, for example by sorbent boom surrounding the work area. Some cleaning materials may damage hull coatings and a small test area should be tried if vessel owners are unfamiliar with the available products. Concerns about product toxicity also mean that the use of cleaning agents may be controlled by local regulations. For more intractable stains, vessels may be slipped or hauled out for cleaning and stronger cleaning agents used. However, some cleaning agents, such as those based on chlorine, ammonia, acetone or ketones, are likely to damage the gel coat of fibre-glass vessels.

The severity of staining depends on a number of factors including the oil characteristics and degree of contamination, the time that the oil is left in place and the type and condition of the hull coating. Older and more porous coatings are likely to be penetrated more easily and therefore stained more heavily than newer ones. Some coatings are finished with a wax polish, which is likely to be removed by the oil, while polymer-based top coats are more resilient.

An area may be established within a marina or harbour where vessels can be cleaned either by their owners or by a contractor engaged specifically for the task. The organisation and logistics required to clean large numbers of vessels



▲ Figure 3: Moored vessels may require cleaning if oil enters a marina or fishing harbour.

should not be underestimated. Cleaned and oiled vessels should be separated to prevent the risk of re-oiling. If vessels are to be lifted out of the water, the hire of a specialised crane may be required. Additional labour may be needed to handle and clean the vessels and contact with vessel-owners, most of whom are likely to be absent, will be necessary to gain permission for their vessels to be cleaned.

In many marinas, the vessels are moored to floating walkways. If oiled, these can be cleaned with high pressure, hot water equipment. On rare occasions, the walkways may have to be dismantled to allow the floats to be cleaned to prevent secondary pollution.

Ports

Ports can suffer similar problems to marinas and harbours, although on a considerably larger scale, and many port authorities demand that the hulls of commercial vessels are cleaned before the ships are permitted to sail. Specialist cleaning contractors may be required and additional demurrage charges may be incurred while the vessel is cleaned (*Figure 4*). Similarly, vessels sailing through slicks at sea may require cleaning before they are authorised to enter port. Considerable disruption may be caused to normal port operations while vessels undergo cleaning or if vessel movements have to be curtailed. Furthermore, ports typically have large entrances, limiting the effectiveness of booms.

Statistical records show that shipping casualties frequently occur close to the coast and in the approaches to ports. In such cases, the casualty itself may present a hazard to navigation or interfere with the traffic moving in and out of a busy port. Disruption to port operations and potentially to businesses served by the port may necessitate alternative routes for the movement of goods and materials. To minimise disturbance of port activities, work to clean jetties and dock walls should be scheduled around normal port operations. Large vessels, particularly leaving or entering port, should move at slow speed to reduce wash that could disturb booms and other deployed resources, as well as to minimise the

spread of floating oil around the port.

The sheltered nature of ports and harbours and the ready availability of spill response equipment in many ports can allow for a rapid and effective response to a spill of oil, particularly if a comprehensive and fully exercised port contingency plan is available. However, removal of oil trapped under wharves and jetties can present serious difficulties because of the numerous piles or columns and difficult and dangerous access (*Figure 5*). A successful approach has been to use fire hoses and the wash from vessels' propellers to deliberately flush the oil out. However, if manual cleaning is required, precautions are needed to ensure the safety of the workforce in the semi-enclosed space under the wharf, especially when tidal fluctuations may further restrict the working head-space. If not addressed, the oil can present a chronic source of secondary pollution as it is flushed out by water movement during berthing operations.

Depending on the nature of the oil spilled, precautions are also required in the enclosed waters of ports and harbours to minimise the risk of fire and explosion. For example, all hot work may need to be stopped after a spill of a volatile oil. Even spills of fuel oils with high flash points warrant additional vigilance, as sparks from hot work can ignite debris, such as rope saturated with oil, which can in turn lead to serious fires with a potential to damage or destroy vessels lying in pooled oil.

Coastal civil engineering & shipbuilding yards

Projects such as sand and aggregate extraction, dredging, land reclamation and coastal construction work can all be put in jeopardy during an oil spill. Typically, the scale of these projects is such that protection using conventional booms is not feasible and disruption is likely to continue until clean-up operations have been completed. Building contracts, in particular, usually have agreed time-lines and penalties may be incurred if these are exceeded due to a spill.



▲ *Figure 4: Specialist clean-up contractors are usually employed to clean larger, commercial vessels.*



▲ *Figure 5: Access underneath wharves may be difficult and dangerous for clean-up crews due to lack of head room and ventilation.*

Port expansion works vary in nature but often involve significant dredging and movement of spoil, the sinking and placement of large pre-fabricated cement structures and rock material, and pouring of cement. Oil passing through or stranding in construction sites risks becoming buried, trapped or otherwise integrated into the sediment or structures and may leach out from hidden spaces on subsequent tides. Contamination of formwork or shuttering into which cement is to be poured may necessitate expert advice from civil engineers before construction can continue. Cleaning of construction sites requires careful supervision to ensure the work is undertaken methodically and safely.

Work on vessels being built or repaired on slipways, such as painting or renewal of antifouling, is likely to be badly affected by contamination by oil, possibly requiring the vessels to be cleaned or the work redone. The external structure of floating dry docks may be contaminated by oil floating within a port. Spills within a floating or land-based dry dock, where oil may be inadvertently released from a vessel during maintenance work or manoeuvring, can be highly disruptive to often tight working schedules and may require considerable effort to clean (Figure 6).

Industrial water intakes

Seawater is widely used in a broad range of industries: as a coolant for thermal and nuclear power stations and refineries, as a feedstock and as a coolant for desalination plants, and as a feedstock for salt production. In addition to aquariums and onshore mariculture facilities, seafood processing plants and numerous other users of seawater rely on the ability to draw clean water from the sea. The design of water intakes depends on a variety of factors, such as the volumes of water required and the environmental conditions at a particular site. In quiescent areas with a low tidal range, the intake may be simply a channel at sea level with a sluice to control water flow. Where the location is exposed to waves and a high tidal range, intakes are usually submerged to a depth that exceeds the likely fluctuations in water levels. The possibility that oil will be entrained into the water flow depends on the

type of oil, the weather conditions at the time of the spill and the design of the intake itself. Deeply submerged intakes are less likely to be affected, except in storm conditions when dispersed oil may become entrained. Light crude oils are dispersed more easily into the water column than viscous fuel oils and are more likely to present a risk of contamination to submerged intakes. However, in exceptionally severe storm conditions, high density fuel oils may disperse into the water column and even deeply submerged intakes may be at risk.

Many different approaches have been taken to protect industrial water intakes. Some are more effective and offer better protection than others. For example, beach wells draw water through sand which provides a first level of filtration and protection against physical contamination, although soluble components of oil may nevertheless contaminate the water. The protection of intakes at or close to the surface with conventional floating booms and bubble barriers depends on weather conditions and the velocity of the water flow, which should be sufficiently low for these techniques to be effective (Figure 7).

Electricity power plants

Electricity power plants use cold seawater circulated through tubes to condense steam from steam turbines. Occasionally following an oil spill, water intakes are shut down as a precaution against damage to machinery and to avoid the more extensive shut-down of the entire plant should condenser tubes and other equipment need to be cleaned. The concern is that the oil will either block the condenser tubes or will interfere with heat transfer so that efficiency of cooling is substantially impaired. The consequences of shutting down a power station are likely to be both far-reaching and severe, as it may become necessary to buy in electricity from other producers to maintain supplies. Consequently, strenuous efforts are usually made to avoid shut-downs.

As well as spill response equipment to protect water intakes, there are normally several levels of defence in place to prevent oil from contaminating the condenser tubes. Debris



▲ Figure 6: Oil spills in dry docks can occur during routine maintenance operations.



▲ Figure 7: Water intakes should be protected to prevent oil affecting heat exchangers that can be difficult to clean and may lead to the shut down of facilities.

screens, used to remove flotsam and jetsam, can become blocked if the oil is particularly viscous, restricting water flow to the tubes. Additional manpower may be required to avoid blockages by ensuring that the screens are constantly cleaned. Two screens are often run in parallel so that one can be brought out of service for maintenance and cleaning while the other remains in operation. The design of the particular facility may include a sedimentation pond downstream of the debris screens, to allow dense sand particles to drop out before the water enters the plant. Such ponds may provide an opportunity to recover floating oil with skimmers or sorbents and to monitor for signs of oil ingress. While oil droplets entering condenser tubes can adhere to the surfaces as a thin film, in general the oil will be slowly flushed through the system, with only a slight effect on heat transfer. The tubes routinely suffer from the build-up of scale and stiff foam balls are often used to scour tube surfaces. These also work well in removing oil films although they need to be replaced more frequently than when used to minimise scale.

Seawater can also be used to warm Liquefied Natural Gas (LNG) when transforming it from a liquid to a gas prior to distribution in gas pipelines. Water is pumped from the sea surface, where it is warmest, using floating skimmers, to the regasification plant. Floating oil may become entrained in the resultant water flow. Debris screens are unlikely to cope with this type of contamination, with a real risk that oil is distributed through the rest of the plant.

Desalination plants

Two types of desalination plant are in common use: multistage flash distillation (MSF) and reverse osmosis. In MSF desalination plants, brine is heated and passed through a series of stages where the pressure is reduced incrementally with salt-free water vapour evaporating at each stage. The experience with MSF desalination plants has been that a certain level of oil can be tolerated without contamination of the fresh water product or undue effects on heat exchangers. On the other hand, reverse osmosis systems rely on semi-permeable membranes to remove salt from seawater and oil



▲ *Figure 8: The production of salt can be severely affected if an oil spill occurs when water is let into the pans. The brine in the ponds naturally takes on a pink colouration due to the presence of microalgae.*

contamination could foul the surface of these very expensive membranes. Some lighter components of the oil may also penetrate to contaminate the product water while more viscous oils are more likely to blind the membrane surface and reduce or block water flow. While it may be possible to successfully clean membranes following mild contamination, it is generally considered that oil would have a seriously deleterious effect on membrane performance.

Salt production

In regions with limited rainfall, salt is often produced by the evaporation of seawater in salt pans along the coast (*Figure 8*). The seawater is collected in shallow ponds and allowed to evaporate in the sun and the wind to produce brine. Insoluble impurities, such as sand and clay, and slightly soluble impurities, such as calcium carbonate, settle to the bottom as evaporation begins. Over a period, the increasingly saline brine is pumped or flows by gravity through a series of ponds until the concentration has increased sufficiently for the salt to crystallise.

Production facilities range from an artisanal scale, with salt pans dug out of mud in salt marshes, to industrial scale with glazed-tile ponds and pumped water supplies. Seawater is generally only drawn into the ponds at high water during spring tides and the flow into the ponds is controlled by sluice gates. In the event of a spill, oil can sometimes be prevented from entering the ponds simply by closing the sluice gates. However, if pollution is prolonged, it may be possible to maintain production by allowing seawater into the ponds through filters constructed from sorbents and shells and by careful monitoring of water quality. While tiled pans can be cleaned relatively easily if oil does get into the ponds, cleaning mud-based ponds can be problematic. The closure of mud ponds over prolonged periods causes them to dry out and leads to the formation of fissures requiring substantial maintenance before salt production can be resumed.

Agriculture

Contamination of crops and farmed animals, although rare, has occurred following a number of marine oil spills. If the spill coincides with high tides and onshore winds, water levels can rise sufficiently to allow oil to strand high up on estuary banks where animals are grazed. In addition, animals such as sheep and cattle may be grazed on the shoreline itself (*Figure 9*) and risk feeding on contaminated feedstuff. In some regions, seaweed stranded after winter storms is collected and used as a fertiliser. Seaweed is cultivated for a number of uses and, as well as a foodstuff, it is used in the production of cosmetics, pharmaceuticals and food additives.

Strong winds and waves can also result in oil being blown ashore in sea spray to contaminate crops and animals. In addition to cleaning the affected animals, supplies of extra feed would be required to replace grazing that has become contaminated. Where oil spills have occurred on navigable rivers and estuaries, livestock, such as ducks and geese, and crops, such as rice irrigated by river water, have also been contaminated. Depending on the severity of contamination,

crops may have to be destroyed or additional fertilisers used to enhance the recovery of the soil and to accelerate the natural breakdown of the oil. Clearly, with sufficient notice, livestock can be excluded from polluted shorelines and sluice gates to irrigation channels closed.

Coastal communities, heritage sites and cultural artefacts

The smell of oil stranded or floating close to the shoreline can be very unpleasant and presents a severe nuisance to people living along the affected coastline. A major spill of a volatile crude oil close to a centre of population is likely to raise health concerns and complaints of breathing difficulties, headaches and nausea. In some parts of the world, coastal communities live on the shoreline or, in some cases, even over the water in accommodation built on stilts. In such cases, the contamination of the shoreline can be more than a nuisance and can interfere with day-to-day life. In extreme cases, the oil may represent a fire hazard and necessitate the evacuation of such communities.

Damage may be caused to cultural artefacts, either through direct contact with oil or as a result of clean-up operations. There may be concerns that human remains buried on shorelines can be disturbed by efforts to clean the shoreline and often the location of such sites is only known to archaeological specialists and local communities. Shoreline clean-up has to be undertaken with great care and under expert supervision. The cleaning of heritage



▲ *Figure 9: Livestock on the shoreline may be affected by oil directly or through contaminated foodstuff.*

sites requires equivalent care and sensitivity. The surfaces of ancient buildings which have weathered and have become porous or are crumbling and where oil stains have penetrated deeply present enormous difficulties. Specialist restoration techniques may be called for since the aggressive techniques which might be used to clean rock faces on the shoreline would probably cause further damage. Provided that sufficient warning of an approaching slick is given, buildings can be wrapped in polythene sheet to protect the ancient stonework from airborne droplets or oil splashing up from the water's edge.

Key points

- A wide range of industries that rely on clean seawater can incur substantial losses following an oil spill. The fisheries and tourism sectors are frequently the most seriously affected.
- In many cases early notification would permit effective contingency arrangements to be put in place to protect marinas and industrial water intakes.
- Although enclosed port waters offer optimum conditions for spill response, the need to minimise disruption to port activities means working around ship movements and can result in extended clean-up operations.
- The consequences of a precautionary shut down of a power station or desalination plant may have far-reaching consequences and may be unnecessary if measures can be put in place to maintain operations.
- Other activities, such as the production of sea salt, coastal engineering and even agriculture have all been adversely affected by oil spills. Where feasible, contingency plans should consider measures that could be used to mitigate impacts.

TECHNICAL INFORMATION PAPERS

- 1 Aerial Observation of Marine Oil Spills
- 2 Fate of Marine Oil Spills
- 3 Use of Booms in Oil Pollution Response
- 4 Use of Dispersants to Treat Oil Spills
- 5 Use of Skimmers in Oil Pollution Response
- 6 Recognition of Oil on Shorelines
- 7 Clean-up of Oil from Shorelines
- 8 Use of Sorbent Materials in Oil Spill Response
- 9 Disposal of Oil and Debris
- 10 Leadership, Command & Management of Oil Spills
- 11 Effects of Oil Pollution on Fisheries and Mariculture
- 12 Effects of Oil Pollution on Social and Economic Activities
- 13 Effects of Oil Pollution on the Environment
- 14 Sampling and Monitoring of Marine Oil Spills
- 15 Preparation and Submission of Claims from Oil Pollution
- 16 Contingency Planning for Marine Oil Spills
- 17 Response to Marine Chemical Incidents

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