A REVIEW OF THE PROBLEMS POSED BY SPILLS OF HEAVY FUEL OILS

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ABSTRACT

Experience shows that spills of persistent heavy fuel oils, whether from cargo carried on tankers or bunker fuel used by ships in general, are among the most difficult to combat. Because of their viscous nature, which leads to prolonged persistence in the marine environment, such oils have the potential to cause widespread contamination of sensitive environmental and economic resources. This is also true for heavy crude oils and those crudes which form viscous and persistent emulsions, and many of the observations contained in this paper apply equally to such oils.

The paper highlights some of the specific problems that ITOPF staff have experienced during their on-site involvement in over 150 fuel oil spills during the last 25 years, including incidents such as the ELENI V (UK/Netherlands, 1978); TANIO (France, 1980); NESTUCCA (USA/Canada, 1988); KOREA HOPE (South Korea, 1990); VISTA BELLA (Caribbean, 1991); KATINA P (Mozambique, 1992); MORRIS J BERMAN (Puerto Rico, 1994); APOLLO SEA (South Africa); IRON BARON (Australia, 1995); NAKHODKA (Japan, 1997); EVOIKOS (Singapore, 1997); KURE (USA, 1997); NEW CARISSA (USA, 1999); ERIKA (France, 1999); VOLGONEFT 248 (Turkey, 1999) and TREASURE (South Africa, 2000).

This review of the practical lessons which can be learnt from past events is intended to provide an informed basis for the selection of more effective response techniques and equipment, and for the development of improved spill response management and contingency planning.

INTRODUCTION

Various factors determine the severity (and cost) of an oil spill, including the type of oil; amount spilled; rate of spillage; physical, biological and economic characteristics of the spill location; weather and sea conditions; and efficiency of cleanup. Of these factors one of the most significant is the type of oil, with heavy fuel oils being amongst the most problematical because of their high viscosity, which is more pronounced in cold waters and in winter months. This means that they do not readily dissipate or degrade naturally, and are thus highly persistent. Heavy crude oils and emulsified lighter crudes may also be highly persistent and many of the observations made in this review may therefore apply more widely than to just heavy fuel oils.

Over the past 25 years almost 40% of the 400 plus ship-source oil spills attended on-site around the world by ITOPF's technical staff have involved medium or heavy grades of fuel oil, either carried by tankers as cargo or used by all types of ship as bunker fuel. This high percentage is indicative of the fact that spills of fuel oils often cause cleanup problems, and give rise to claims for compensation that are out of proportion to the amount of oil spilled.

Spills of heavy fuel oils have the potential to travel great distances from the original spill location and to cause widespread contamination of coastlines and sensitive resources. For example, oil from the ELENI V, which was cut in two by a French freighter in the North Sea 10 km off the UK coast in May 1978, came ashore two months later in the Netherlands (Blackman & Law, 1980). Oil spilled off Singapore from the EVOIKOS incident in 1997 drifted for over two months before coming ashore in Malaysia, 500 km away. Similarly, in the United States, eight days after heavy fuel oil was spilled from the barge NESTUCCA, it was unexpectedly found to have drifted 175 km and over the next three weeks small amounts of oil washed ashore sporadically along the 500 km length of western Vancouver Island, Canada (Owens, 1991). In the VISTA BELLA spill in the Caribbean a similar sequence of events created a very complex incident with oil adrift for a month and affecting islands in five different jurisdictions. A wide distribution of oil was also one of the key characteristics of the NAKHODKA incident in Japan in 1997. Whereas most major tanker spills occur close to the coast, the NAKHODKA broke up over 100 km offshore, bringing a longer stretch of coast under threat from pollution and resulting in oil stranding along a distance of more than 1000 km. The intermediate fuel oil cargo formed stable and persistent water-in-oil emulsions which caused a five-fold increase in the volume of pollutant as the water content of the emulsions reached over 80% (Moller, 1997).

In the following sections the generic features of heavy fuel oil spills are reviewed and best practice disseminated, identifying opportunities for achieving as much as possible with the existing experience and technology.

FUEL OIL CHARACTERISTICS

Heavy fuel oils are characterised by high specific gravity, typically in the range 0.92 - 1.02 g/cm³, and by relatively high kinematic viscosities, in the range of 5,000 to 30,000 mPas @ 15º C. Some viscosities are higher still, which coupled with high pour points can render the oils solid at ambient sea temperature (10 - 25º C). These gross characteristics common to most heavy fuel oils belie their complexity and diversity.

Although hundreds of different crude oils are produced and transported, the characteristics of each crude is generally well researched and their properties are available from a range of published sources. Refined products generally also exhibit well-defined and predictable characteristics since a product like gasoline or diesel contains a range of similar hydrocarbon compounds within a narrow distillation temperature band. However, residual fuel oils such as intermediate (medium) and heavy fuel oils are more diverse. This is because such oils often consist of the viscous and tarry residues of crude oil refining with complex mixtures of heavy aliphatic and aromatic compounds, bitumens and asphaltenes. Waxy residues from crude oil storage tank cleaning may also be added to the residues from crude refining. Such residues are then blended with light fuels or products to meet a viscosity specification suitable for the engines or burners for which the fuel is destined. Thus, the characteristics of a certain intermediate or heavy fuel oil will depend on the properties of the crude oil(s) from which the residue is derived, as well as the nature of any oils or other products blended in to allow the fuel to meet a particular specification for viscosity and flash point.

Unfortunately, the nomenclature used to describe fuel oils in different countries and within different parts of the oil and shipping industry can cause confusion. Fuel oils can be called variously: Bunker A, B, C; Fuel Oil No. 2, 4, 6; Intermediate Fuel Oil (IFO 180); or Heavy Fuel Oil (IFO 380). The relationship between different classifications is not always clear. The Bunker A - C scale and ASTM fuel oil scale are roughly equivalent as shown in Table 1 below. The IFO scale specifies the viscosity of the oil in centistokes (≈mPas) at 50º C. However, the French classification uses reverse numbering to the ASTM scale, which caused confusion in the early stages of both the TANIO and ERIKA incidents. Early reports correctly stated that the oil involved was a No. 2 Fuel Oil by the French classification (Heavy Fuel Oil), which is very different from No. 2 Fuel Oil on the ASTM scale (diesel oil).

TABLE 1.

EXAMPLES:	Bunker Scale:	ASTM F.O. No.	French F.O. No.	IFO No.
Light fuels, diesel and domestic heating oil	A	2	6	
Diesel, gas oil, light fuels for marine engines	B	4	4	60
Heavy gas oil, intermediate fuel oils	B	5		180
Heavy fuel oils-marine engines & industrial burners	C	6	2	≥380

BEHAVIOUR OF HEAVY FUEL OIL IN THE MARINE ENVIRONMENT

The characteristics described have important implications for the behaviour of spilled heavy fuel oil in the marine environment. Because of their high viscosity and pour point, they are very viscous liquids or solids at low ambient temperatures, and difficult to pump. Their high specific gravity confers little buoyancy and heavy fuel oils are easily swamped by waves, especially in rough sea conditions when the oil is tumbling with the orbital motion of the waves rather than floating on the surface. Often there is little or no sheen emanating from the oil to act as a tell-tale sign for aerial observers. The movement of spilled heavy fuel oils may become less predictable and more difficult to model, since the oil patches are not influenced so much by the wind. It is also difficult to assess the quantity of oil floating on or just below the water surface, because viscous heavy fuel oils tend not to spread into thin layers as much as crude oils (especially in cold climates) but instead remain in sharply-edged patches, the thickness of which is impossible to assess from the air.

In the case of the NESTUCCA, oil was initially detected moving away from the spill site as a sheen. It was later determined, however, that a substantial slick was also moving beneath the surface. The initial estimates of the amount spilled were inaccurate and only small globules of oil could be detected at sea a week after the spill. It was not until the NESTUCCA was properly gauged that the loss of over 700 tonnes of oil was discovered, which explained the extensive drift observed (Yaroch, 1991). Problems were also encountered with the MORRIS J BERMAN spill in Puerto Rico. The spilt oil was tracked using three different methods: visual observations, remote sensing and helicopter-based, infrared (IR) imaging (for night-time observation). All three methods had only limited success once the oil formed widely scattered tarballs and pancakes since these did not provide a sufficiently strong visual or IR signal to allow effective tracking from the air (Petrae, 1995).

A combination of cold waters, strong wind, wave action and strong currents encountered during the OSUNG No. 3 incident in South Korea caused a heavy fuel oil slick of more than 1,000 tonnes to become fragmented into small pieces and very widely scattered over hundreds of square kilometres. A 30,000-tonne spill of heavy fuel oil in warm tropical waters (26º C) off Singapore in the EVOIKOS incident in October 1998, behaved very differently. Strong tidal currents elongated the oil (viscosity 2,000 mPas @ 20º C) into slicks and streamers. After a few days the viscosity of the oil had greatly increased through natural weathering (20,000 - 100,000 mPas), but the oil continued to produce heavy sheens. During subsequent weeks the oil drifted slowly into the Malacca Strait, spreading over more than 3,000 square kilometres of sea surface, but without coming ashore. Not until the end of December did some 100-200 tonnes of oil finally come ashore in places along a 40 kilometre length of the Selangor coast of Malaysia. It is likely that oil began to sink as it weathered in the later stages of drifting, leaving a decreasing proportion available to strand on shorelines. A series of aerial surveillance observations showing the gradual drift over more than two months is summarised in Figure 1.

The sinking of heavy fuel oil has been observed on many occasions and has been comprehensively reviewed by National Research Council (1999). Some oils are denser than seawater, whilst others may sink as a result of the incorporation of sediment particles. In the open sea where the concentration of suspended material is low this effect is unimportant, but in the surf zone sand grains readily become mixed into the oil. The longer term fate of oil sunk in this way is likely to be burial under fresh sediment in nearshore waters or stranding by waves casting the oil onto the shore.

In the case of the THUNTANK 5 grounding in the Baltic Sea in December 1986, the spilled heavy fuel oil cargo was denser than the surrounding water and sank, but as the water temperature increased in summer the oil became more liquid and buoyant, and was washed ashore during rough weather. Repeated shoreline oiling occurred near the grounding site in the summers of 1987, 1989, 1990 and 1991. Sinking may also occur because natural weathering reduces the buoyancy of the oil, and the process may be enhanced if sediment particles become attached to the oil, for example in coastal waters where sediment content may be high. In both the recent ERIKA and VOLGONEFT 248 incidents, oil stranded on beaches became mixed with sediment in the surf zone, and was subsequently swept into shallow waters close to the coast by tides and wave action. Storms later moved the submerged oil back on to beaches, many of which had already been cleaned. As the water temperature increased during the summer the oil became more fluid and worked loose from the sand, stones and other debris weighing it down.

THE EFFECT OF HEAVY FUEL OIL PROPERTIES ON CLEAN-UP

Response at Sea

The limitations on containing and recovering spilled oil at sea are well known, especially in bad weather, but the nature of heavy fuel oil imposes additional problems. Skimming devices must be able to handle highly viscous or solidifying oil that can often have floating debris incorporated. This rules out the use of skimmers designed for light and medium oils. Recovery attempts at sea during the response to the ERIKA incident were further hampered by the low buoyancy of the oil. Rafts of solid oil up to 40 cm thick were floating just below the surface, which made it difficult to see from the recovery vessels and greatly reduced skimmer efficiency. During the NAKHODKA incident, considerable success was achieved using crane barges with mechanical grabs to lift oil out of the sea without the need for skimmers or pumps. The challenge is to identify existing containment and recovery systems that work best with highly viscous oils and to see if further improvements can be made.

During clean-up at sea, it is common for response vessels to become very oily and, in the case of heavy fuel oil, it has often proved difficult, slow and costly to clean the vessels to an acceptable state. Heavy fuel oil also poses problems of temporary storage, and barges are generally favoured so as to facilitate the transfer of oil to shore. The barges will often require heated tanks to keep oil sufficiently liquid for pumping.

Recent development of chemical dispersants have improved their ability to treat more viscous oils, but conventional dispersants still remain ineffective on viscous oils. A classic example is provided by the ELENI V spill of 7,500 tonnes of heavy fuel oil when 900 tonnes of dispersant were applied from 22 vessels during three weeks, but to no effect. Virtually all the oil came ashore (Nichols & Parker, 1985). The heavy fuel oil spilled from the EVOIKOS was of moderate viscosity (2,000 mPas at 20°C) and in the high ambient temperatures in Singapore waters was initially dispersible, but after 3 to 4 days dispersant application trials with both old and new generation dispersants revealed that none was able to disperse the oil.

The *in-situ* burning of spilled oil is not a realistic option for most spills of heavy fuel oils in view of the low level of volatile components required to sustain combustion. In addition, it is likely that the residue from attempts to burn heavy fuel oil would sink, thereby posing a risk to sea bed communities and fishing activity, particularly trawling.

Oil which has sunk in open waters is unlikely to be recoverable, because of wave action, water depth or the scattered distribution of the oil on the sea bed. In sheltered shallow water some success has been achieved. In the THUNTANK 5 incident, a simple vacuum system was devised to recover pooled oil on the sea bed. Hot water was fed from a work barge to nozzles fixed to a suction pipe held by a diver. The nozzles were set to project hot water up the pipe, creating suction and lubrication for the recovered oil. Rough separation of oil and water was carried out on the barge. In other cases involving sunken oil in harbours, submersible pumps and dredging equipment have proved effective. However, many pumping systems are constrained by high oil viscosity.

Shoreline Cleanup

When heavy fuel oil comes ashore there is a tendency for it to become firmly attached to any solid surfaces and to resist all but the most aggressive clean-up efforts. However, in cases where the oil has emulsified it has also been observed that the oil does not adhere to surfaces, particularly if they were wet beforehand. The clean-up techniques for heavy fuel oils on shorelines are generally the same as for other types of oil, especially when manual methods are used. Removal of heavy fuel oil from hard-packed sand beaches using non-specialised equipment and manual labour is normally straightforward. This was shown dramatically during the KATINA P spill in Mozambique in 1992. Despite a complete lack of planning, training, experience and specialised equipment, an effective clean-up response was quickly mounted with a casual labour force equipped with shovels and plastic bags. As with other types of oil, care needs to be taken so that excessive amounts of clean material are not removed and oil is not mixed into the beach substrate. One advantage of viscous heavy fuel oil is that penetration into sandy beaches is likely to be minimal and it is easily separated from the underlying sand using hand tools. Conversely, careless use of machinery can generate problems. During the TANIO clean-up operations, heavy earthmoving equipment was used, including bulldozers and front-end loaders. While much oil (and a considerable amount of beach material) was removed within a short time, the beach substrate in the tracks left by the vehicles was heavily contaminated and required extensive restoration work at a later stage (Ganten, 1985).

There is some scope for washing oily stones, gravel and sand in containers or machinery set up on-site. Kerosene or other solvents are used as the washing agent, but this kind of batch treatment is very slow and often impractical. Pushing oily beach material into an active surf zone (surf washing) can be an effective approach to releasing oil from beaches, particularly if oil has become buried in the beach substrate. On sand beaches, mechanical sieving can be an effective technique for removing solid residues (tar balls) during final clean-up, particularly at low temperatures or once the oil has weathered or mixed with sand and become virtually solid. Specialised beach cleaning machines used to remove litter and debris from tourist beaches were employed effectively for removal of small tar balls and residues during the ERIKA incident.

On rocky shores the work necessary to remove heavy fuel oil can be considerable, starting with the removal of thick layers manually. Attempts at using pumps and vacuum trucks are often unsuccessful when temperatures are low or after weathering of the oil. The rock washing phase involving dispersant treatment and/or high-pressure washing with hot or cold water is inevitably a slow process. Occasionally more aggressive methods such as sand blasting may be necessary if all traces of oil must be removed, but such techniques are likely to cause damage to marine life and to the surfaces being cleaned. The highly persistent nature of heavy fuel oil prolongs the cleanup effort, and there is a tendency for laboriously cleaned areas to become re-contaminated by oil released in the washing process or by sunken oil cast ashore during subsequent storms.

Dispersants and other solvents can be an effective tool for releasing oil from rocks or man-made surfaces. In most cases it is necessary to collect the liberated oil since it is usually too viscous to disperse properly. In the case of the TANIO, dispersants were used in great quantities, either mixed with water for rock washing or applied neat to the oil on the rocks before washing. The efficacy of the dispersants was a matter of considerable technical debate, and even the most successful formulations appeared merely to reduce the viscosity of the oil by solvent action rather than to promote dispersion (Ganten, 1985).

During the ERIKA clean-up, access for vehicles along the coast was often limited or non-existent. In such cases, oil was collected manually into tubs that were first sprinkled with a handful of sand to stop the oil from sticking and allowing it to be tipped out into skips more easily. The filled skips were then lifted out by crane. The subsequent rock washing phase was greatly hindered by the tides. As much of the cleaning was carried out at low tide, and the sea conditions were frequently very rough, there was little opportunity to use skimmers to recover released oil. Practical solutions were found whereby the washings were flushed through geotextiles and fine mesh nets to trap the oil released during the rock washing.

Temporary storage of recovered heavy fuel oil present particular problems. There is a strong tendency for recovered residues to solidify, which can make emptying portable plastic or rubber temporary storage units very difficult without causing damage. Similar difficulties can be encountered with vacuum trucks, unless the back section can be opened for cleaning. Accumulations of debris such as seaweed and sea grass are often found on beaches. During the ERIKA clean-up, about 5,000 cubic metres of lightly oiled seaweed and sea grass were collected from sandy shorelines. A pragmatic solution was found whereby the seaweed was left out to dry on the shores, thus greatly reducing its volume prior to transportation and disposal.

In the VOLGONEFT 248 incident in Turkey, detailed records were kept which allowed progress of the manual clean-up operation to be closely monitored. Expended effort was measured in terms of man-days, including workers, supervisors and managers. Flat concrete surfaces were roughly cleaned at a rate of 50 m^2/man-day, whilst on sand beaches the rate of surface oil removal was 33 m^2/man-day. Oil buried in an amenity beach took much greater effort to excavate and in the final treatment phase small pieces of tar were separated from the beach sand by manual sieving (25 m^2/man-day). The average quantity of oily waste collected was ½ tonne/man-day, of which the proportion of pure oil was just 13%. Emulsified water (13%) and beach material (74%) accounted for the rest of the waste. This example clearly shows that even when manual clean-up techniques are used and the work is carefully supervised, the incorporation of sand and shoreline debris is considerable. Transportation and disposal costs are directly proportional to the amount of waste collected.

Disposal

The transport, segregation and final disposal of waste generated during oil spill cleanup is frequently a major challenge, both in terms of the nature of the waste and often because of the large quantities involved. Empirical observations reveal that a tonne of oil on a beach usually generates about 10 tonnes of oily waste during beach cleaning. The scale of the potential problem is clearly shown by the ERIKA spill. An estimated 20,000 tonnes of heavy fuel oil were spilled, and more than 180,000 tonnes of oily waste material have been recovered. Inadequate plans and the lack of suitable pre-arranged disposal sites made the management of large volumes of waste difficult and resulted in poor segregation of different wastes. Many small temporary storage pits were constructed along the coast, lined with plastic sheeting and filled with oily waste. When the pits were later dug out and the contents transported to the final storage site, all the material became mixed, including the plastic lining.

Lack of segregation makes final disposal more difficult and costly because most treatment technologies have been developed to treat relatively homogenous material. If recovered bulk oil is not been kept separate, the potential for re-cycling is reduced, and the amount of oily waste needing other types of treatment is increased. Ideally, wastes should be segregated to allow the option of dealing with different materials in different ways. For example, bulk oil can often be re-cycled, oily seaweed composted, oily sand stabilised and land-filled, and oily plastic sheeting, bags and protective clothing incinerated.

In the VOLGONEFT 248 case all collected oily waste was either incinerated or landfilled, depending on the oil content of the waste, measured in terms of calorific value. The heavy fuel oil cargo on board the tanker was known to originally have had a calorific value of 40.38 MJ/kg, yet the value for freshly spilled oil was measured at about 20 MJ/kg, indicating that a 50% water-in-oil emulsion had formed within a few hours in the stormy weather prevailing at the time of the incident. The routine measurement of calorific values also provided a reliable way of calculating the oil content in collected oily waste, since the non-oil portion of the waste was essentially inert (water, sand, stones). Measurements of the calorific value for each of over 400 truck consignments of oily waste indicated oil contents of between 1% and 55%, with a mean of 13%. The total amount of oil recovered during the clean-up operation corresponded to about 55% of the spill volume. This case has demonstrated that valuable insights can be gained into the effectiveness of a clean-up operation through systematic sampling and analysis of collected oily waste.

ENVIRONMENTAL AND ECONOMIC EFFECTS

Whilst heavy fuel oils are particularly difficult to clean up, there is less in terms of environmental impact to distinguish them from crude oils. In the following examples some of the more striking characteristics are highlighted.

Heavy fuel oils are generally less toxic than crude oils and many refined products, but pose a greater threat of physically contaminating marine life, including sea birds and marine mammals reliant on fur or feathers for insulation. It may be no coincidence that some of the greatest havoc in sea bird populations has been wrought by spills of heavy fuel oil. The strong adhesive properties and the high persistence of heavy fuel oils are key factors. The clean-up and rehabilitation of oiled animals can present enormous logistic problems, the successful resolution of which also depend on the resilience of the animals when held in captivity. At least 100,000 bird are believed to have perished as a result of the ERIKA spill and comparatively few were successfully cleaned and returned to the wild. After the grounding of IRON BARON in Tasmania some 2,800 Little Penguins were cleaned, but since their environment was still contaminated a decision was taken to release the birds 360 km away from the spill site, from where they slowly made their way back, allowing time for the clean-up operations to be completed (Hull et al, 1998). A similar relocation strategy was adopted after about 1,000 tonnes of oil spilled from the sunken TREASURE in South Africa. Approximately 19,000 oiled African Penguins were cleaned in a large-scale operation whilst a further 19,500 un-oiled penguins were captured at two threatened colonies and relocated to prevent them becoming contaminated. The relocated birds returned to their home waters after a 800-km swim lasting about 3 weeks. Whilst these cases demonstrate the vulnerability of penguins to oil contamination, the birds have proved to be relatively robust and submit to human handling, cleaning and relocation with few casualties. However, successful wildlife rehabilitation depends on experience, planning and correct procedures, and in an earlier heavy fuel oil spill off South Africa involving the APOLLO SEA the mortality of captured penguins was much greater (Crawford et al. 2000).

Numerous heavy fuel oil spills with serious economic consequences have occurred in Japan and South Korea. These are industrialised countries with dense maritime traffic and many small vessels at risk of spilling bunker or cargo oil in collisions and groundings. Extensive coastal areas are devoted to fisheries and mariculture activity, and so although spills resulting from the small commercial vessels tend to be less than 100 tonnes, the economic losses are disproportionately large. The oil spills pose a threat of business interruption in the fisheries sector as well as causing contamination of fishing gear and catches. They may also affect industrial sea water intakes by virtue of the high density of heavy fuel oil and its tendency to travel subsurface, out of sight. Booms deployed to protect sensitive resources will then become ineffective and installations such as power stations and desalination plants may be forced to shut down.

As a category, heavy fuel oil spills are the most expensive to clean up, calculated on a cost per tonne basis. Many examples can be found amongst small Korean and Japanese spills when comparisons are made between incidents involving crude oils and heavy fuel oil (Moller et al, 1987; Grey, 1999). However, the difference was illustrated the most clearly in France where two major spills occurred affecting the same coastline in the space of two years. The cost of cleaning up 14,500 tonnes of heavy fuel oil spilled from the TANIO in 1980 was almost as expensive as for the 223,000 tonnes of crude oil spilled from the AMOCO CADIZ in 1978.

DISCUSSION

Taken separately, the characteristics of heavy fuel oils are not unique as compared with other oils, notably crude oils. However, it is fair to conclude that heavy fuel oils exhibit the most extreme traits of viscosity and persistence, which have a direct bearing on their behaviour when spilled and, consequently, on the efficacy of response operations.

As with any attempt to combat oil pollution, it is important to judge the success of a contemplated or ongoing activity in context. There are occasions when the benefits of a particular response option will not repay the investment in time, effort and money because of factors such as the type of oil and prevailing weather conditions. From a purely technical point of view, therefore, it can be argued that clean-up attempts are only worthwhile if a significant benefit results, for example, in terms of a reduced impact on environmental and economic resources. Such considerations are particularly important in the case of heavy fuel oil spills given the fundamental difficulties that they can pose.

For example, evaporation, dispersion and other natural removal processes that often assist the response to crude oil spills will be slower and less pronounced with heavy fuel oils. Such oils also often travel below the water surface which means that those attempting to predict oil movement have to resort to anticipation and educated guesswork since, at the present time, neither remote sensing techniques nor computer models offer significant insights into how oil behaves once it has sunk from view.

Those who have been trained in spill response are familiar with the limitations of clean-up of all types of oil at sea, and will also appreciate the additional limitations that heavy fuel oils impose on spill response measures. However, unrealistic expectations of what may be achieved by clean-up attempts at sea remain widespread amongst non-specialists, for example those central and local government administrators and politicians who become involved in spill response. Less surprisingly, the media and the general public are also unaware of the realities. Targeted training and education would serve to dispel some of the prevailing misconceptions, thereby reducing wasted effort on futile activity forced upon responders by influential parties with a legitimate interest but a poor grasp of the subject.

These observations apply also to the problems of dealing with sunken oils for which effective response options are severely limited. Providing sunken oil is accumulated within a small area, in shallow water and in calm conditions, submersible pumps and vacuum systems can be effective, but elsewhere sunken oil is likely to be unrecoverable.

The clean-up of shorelines contaminated by fuel oils needs to be carried out in accordance with a clear strategy that takes account of the characteristics of the particular oil, as well as relative environmental, economic and amenity sensitivities and priorities of the affected areas. At one end of the scale, a high degree of cleanliness will require aggressive and potentially damaging cleaning techniques. Conversely, where residual oil can be left to weather naturally, the process will often be much slower for heavy fuel oil than for many other types of oil. This latter approach of relying on natural recovery may still be the preferred environmental choice, but the slower rate of degradation can create the impression to casual observers of the problem being ignored.

The problems of temporary storage and final disposal of contaminated oil and beach material are seldom given sufficient consideration during contingency planning. It would be worth disseminating current best practice from spills world-wide, bearing in mind the ever more stringent waste disposal regulations in many countries, and reviewing whether heavy fuel oils pose particular problems in this regard. Investigating opportunities and limitations in the recycling of oily wastes and their use as secondary raw materials would also be worthwhile.

Where the impact and costs of a spill are a concern, it should be recognised that the consequences of heavy fuel oil spills can be more prolonged because of the persistent nature of the product. The threat to vulnerable marine life such as seabirds as well as economically sensitive resources can therefore on occasions last longer in the event of a heavy fuel oil spill. Sunken oil can also bring sea bed resources and a range of fishing and mariculture activity under threat, when these would normally be unaffected by floating oil. These and other implications of heavy fuel oil spills should be reflected in risk assessments and contingency planning work.

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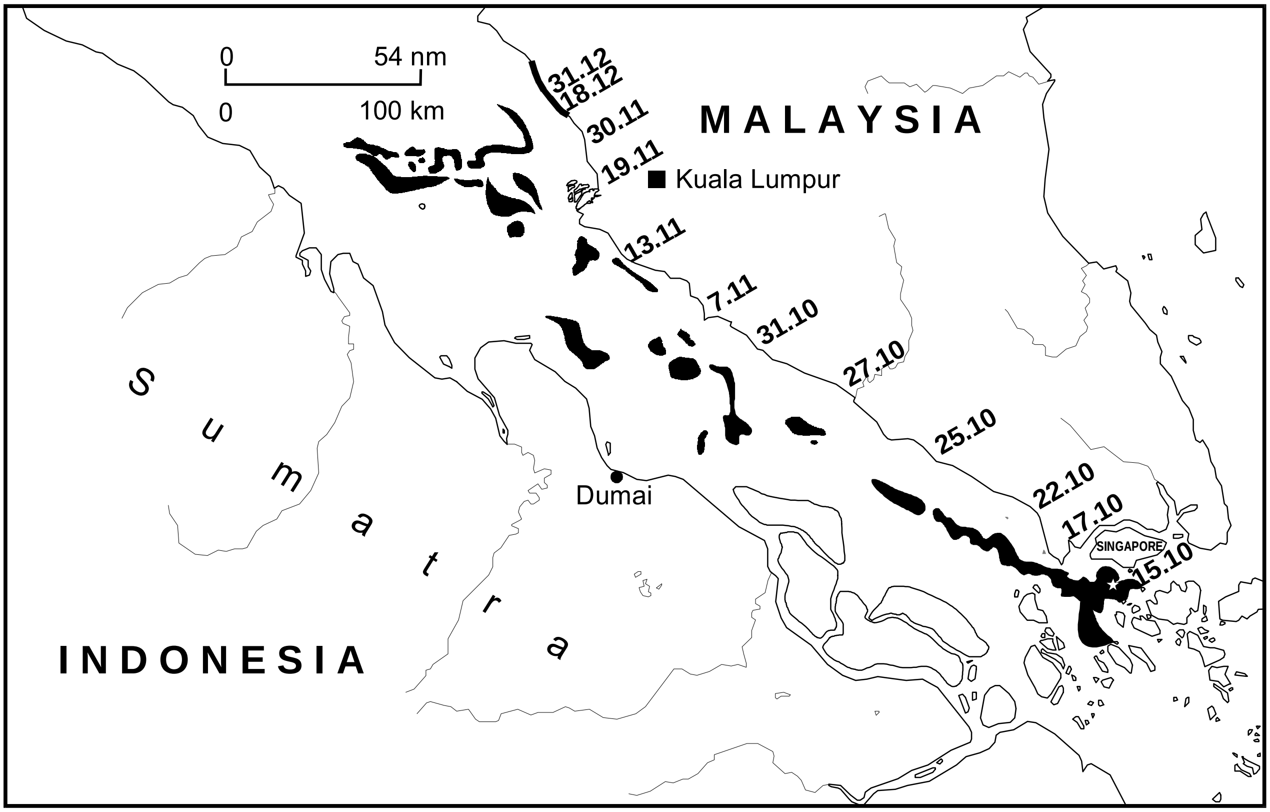

Figure 1. Distribution of spilled heavy fuel oil from the EVOIKOS incident off Singapore on successive dates from mid-October to the end of December, 1997.