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AT-SEA RECOVERY OF HEAVY OILS – A REASONABLE RESPONSE STRATEGY?

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ABSTRACT

Within the wider debate on the effectiveness of at-sea recovery, this paper investigates whether the particular characteristics of heavy oils warrant special consideration when planning and responding to spills of these oils. The paper reviews arguments for and against greater at-sea recovery efforts than would be justified with other, lighter oils. Attention is given both to theoretical considerations as well as to actual experience gained in such spills of heavy oils as the BALTIC CARRIER, ERIKA, EVOIKOS, NAKHODKA, VOLGONEFT 263 and other spills. The paper reviews and compares the observed effectiveness of state-of-the-art equipment with non-specialised equipment such as mechanical grabs. It is concluded that while heavy oils often warrant special attention, large investment in specialised equipment and R&D are likely to be less beneficial than improved planning and preparation with locally available resources.

1 INTRODUCTION

World-wide statistics on oil spills show that the incidence of major oil spills has significantly fallen over the last three decades. However, environmental awareness and sensitivity to the impact of oil spills have grown at an even quicker pace over the same period. There is no doubt, therefore, that continued investment in preventive measures and emergency response capabilities is justified. Less clear is just where to make these investments.

In terms of emergency response, it is true that much of the planning, training and purchase of equipment stockpiles is straightforward for the simple reason that many spills are predictable.

Decades of statistics show, for example, that the greatest number of spills are “operational”. These small spills (e.g. under 7 tonnes) typically occur during pier-side activities like cargo loading, discharging or bunkering. For such spills it is not difficult to prepare detailed response strategies, purchase suitable skimmers for the expected type and quantity of oil, pre-position boom in strategic locations and arrange for adequately-scaled response vessels. Training and exercise, pre-requisites for all effective spill response, can also be easily organised and focused, given that the best responders for these spills are often those working at the facility, plus the fact that relatively little outside co-ordination is necessary. The predictability and straight-forward contingency planning for operational spills has rightly led many governments to give the responsibility for dealing with such “Tier 1” incidents to facility operators themselves.

Contingency planning for larger, infrequent, incidents is considerably more difficult because of their unpredictability. Unlike small spills, large spills are typically the result of catastrophic accidents. ITOPF statistics on oil tanker spills world-wide show the major causes of spills over 700 tonnes to be groundings (35%), collisions (28%), hull failure (14%), fires and explosion (6%). While many of these happen relatively near to shore, in congested traffic lanes or in port approaches, large casualties can and do occur in the open sea (e.g. hull failures).

The fact that large oil spills can occur just about anywhere poses a problem for contingency planners. Risks can be assessed based on traffic patterns, navigational hazards, currents, prevailing winds, sensitivity maps and other considerations, but often the question remains: what is the optimal division of limited resources between at-sea and shoreline response? Should the basic principle of the response strategy be to attack the oil at sea or is it better to concentrate efforts near shore, booming off sensitive shoreline and/or deflecting oil towards pre-chosen collection areas (e.g. sand beaches)? This is an important question because the required types of equipment, training and response plans will depend on where the response is to be focused.

Clearly there is no simple answer to the question. Since contingency planners are always faced with limited budgets, simply outfitting every equipment stockpile with every possible piece of equipment is not a viable solution. The purpose of this paper is to help contingency planners understand both the potential and limitations of at-sea recovery operations for heavy oils and thus make a balanced decision on the optimum allocation of response resources in their jurisdictions.

In order to focus on this particular issue, the topics of training and exercises will not be specifically addressed in the paper. Nonetheless, the fact that many at-sea recovery operations are not successful emphasises the importance of specialised training and co-ordinated exercises between the different response organisations that may have to work together in the case of an emergency. The experience of recent years has been that for every successful co-operative effort there have been scores of examples where resources mobilised for the response have lain idle because administrative or technical barriers were not identified in advance. This is why realistic exercises are important. Training is especially an issue where response relies on "borrowed" equipment and vessels of opportunity with which personnel may not be familiar.

In this paper the term "heavy oils" will include both heavy fuel oils, heavy crude oils and the weathered products of lighter oils. This latter group will include weathered crudes, weathered light/medium fuel oils as well as water-in-oil emulsions. Grouping these different products together on the basis of their similar spill behaviour rather than the characteristics of their parent oils is useful because response strategies must be oriented towards the oil as it is found in the water, rather than in its commercial form (for a detailed review of heavy fuel oils, see Lewis, *ibid.*).

2 PROPERTIES OF HEAVY OILS

Among the numerous physical and chemical variables that can be used to describe and differentiate between petroleum products, the most significant for spill response to heavy oils include density, viscosity, pour point and volatility (see ITOPF, 1986; CONCAWE, 1983 and 1998; NRC, 1985; Doerffer, 1992; Lewis, *ibid.*). The following sections briefly review these properties and the arguments that can be made using them to either support or advise against more extensive at-sea recovery efforts for heavy oils than for light oils.

2.1 Density/ specific gravity

Because it provides a first indication as to volatility and distillation characteristics (among other things), the specification of an oil's density is one of the many standard parameters used commercially to describe petroleum products. This information is also important to spill responders for what it says about expected evaporation loss and the development of other weathering processes, especially the way the oil floats. Because heavy fuel oils typically have specific gravities that fall within the range of 0.92 to 1.02 at 15 °C (CONCAWE, 1998) they can generally be expected to float in seawater (specific gravity 1.025), but may fail to do so in brackish or fresh water.

The floating characteristics of an oil are a critical factor in any response, since the ability to observe the oil, whether directly from the bridge of a recovery vessel or from reconnaissance aircraft above, is a pre-requisite to all at-sea response, especially if the oil is drifting. Although most heavy oils are unlikely to sink in open waters, it is often the case that they are masked by water washing over them (Dicks et al, *ibid.*). This is especially true in heavy or wind-blown seas where both visual observation and more sophisticated remote sensing techniques may fail to track scattered patches of heavy oil.

It has been ITOPF's experience that oils generally do not sink unless exposed to sand or other particulates. This is usually a result of being washed in surf or up onto beaches (Dicks et al, *ibid.*). If not collected on shore, the sand-laden oil may move back out to sea where it can wash along the bottom until a storm re-deposits it on the beach. Offshore recovery efforts for submerged oil tend to be labour intensive, dangerous and ineffective. In those rare cases when they are carried out, it is generally in shallow waters near popular coastal areas (see Moller, *ibid.*).

In terms of spill response, the practical implications for at-sea response to heavy oils are clear: because heavy oils have a high specific gravity, they float lower in the water than lighter oils and are therefore difficult to see, especially in rough seas. Because oil that is not readily visible cannot be tracked, it cannot be contained or collected. In calm seas, however, the high density itself should not be a hindrance to skimming techniques, all of which require oil to float.

2.2 Viscosity

Viscosity, a liquid’s resistance to flow, is an important topic in the discussion of response to heavy oils because these oils tend to be highly viscous (i.e. slow to flow). This makes them considerably more difficult to skim, pump and clean from equipment than lighter oils. Also, because viscosity is directly related to temperature, the colder the environment the more difficult viscous oils become to handle.

In terms of collection, viscous oils can cause problems for a wide variety of skimmer types (see Le Roux, 2000). Viscous oils can be extremely adhesive and can easily ‘gum-up’ most standard skimmers, including oleophilic disc and drum skimmers, rope skimmers and weir skimmers, to name but a few. In some cases these skimmers can be successfully used to pick up heavy oils, but to do so requires great attention, maintenance work and caution. Skimmers in viscous oils are liable to stop working at any moment; scrapers and other moving parts must, therefore, be continually nursed. Because viscous oils are very adhesive they tend to collect a much greater amount of debris than other oils. The debris must be continually removed from the skimmers, often at risk to crew members who typically need to lean overboard, or over open tanks of oil, to do so.

Of course, there are specialised skimmers that have been developed for highly viscous oils. These include toothed discs, inclined belts, paddle belts, helical drums, oleophilic drum or belt brushes (see Schulze, 1998). These devices collect the oil by pulling, lifting, dragging or otherwise by physical capture. They are especially effective when used in large concentrations of heavy oils. Experience has shown that when large quantities of viscous, heavy oils are encountered, the most effective way of recovering it can be to manually scoop it up from the water using crane-operated clamshells, buckets or other mechanical grabs. These are readily available pieces of equipment, often already part of dredging vessels’ standard equipment or are easily mounted on response vessels or vessels of opportunity. When placed into thick mats of oil, these clamshells can pick up and move half a tonne of oil at a time. Another advantage is that they can usually deliver the oil straight into the recovery vessel’s hold or into a temporary storage barge. This avoids one of the most difficult aspects of viscous oil recovery: pumping the viscous oil from the skimmer into the temporary storage tank.

Examples of spills where the mechanical grab approach was found to be advantageous include the VOLGONEFT 263 (1990), NAKHODKA (1997), EVOIKOS (1997), NATUNA SEA (2000), and BALTIC CARRIER (2001). The safety concerns related to the use of crane-dependent recovery techniques, whether for skimmers or mechanical grabs, must always be taken into consideration when attempting operations in rough seas (see Peigné, 2000).

Because viscous oils are so slow-moving and adhesive, many skimmers that at first succeed in picking up the oil (e.g. a drum skimmer), nonetheless have difficulty moving the heavy oil from the point of collection (e.g. the scraper) to its collection sump from where the pumping is to take place. While lighter oils will flow naturally down a collection trough, heavier oils often need constant manual assistance (which makes these skimmers impractical in most cases). When it comes to the pumps, free-floating skimmers either have external or on-board units. Smaller skimmers tend to use external pumps because these reduce the weight that the skimmer must carry. External pumps work very poorly with highly viscous oils because they must suck the oil. Skimmers with on-board pumps, on the other hand, can use positive-displacement, such as in piston pumps or Archimedes screw pumps. Because these powerful pumps mechanically push the oil, they have higher tolerances for viscosity. However, they do make the skimmers heavier and less likely to follow waves, resulting in greater water intake.

Although positive displacement pumps may be quite powerful and effective, highly viscous and adhesive oils may cause such great internal friction in the discharge hoses and pipes that the maximum rated pressures of the systems are still not sufficient to effectively move the oil. Research on this problem has targeted heat/steam injection and water lubrication as promising solutions (see Hvidbak, 2001; Cooper and Mackay, 2001; or Loesch et al, 2001). Steam/water injection flanges placed before and/or after positive placement pumps can increase flow rates and decrease pumping pressure without necessarily promoting emulsification of the pumped oil. Further R&D in pumping systems that meet the particular needs of oil spill response would be helpful.

Naturally, the bottleneck of pumping viscous oils does not end when the oil is in the response vessel’s hold (or other storage tank). This is only a temporary storage location and must be emptied regularly in order for skimming operations to continue. Depending on the distance from port, the sea state and the availability of other vessels, the best solution may be to continually transfer the oil to shuttle vessels which take it to land-based storage and/or disposal. Heavy oils complicate the matter by slowing the transfer rate or even requiring that the recovery vessels themselves return to port to have the product removed. Lengthy sea journeys and extended port stays clearly reduce the available recovery time of the vessel. Heated storage tanks can make transfer operations much more efficient.

In summary, the greater the viscosity, the slower and more laborious operations will be. Much of the standard and/or sophisticated recovery equipment will become coated and clogged in the sticky, heavy oil, thus requiring continual maintenance. Pumping into and out of on-board temporary storage will be much more difficult than with lighter oils. In many cases special high viscosity pumping systems will be necessary. Given good weather, calm seas and the proper equipment, a well-trained team with low-tech mechanical clamshells can often be used quite successfully. Overall, the more viscous the oil, the less oil that the operation is likely to recover in a given time frame (e.g. during a good-weather window).

2.3 Pour point

In addition to being thick and adhesive, many heavy oils are (semi) solids at relatively high ambient temperatures. For this reason, they are usually transported in heated tanks. In an incident where heating systems fail, the oil may cool to temperatures below its pour point and thus solidify. This change in state, from liquid to semi-solid, arises from internal changes in the oil’s crystalline wax structure and is a key variable in the spill response. Yet because oils differ in their relative wax content, depending on the origin of the crude and as well as the refining process, they also differ greatly in their pour points (see Lewis, *ibid.*). With crude oils, for example, the range of pour points is from -60°C to +40°C. Because heavy fuel oils (as well as weathered crudes) are residual products, they tend to have a higher relative wax content and thus have pour points which typically fall within a higher range. The pour points for many heavy fuel oils are often 30°C or higher (CONCAWE, 1998).

Given that typical sea temperatures are between 10-25°C, it is easy to predict that some crude oils and many heavy fuel oils will act as viscous semi-solids soon after being spilled. In the BALTIC CARRIER spill, for instance, heated heavy fuel oil cargo spilled into the cold waters (approx. 5°C) of the Baltic Sea and quickly cooled to temperatures below the oil's pour point (18°C), taking on a 'chewing gum' consistency. In the NATUNA SEA incident, the seawater in the Singapore Strait was quite warm (28°C), yet not warm enough to prevent the spilled Nile Blend crude from solidifying (pour point 35°C).

When released at temperatures below their pour point, heavy oils will not spread in the same manner as lighter, liquid products. Gravity, along with wind, waves and currents will have some effect, laterally pushing the semi-solid oil into mats, which can be virtually any thickness. Such concentrations of oil can be quite advantageous for containment and recovery operations, provided the seas are calm, and if proper equipment and personnel are available and can be guided to the mats of thick oil before they are broken up by wind and waves. Because the thickness of semi-solid slicks is difficult to judge (e.g. by colour or texture) from the air, and cannot be accurately assessed using remote sensing techniques, guiding vessels to the thickest concentrations of semi-solid mats of oil is not entirely straightforward.

Many of the skimming problems related to the fact that an oil is a (semi) solid are the same as those arising from high viscosity. In particular, much of the more sophisticated recovery equipment depends on the product being in a liquid phase (e.g. weir skimmers). Specialised skimmers for (semi) solid-phase oils (e.g. belts or helical drums) lift the oil in one way or the other from the water. Because (semi) solid oil does not spread as a liquid oil would, skimmers have an inherent difficulty maintaining sufficient feed of such oil when used in stationary deployment. In other words, even when placed in thick slicks of contained oil, stationary skimmers are often observed to skim a 'hole' of clean water in front of their intake areas. This difficulty may be overcome by moving the skimmer through the water, either by mounting the skimmer on the bow of the vessel or using sweep arms to force the oil into an opening in the side of the vessel. Another approach is to draw the oil towards the skimmer with water currents generated by the skimmer itself (e.g. with underwater jets).

As with viscous liquid oils, (semi) solid oils are difficult to pump. Typical problems that arise are related to the task of moving small quantities of oil with positive displacement pumps, the need for extensive decanting when water is used as the carrying medium, as well as the difficulty of removing non-pumpable, solidified oils from temporary storage.

Low-tech recovery methods (e.g. mechanical grabs) are likely to be more efficient than sophisticated skim-and-pump techniques. Following this route requires, of course, that the weather is adequate for operation of such techniques and that the oil can be sufficiently contained.

2.4 Volatility

The volatility of an oil is described by its distillation curve. This curve relates the temperature at which each component (at atmospheric pressure) can be removed from the oil. For heavy fuel oils the typical boiling point range is 350-650°C (CONCAWE, 1998), meaning that no measurable evaporative loss should be expected at ambient temperatures. For a product containing light ends (e.g. crude), evaporation will leave the remaining oil heavier and increasingly viscous. It will also have a higher relative wax and asphaltene content, as well as higher pour and flash points. Table 1 uses the example of a Kuwait crude to illustrate how evaporation of light ends can greatly increase the viscosity (CONCAWE, 1983).

Table 1: Increase in viscosity of Kuwait Crude as a result of evaporative weathering

Evaporative Loss (% wt)	Residual oil viscosity (cSt @ 10°C)	Approximate time scale
0	23	At release
15	86	1 hour
20	197	2 hours
27	1,023	4 hours
33	2,650	1 week

Because volatile components have been removed through refining from heavy oils, they are in negligible amounts and evaporation will not result in significant reduction in volume. This is an important consideration when deciding to respond to a heavy oil spill, as evaporation is one of the most significant routes by which lighter oils are removed from the sea surface. Heavy oils are therefore much more persistent. When light cutter stocks are blended into residual fuels to make them less viscous and commercially more manageable, there may be some evaporation (see Lewis, *ibid.*).

The major implication for spill response is that the response will not be assisted by evaporation, so early recovery efforts, when possible, will be the most rewarding. Another difference is that because they contain so few volatile components, heavy oil spills will not pose the same explosion and fire danger in the first few hours after release. Unlike with some spills of lighter products, containment and recovery can begin as soon as the equipment arrives.

3 WEATHERING BEHAVIOUR OF HEAVY OILS

As with all other oils, when heavy oils are exposed to the elements after a spill, physical and chemical processes ("weathering") will work to change the volume, composition and characteristics of the original oil. However, because they differ in physical and chemical make-up from lighter oils, heavy oils will behave differently. The weathering processes that are especially important for the response to heavy oils include: spreading, drift, dispersion, tar ball formation, and emulsification. The following sections describe these interrelated and competing processes and their impact on at-sea recovery efforts.

3.1 Spreading

One of the most prominent behavioural effects exhibited by *liquid* oil when it first spills into water is the lateral spreading over the surface. The prime factors influencing the spreading rate of *liquid* oil are density, surface tension and viscosity.

Once the initial, gravity-dominated release and spreading is complete (i.e. within minutes to hours after the release), the spreading rate of liquid heavy oils will slow more quickly than that of light oils because of the limiting effect of higher viscosity. Light oils, once spilled, tend to spread so thinly, so quickly that by the time skimmers arrive they can no longer encounter the oil at an efficient rate. Containment with booms can help, but these often also arrive after considerable spreading has taken place. Even heavier oils, if in liquid state, can spread far beyond the effective reach of any reasonable number of response vessels. In some cases the oil will spread right up onto the shore, especially for spills in estuaries, rivers, bays or near coasts. This was the case in the recent NEW AMITY spill (2001) in the Houston Ship Channel in the United States of America. With sun-warmed water temperatures fluctuating just around the oil's pour point (30°C), the 120 tonnes of spilled IFO 380 quickly spread to near-shore areas beyond the reach of skimmers permanently stationed and on stand-by within the spill zone.

To complicate matters, spreading at sea is far from uniform. It is highly influenced by wind, waves, debris and the formation of emulsions. Windrows are formed and/or the oil is broken into uneven patches by the waves. Relative to the strength of the sea, the anti-spreading forces of an oil's high viscosity and low spreading coefficients diminish in importance. In the open seas, it is not unusual for spilled oil, whether heavy or light, to be broken up into fragments and spread across an area of hundreds, if not thousands, of square kilometres.

The following illustrative example clarifies the task faced in skimming such large areas: Assume a dedicated ocean-going response vessel has two sweep arms of 15m each. The vessel is 15m wide, giving a it theoretical sweep of 45m. Given a realistic average skimming speed of 1 knot (1.85 km/hr), such a skimming vessel could cover a surface area of 0.084 km^2 per hour or about 1 km^2 per 12-hr day. If they never crossed paths, it would take 20 such vessels working together for five days to cover an area of just 100km^2. To put this area in perspective, during the EVOIKOS spill off Singapore and Malaysia in 1997, aerial surveillance showed that the fragmented slicks of heavy oil covered an area of about 3000km^2.

The implications for spill response are obvious: because spreading is the main obstacle to successful at-sea recovery, the less an oil spreads, the greater the chances that a well-equipped, planned, and exercised operation is likely to have a meaningful encounter rate, all else being equal. The way in which a spilled oil is spreading, in particular whether it is acting as a liquid or a (semi) solid, should therefore be a key variable in the decision to put the main emphasis of the response on at-sea recovery or on near-shore protection, containment and recovery.

3.2 Drift

It is a commonly used approximation that surface slicks will move at 3% of the wind speed and 100% of the surface current speed. However, because heavy oils (including emulsions) float lower in the water than slicks of lighter oils, they are often less influenced by the wind. The result can be that slicks of heavy oils will drift at different speeds and/or in different directions than lighter oils/sheens, depending on the particular overlap of the wind and current vectors.

There are several implications for oil spill response. One is that a heavy oil may not be as likely as a light oil to be blown onto a coast by an on-shore wind. Of course, if the wind creates waves, these will affect the heavy oil in much the same way as a lighter oil in terms of drift. Another implication is that free-floating skimmers or slick tracking beacons (both of which will be affected more by the wind than the oil) may have even more difficulty remaining with slicks of heavier oil than lighter oil. Further, because they are drawn by the currents into conversion zones in much the same way as other floating matter, heavy oils will naturally be brought together with accumulations of debris. As mentioned above, the entrapment of debris can greatly slow the collection and pumping of oil.

The most important implication of drift for response to heavy oils is that it is a mechanism by which a spill of persistent oil can potentially impact a long series of coastal areas. With a spill of light oil the wind, waves and tides may carry part of the spilled oil ashore while the simultaneous weathering processes of evaporation, dispersion, and dissolution work to diminish the rest. Because lighter oils are less persistent, weathering will degrade that part of the slick which does not hit the coast long before the same will happen with a slick of heavy oil. Therefore, even with the combined forces of tidal cycles and drift, the ability of a lighter oil to continually contaminate new areas with each tidal/storm cycle will greatly diminish. Heavy oils, on the other hand, are so persistent that they can drift along a coastline and continue to impact new areas for a much greater number of tidal/storm cycles. In fact, this process of contaminating new areas can continue until most of the originally spilled oil is spent on the coast. This is certainly a strong argument for at-sea recovery of these oils. At the same time, it is also an important measure for success of such operations: keeping oil from affecting new areas (see Peigné, 1992).

3.3 Dispersion/ tar ball formation

In spills of light oils, chemical dispersants are sometimes applied to slicks to help aid the natural dispersion. In general, however, experience has shown that chemical dispersants do not work well with heavy oils. The reason is that the high viscosity retards the mixing that the surfactants in the dispersant need in order to complete the molecular re-alignment that produces the dispersible drops of oil. Further, because oil calms the water, the thicker and heavier the slick, the calmer the water will be. Thus, the heavier oils will be subject to less wave action and will disperse less readily than lighter oils.

In terms of natural dispersion, there is an argument that heavier oils, when in a liquid state, may disperse more easily than lighter oils: the heavier the oil, the more similar the densities between oil and water and thus the easier it is for globules of oil to form and break away. And, since these droplets are relatively heavy, they will mix deeper into the water column, thereby increasing the success of the dispersion. This process is, however, opposed by the forces of viscosity which retard such droplet formation and thus slow the natural dispersion of heavy oils (CONCAWE, 1983; Doerffer, 1992).

Rather than disperse in tiny droplets, heavy oils are known to readily generate tar balls. Since most heavy oils have pour points greater than ambient sea temperatures, they will tend to form thick uneven mats, rather than spread like thinner oils. Given sufficient wave energy, these mats can be torn into smaller pieces and eventually into persistent tar balls of varying sizes.

In terms of response strategy, it should be self-evident that the best approach is to contain and collect the oil while it is in thick mats, before storms can break these up into tar balls. The arrival of such storms will force the at-sea response to be suspended. First, because of the danger of operating in rough seas and the general poor efficiency of the recovery devices. Second, because if natural dispersion is to happen at all, it will most likely be during turbulent seas. And finally, even in calm weather, at-sea recovery of widely scattered tar balls is not feasible.

3.4 Emulsification

Many crudes and heavy oils form water-in-oil emulsions relatively easily in rough seas. Research is still on-going regarding the exact environmental conditions and oil properties that are necessary for the formation of stable emulsions, yet it is thought that the formation of stable emulsions is related to an oil's asphaltene content (Fingas et al, 2001). Whatever the cause, the water droplets within the oil are stabilised in such a way that they do not merge and break the water/oil phase separation. Temperature also plays a role in that the colder the emulsion, the more viscous it will be and the more likely the water droplets will remain in suspension.

In terms of spill response, there are a few key characteristics of emulsions which put them at the extreme end of the heavy oil spectrum. Because they can take up such large amounts of water (70-80%), they can become very heavy with a specific gravity nearing that of water. This results in a considerable increase in volume, up to 5-fold. Removing water from emulsions is much more difficult than removing entrained water through decantation of non-emulsified oils. It can be done with heat or special chemical agents, two approaches that are not always available. This means that temporary storage of emulsions requires more storage per tonne of pure oil than non-emulsified oils.

Emulsification also significantly increases viscosity which creates a great burden for pumping and storage of emulsions. Another way in which emulsions differ from non-emulsified oils is a their reduced adhesiveness. This has a strong bearing on the skimmers that can be used, as those based on oleophilic principles, such as disks or drums are of little use when the oil will not stick to the collection surfaces (Mansfield et al, 1995). Many of the specialised belt, paddle or helical drum skimmers mentioned above can be used for recovering emulsions, as can simple mechanical grabs.

In summary, emulsions are among the most difficult forms of oil to recover. At the same time, their great persistence speaks greatly in favour of recovery where feasible. Some of the specialised techniques developed for skimming viscous and (semi) solid oils will also work with emulsions. Pumping is always a problem; solutions include steam/water-assisted pumping, mechanical transfer (e.g. with belts) or, to some extent, emulsion-breaking heat/chemical treatment.

4 DISCUSSION

The major difficulty with at-sea recovery is not being able to encounter enough oil to contain and skim meaningful quantities. Liquid oil begins to spread the moment it hits the water, yet even the most efficiently mobilised response vessels generally need hours if not days to arrive on site. Therefore, the encounter rate is invariably low. Add to this the power of wind, waves and currents which stretch and tear the slicks into long, thin windrows and scattered patches. By the time skimming could begin, the chances are that the oil is scattered in fragments over many square kilometres of open seas, has been blown beyond the reach of response vessels into shallow or rocky coastal waters or has already landed on the shore. Of course, it can happen that the release is not sudden and there is sufficient prior warning for the emergency response vessels to mobilise and arrive on site. Given calm seas, little wind, sufficient draft and adequate logistical support (especially regarding the temporary storage and transport of the collected oil) a properly equipped team of response vessels can potentially contain and collect a relatively large percentage of the released oil.

The “success” of an at-sea recovery operation is not directly related to the quantity or percent of oil recovered. At-sea recovery operations are successful when they reduce the extent of affected shoreline. Further, when oil does go ashore, there is no simple one-to-one relationship between environmental impact/ required shoreline cleanup effort/ volume of waste and the amount of oil that lands on given segment of shoreline. An at-sea operation, for instance, which reduces the average level of oiling from a 2cm to a 1cm thick coat of oil along 10 km of beach is not nearly as successful as an at-sea skimming operation which reduces the length of the contaminated beach, say from 10km to 5km. This is a strategic principle that decision makers should always consider when planning their at-sea attack.

This measure for success was certainly fulfilled in both the BALTIC CARRIER and VOLGONEFT 263 responses. The BALTIC CARRIER response succeeded in removing 33% of the spill volume and avoided the oiling of additional coastline areas by capturing some 400 tonnes of oil that had drifted in the current beyond the affected shoreline areas. The VOLGONEFT 263 incident (1990), also in the Baltic Sea, was a very successful at-sea recovery of 900 tons of oil/water mix relative to the 1,318 tonnes spilled. Most importantly, only a small amount of the oil that was not collected went ashore. Like the BALTIC CARRIER response, that for the VOLGONEFT 263 was carried out in calm weather and in cold waters by an organised team of international responders who exercise together on an annual basis.

It would be hard to make the same argument for the weather-constrained at-sea responses to the ERIKA and NAKHODKA. Both of these spills required massive shoreline clean-up. In the ERIKA incident (1999), a spill which coincided with France's worst storm of the century, a fleet of response vessels was able to collect 1,100 tonnes of emulsified oil, or about 3% of the spill volume, in the two weeks before the first oil landed on the shores of Brittany. Weather also played a major role in the NAKHODKA spill (1997), off Japan's northern coast. Recovery efforts here were continually interrupted by winter storms. In weeks of effort, more than 1,200 tonnes of emulsified oil were collected using barge-based crane grabs and mechanical scoops from a variety of vessels ranging from warships to fishing boats. This represents approximately 10% of the over 6,200 tonnes released (given 50% water content).

5 SUMMARY AND CONCLUSIONS

It is clear that there are a number of arguments that speak for and against greater at-sea recovery efforts for heavy oils relative to light oils:

1. Given the high persistence of heavy oils, it is desirable to exert more effort in recovering heavy than light oils.
2. Given slower spreading typical of heavy oils (especially in cold conditions and with relatively high pour points), the chances of encountering skimmable quantities of oil during an at-sea containment and recovery operation are greater with heavy oils than with light oils. In windy weather or turbulent seas which fragment the oil or in warm waters which allow the heavy oil to spread as a liquid, this advantage disappears.

3. Given the high specific gravity of heavy oil, slicks will float low in the water and may be difficult to find, especially in rough seas. Nonetheless, heavy oils will generally float high enough to skimmed/grabbed.

4. Given the high viscosity and adhesiveness of heavy oils, recovery is slower and more prone to technical difficulty than with light oils. The same is true of temporary storage and ship-to-shore transfer.

5. Given fewer volatile components and less spreading, heavy oils offer a longer opportunity to recover oil. Fewer volatile components also means safer operations (i.e. less danger of fire/explosion) and greater scope for use of vessels of opportunity which may not meet highest explosion-proof standards.

These arguments should make it clear that there is no simple answer that allows one to justify or reject at-sea recovery across the board. There are strong arguments in both directions. The degree of success will inevitably be a function of the environmental conditions faced during response, above all, sea-state, wind and ambient temperatures. In other words, the best chances for success are to be expected in cold and calm conditions.

In terms of equipment, contingency planners would be best advised to purchase skimmers, pumps, storage tanks, and support equipment that can be used for the widest possible range of oils and conditions. In particular they should focus on those skimming systems that cope well with heavy oils or weathered residues – the inevitable fate of lighter oils and crude. However, because both equipment budgets and storage space on vessels will always be limited, it is advantageous to avoid dependency on overly-specialised devices. In fact, experience has shown that the most efficient strategy is often to use low-tech approaches. Nonetheless, further development of recovery systems that can deal with a variety of oil types would seem to be a particularly good area for future R&D investment.

Along the same lines, further development of equipment for use with vessels of opportunity would also be a valuable contribution (see, for example, Mensonides, Schut and Kramer, 1995) Other areas where additional R&D investment would be beneficial include improving pumping systems for (semi) solid and viscous oils as well as improved remote sensing for low-in-water oils, especially in heavy seas.

Of course, even with good weather and the right equipment, the oil will not leave the water unless adequate plans have been prepared and the response teams are well trained and exercised. Oil slick surveillance, boom-towing, skimmer operation, or any of the other required tasks are challenging and must be well co-ordinated in order to function. During a spill is not the time to learn. Add to this the fact that response vessels are often brought together from different jurisdictions or countries and need to work smoothly together. Language, culture, and administrative hurdles might be greater than the technical difficulties of recovering the oil. Experience has shown, however, that internationally organised at-sea recovery operations can work, but to do so requires considerable pre-spill preparation, including regular exercises.

In summary, a review of the characteristics and behaviours of heavy oils should lead the contingency planner to strive to be ready for at-sea recovery but not to rely on it. Because the best and most meaningful chance to recover heavy oils from the sea is during favourable weather and calm seas, there is no need to invest in large stockpiles of overly sophisticated and specialised recovery equipment. Planning, co-ordinated training, and using a mix of standard oil spill response equipment and locally-available resources would seem to be the best approach.

6 BIOGRAPHY

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