INTERNATIONAL TANKER OWNERS
POLLUTION FEDERATION LIMITED

OIL SPILL RESPONSE IN THE ARCTIC & COLD CLIMATES – TECHNICAL ADVISORY NOTE

A Report for Skuld P&I Club

2nd November 2012

ITOPF

Report for Skuld P&I Club

Oil spill response in the Arctic and cold climates – technical advisory note

2nd November 2012

Produced by ITOPF Ltd

THE INTERNATIONAL TANKER OWNERS POLLUTION FEDERATION LIMITED (ITOPF)
1 Oliver's Yard, 55 City Road, London EC1Y 1HQ, United Kingdom
Tel: +44 (0)20 7566 6999, Fax: +44 (0)20 7566 6950, 24hr Tel: +44 (0)7623 984606
Email: central@itopf.com Website: www.itopf.com
Registered in England No. 944863. Registered Office as above

ITOPF Background

ITOPF is a not-for-profit organisation funded by the global shipping industry. Over 90 percent of our income comes from subscriptions paid by P&I insurers on behalf of their shipowner members, who are enrolled with ITOPF as either Members or Associates. This gives them access to the organisation's full range of technical and information services, usually at no cost.

Since its formation in 1968, ITOPF's technical staff have responded to almost 700 ship-source spills in 99 countries in order to give objective, technical advice on clean-up measures, environmental and economic effects, and compensation. Whilst most of these incidents have historically involved crude oil spilled from tankers, ITOPF is increasingly called upon to respond to spills of bunker fuel, chemicals and bulk cargoes from all types of vessel. Advice is also occasionally given in relation to oil spills from pipelines and offshore installations, and physical damage to coral reefs resulting from ship groundings.

The first-hand experience gained by our staff through direct involvement in pollution incidents is put to good use during contingency planning and training assignments, as well as in the production of technical publications.

ITOPF's Membership comprises over 6,300 tanker owners and bareboat charterers, who between them own or operate about 10,900 tankers, barges and combination carriers with a total gross tonnage of about 338 million GT. This represents virtually all the world's bulk oil, chemical and gas carrier tonnage and so it is extremely rare for the owner of any such ship engaged in international trade not to be a Member of ITOPF. Associates comprise the owners and bareboat charterers of all other types of ship, currently totalling some 530 million GT. This reflects ITOPF's increasingly important role in recent years in responding to bunker spills from non-tankers. ITOPF's activities are overseen by an international Board of Directors representing the organisation's independent and oil company tanker owner Members, its Associates and P&I insurers. Since its establishment in 1968, ITOPF has evolved into the maritime industry's primary source of objective technical advice, expertise and information on effective response to ship-source pollution. ITOPF has observer status at both the International Maritime Organization (IMO) and the International Oil Pollution Compensation Funds (IOPC Funds) and we regularly contribute to discussions on matters relating to ship-source pollution.

TABLE OF CONTENTS

1. INTRODUCTION

In addition to the rise in offshore oil and gas exploration and production activities in the Arctic, as the annual average extent, age and thickness of sea ice continues to decrease, increasing attention is being focussed on Arctic shipping routes. Of these, the Northern Sea Route is considered to be the most economically viable; the North West Passage is currently not viable due to navigational difficulties, but may become so in the future. In addition to the use of Arctic shipping lanes to reduce transit distances between northern European and northern Pacific ports, intra-Arctic shipping is likely to increase as sea ice retreats. In response to this, ITOPF has formed an internal Arctic Response Working Group, which was requested by Skuld P&I Club to provide technical advice on the response to oil spills in the Arctic, to be included in guidelines for members.

2. OIL FATE & BEHAVIOUR IN ARCTIC CONDITIONS

Cold temperatures and the presence of sea ice in the Arctic affect the fate and behaviour of oil in a number of ways. Some of these effects may act to increase the recoverability of spilled oil, whilst others will make recovery more difficult. The various effects and their implications for oil spill response are summarised in Table 1 below.

Table 1: Effects of Arctic conditions on oil fate and behaviour

Factor	**Effect**	**Implications**
Extreme cold	Reduces the rate of natural weathering processes such as evaporation and biodegradation; increases oil viscosity	Oils will be more persistent
Pack ice	Dampens wave energy and reduces natural dispersion and emulsification	Increased window of opportunity for chemical dispersion and in-situ burning
Fast ice	Oil may become encapsulated within or trapped underneath ice	Difficult to detect, track, and recover oil

'Sea ice' exists in many different forms, which will interact differently with oil. Land-fast ice, or simply fast ice, is sea ice that has frozen along coasts or to the sea floor over shallow parts of the continental shelf. Unlike drift ice, it does not move with currents and wind, and oil spilled on or under fast ice is unlikely to drift appreciably. Pack ice floats freely on the sea surface, rather than being held fast to the coast or sea bed, and will vary in form according to the size of individual chunks and whether or not it is contained and concentrated against the shore or the edge of the fast ice. The age of sea ice will also influence the behaviour of spilled oil. First-year ice melts more easily than older ice as it is thinner and less permeable, meaning summer melt-water tends to form deeper ponds on the first-year ice surface than on older ice, which absorb more solar radiation and warm the surrounding ice faster. Multi-year ice tends to be more stable, and in general will pose more of a problem to shipping, as it is thicker, stronger and more complex in 3-D structure than first-year ice. The interactions between the various forms of sea ice and spilled oil are illustrated in Figure 1.

Much of the research into the fate and behaviour of oil-in-ice has been conducted by the Norwegian research institute SINTEF, and has featured heavily in the Joint Industry Programme 'Oil In Ice', an oil industry funded initiative to promote research and development of Arctic oil spill science and technology. Further information and downloadable reports can be found on SINTEF's website, http://www.sintef.no/Projectweb/JIP-Oil-In-Ice/.

It should be noted that the standard oil spill fate and behaviour models that are commonly used to predict the effect of weathering processes on spilled oils under ambient conditions at lower latitudes do not apply to Arctic conditions. SINTEF is working to develop Arctic-specific crude oil weathering models, but it is not yet known if or when these will become commercially available.

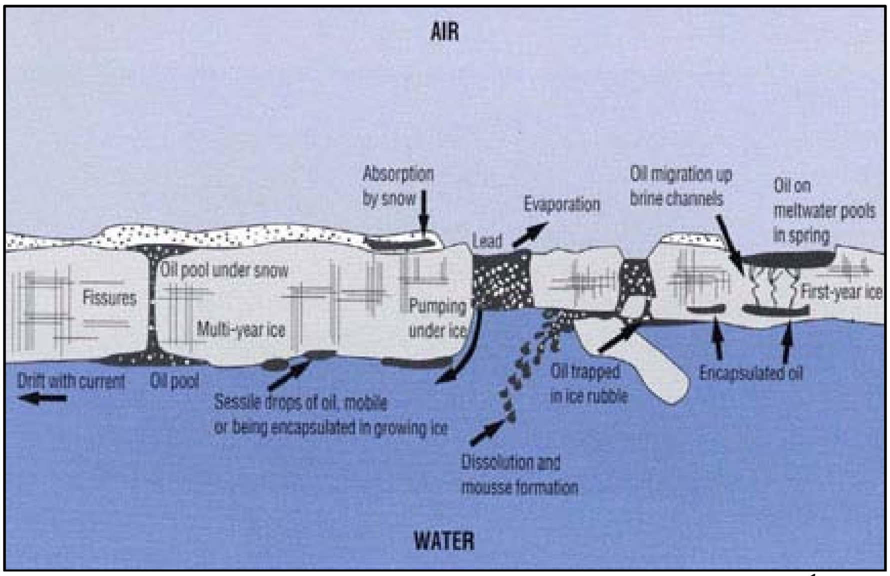

Figure 1: Potential interactions between sea ice and spilled oil[1]

3. DETECTING OIL IN ICE & ARCTIC OIL SPILL TRAJECTORY MODELING

The detection and tracking of oil in ice is one of the major technological challenges facing the Arctic spill response community. Whilst various techniques have proven successful in certain conditions, there is currently no one option that is suitable for all weather and ice conditions, and traditional techniques such as aerial surveillance will be hindered in the Arctic by the limited or lack of daylight. The most developed techniques, and their limitations, are outlined below.

3.1 Radar remote sensing

Radar remote sensing of oil spills utilises the physical principle that oil dampens wind-generated capillary waves on the sea surface, thereby reducing the radar backscatter signal. Various radar platforms are commercially available, including synthetic aperture radar (SAR; satellite-mounted) or side-looking airborne radar (SLAR; aircraft-mounted). Although both are designed primarily for the remote sensing of oil in open water, they are capable of detecting oil in ice leads if the leads are sufficiently large for wind-generated waves to occur, and if the foot print of the sensor is smaller than the lead. For satellite SAR data the typical resolution on surveillance mode (wide swath) is 25m, but this could be improved to 1m for pre-arranged specific locations. For airborne SLAR data, typical resolution is about 1m. A major limitation of satellite remote sensing of oil spills is that it is reliant on clear skies, and conditions in the Arctic are typically cloudy (approximately 90% of the time). Airborne sensors have the advantage of being able to fly under cloud cover, but are limited by the regulatory challenges of accessing Arctic airspace, pilot availability, operational health and safety considerations, communications challenges, and a general shortage of suitably equipped aircraft in the far North.

---

[1] Source: DF Dickens *et al*. (2004). Advancing oil spill response in ice-covered waters.

The most promising technique being developed for the detection of oil under ice is ground-penetrating radar (GPR; airborne or surface-carried). For airborne units, a low flight altitude is required; greater penetration is possible using surface-carried units, but these are large and heavy, and a trade-off must be made between resolution and penetration. Currently, GPR can be used to detect oil accumulations greater than 1 inch in thickness, under snow or in/under ice, but is unable to detect thin oil slicks, or oil trapped under new ice, young ice, first year ice, rafted ice, rubbles or ridges, or ice thicker than 7 foot (for surface-carried units, or 3 foot for airborne units).

3.2 Chemical sensing

High sensitivity airborne ethane and methane sensors have the potential to detect volatile compounds evaporating from fresh oil spills; depending on the rate of weathering, the window of opportunity for this technique will range from hours to days. These sensors require the use of low flying aircraft, with the attendant health and safety implications; hand held or vessel-mounted sensors are currently less sensitive, and can only be used if ice and weather conditions and the location allow access by personnel on the ground or by vessels.

SINTEF has investigated the use of dogs to detect oil under ice or snow; when properly trained, dogs have been shown to be able to reliably detect relatively small volumes of oil, but are of course subject to similar health and safety considerations as ground personnel.

3.3 Oil spill trajectory modelling

Oil trapped within or under fast ice can be expected to remain relatively stationary, as this ice is not mobile and currents under the ice are minimal. However, for oil trapped in the highly dynamic pack ice zone, movements can be both considerable and unpredictable. Standard oil spill trajectory models for open water conditions do not apply in the presence of ice; this is an area of ongoing research but at present no modelling capability exists for oil in pack ice. In addition, the oil may become frozen in over winter and then remobilised following the spring thaw.

4. RESPONSE OPTIONS

The main at-sea response options in the Arctic are containment and mechanical recovery, chemical dispersion, and in-situ burning[2].

4.1 Mechanical recovery

Mechanical recovery of oil in the Arctic will need to overcome several physical challenges, including the presence of ice that is likely to prevent the use of booms, the extreme cold that may hinder the operation of skimmers and pumps, and the increased viscosity of oil under Arctic conditions. However, the action of ice to contain oil and restrict spreading, and the limitation of weathering processes (especially the reduction in emulsification), may aid containment and recovery operations. Specialised Arctic skimmers and 'winterised' pumps and power packs have been developed by internationally-recognised manufacturers (e.g. Lamor, Desmi), that claim to be able to operate efficiently in Arctic conditions. Arctic skimmers are similar to the stiff brush skimmers that are commonly used to recover highly viscous oils at lower latitudes, and are designed to cope with up to

[2] For further technical information regarding mechanical recovery and the use of dispersants, please see http://www.itopf.com/spill-response/clean-up-and-response/.

approximately 30% ice cover, above which mechanical recovery becomes a less appropriate response technique. Specialised skimming vessels for oil recovery in ice may incorporate oil and ice separators in order to screen out ice chunks and reduce the volume of oily water collected.

Logistical challenges such as the availability of suitable vessels and facilities for the storage and disposal of oil recovered will also need to be overcome. These logistical challenges mean that much effort has been devoted to the development of techniques that treat spilled oil in situ, rather than recovering it for subsequent disposal.

4.2 Chemical dispersion

One technique that has the potential to effectively treat oil in situ is chemical dispersion. Dispersants are widely used to respond to oil spills at lower latitudes, and specific formulations are being developed that are suited to Arctic conditions. Dispersants consist of a surfactant and a solvent; the solvent delivers the surfactant molecules to the oil–water interface, where they act to reduce the interfacial tension and cause the oil slick to break up into smaller droplets. Provided there is sufficient mixing energy, these become suspended in the water column where they are broken down by naturally occurring micro-organisms; this biodegradation is accelerated thanks to the increased surface area of oil exposed to microbial action with smaller droplets. If the water is sufficiently deep (e.g. at least 20m), oil concentrations in the water column rapidly fall to very low levels (parts per billion).

As described above, the presence of ice and the cold air and water temperatures in the Arctic can act to decrease oil weathering and emulsification, and thereby potentially expand the window of opportunity for dispersant application from a few hours (typical of lower latitude response conditions) to days or even weeks. However, the dampening effect that sea ice has on wave action means that it would most likely be necessary to artificially increase mixing energy in the water column for successful dispersion; SINTEF has found that agitation using vessel propeller wash can facilitate the action of dispersants. Chemical dispersants will only be effective in removing oil slicks from the sea surface if they come in to contact with the oil; applying dispersants to oil contained in leads in the pack ice for example may be difficult. To this end, SINTEF has developed vessel-mounted manoeuvrable spray arms for targeted application of dispersants to oil within the pack ice.

It should be noted that the application of chemical dispersants is not currently pre-approved for Arctic waters; approval would need to be sought from the relevant regulatory authority, and may be difficult to obtain in shallow, nearshore waters or in the vicinity of sensitive benthic resources or fish spawning grounds, for example.

4.3 In-situ burning

In-situ burning of oil (ISB) was trialled extensively during the response to the Macondo well incident in the Gulf of Mexico (DEEPWATER HORIZON), as it is capable of removing large volumes of oil from the water surface with relatively little effort in terms of manpower or vessels, and only minimal waste generation. In-situ burning requires a minimum slick thickness of 3–4mm (for crude oil) in order to support an efficient and sustainable burn; in the Macondo response this was achieved by containment within fire-resistant boom or the use of chemical herders (which act to constrict the spread of a slick). In the Arctic, the action of ice to contain oil may allow efficient burns to be sustained without the need for booms or herders. In-situ burning can also be used to remove oil that has surfaced from under the ice during the spring melt to form pools on top of the ice.

Whilst experimental burns have reported oil removal efficiencies of upwards of 90%, a thick and tar-like residue will remain that has the potential to sink as it cools (due to the increased density) and may need to be recovered. The toxicity of such residues on Arctic flora and fauna has not yet been tested. Another issue with in-situ burning is that it creates a dense smoke plume, which will restrict burns in close proximity to settlements and sensitive coastal resources. In Arctic conditions, or with more heavily weathered or higher viscosity oils, ignition or combustion aids may be required to start and sustain a burn. As with the use of dispersants, in-situ burning is not a pre-approved response technique for Arctic oil spills; the highly visible smoke plume generated and concerns over the health and safety of not only responders igniting and monitoring the burns, but also indigenous populations and wildlife in the area mean that in some locations approval may be difficult to obtain.

5. CAVEATS & IMPORTANT CONSIDERATIONS

It is important to note that there is a discrepancy between the research and development that has been and continues to be undertaken, and the response technology that is commercially available. In addition to this, although techniques have been developed for the recovery or removal of oil spilled in the Arctic, and in many cases proven in laboratory and controlled field experiments to be successful, following a pollution incident in the Arctic there will be major logistical and health and safety challenges to overcome. These may include:

- Gaining access to contaminated sites, which may be very remote. Infrastructure in the Arctic region is extremely limited; ports and airstrips, where they exist, are likely to be operational for only a few months of the year.
- Sourcing and mobilising specialised equipment and trained personnel (trained not only in oil spill response, but also in extreme environment first aid and survival skills) over potentially vast distances, and ensuring the comfort and safety of these personnel in Arctic conditions which may include 24-hour darkness, extreme cold and exposure, the presence of ice, and potentially dangerous wildlife.
- Sourcing and mobilising suitable vessels and aircraft within a reasonable timeframe.
- Storage, transport and disposal of oily waste.
- Incident management and communications in the far North.

The first question to be addressed during contingency planning and following an incident in the Arctic will be: given the location, the time of year, and the environmental conditions, is it possible to respond? If it is possible to respond, the question of whether or not a response is necessary must be addressed, taking into account the sensitive ecological and socio-economic resources at risk. Given ITOPF's remit to promote effective oil spill response, the issue of 'reasonableness' must also be considered in the context of ship-source pollution. In remote regions, where the logistical challenges facing responders are especially high and the density of sensitive coastal resources may be relatively low, this issue becomes even more important.

To date, research and development of Arctic response techniques has focussed on crude oils, driven by the increase in exploration and production activities in the Arctic, as well as the threat of a tanker spill. However, over recent years ITOPF have attended an increasing number of spills of bunker fuels from non-tankers, highlighting the potential pollution risk associated with any shipping activity in the Arctic. Heavy fuel oils tend to be less dispersible than crude oils under any environmental conditions, and although they are designed and produced expressly for combustion, in-situ burning of refined fuel oils may not be possible under Arctic conditions. ITOPF understands that SINTEF also considers the response to spills of non-crude oils in the Arctic to be an important area for future research, and has conducted some preliminary research in to the dispersibility of fuel oils under Arctic conditions. The results of these tests are not yet available, but ITOPF's Arctic Working Group will continue to follow this and other relevant research and development.

Dr Nicola Beer
Technical Adviser