INTERSPILL 2015

Abstract – Paper Submission

Conference stream: Future risk / Future requirements

Title : **The ITOPF perspective on current challenges in responding to an oil spill in the Arctic**

Authors: Dr Franck Laruelle & Dr Nicola Beer - ITOPF

As Arctic sea ice diminishes, northern shipping routes are becoming more commercially attractive. Despite the advantages of reduced voyage times and associated reductions in emissions, the potential for an oil spill in the Arctic is an increasing concern within the shipping and oil industries. Arctic oil spill preparedness and response capability remain untested, and given the logistical, operational, and safety challenges in such remote and harsh environments, an effective response may prove extremely difficult.

Although relying on the same principles as elsewhere, response strategies in the Arctic will be strongly affected by oil's specific fate and behaviour in ice-infested conditions – some increasing and others limiting the response options. Detecting and tracking oil in ice is a major technological challenge: although various techniques have proven successful in certain conditions, there is currently no universally-applicable tool.

As in other maritime areas, the main at-sea Arctic response options are mechanical recovery, chemical dispersion, and *in-situ* burning (ISB). While in theory all three techniques could be applied to most crude oils, decision-making could be delayed by the lack of pre-approval for dispersant use or ISB in Arctic territorial waters, and options to respond to a spill of heavy oil not amenable to dispersion or ISB would be limited, whereas waste storage capacities could rapidly become a limiting factor to mechanical recovery. Shoreline response would need to consider how to minimise waste, protect unique and sensitive Arctic shorelines, and incorporate seasonal variability.

This paper summarises the challenges in responding to an oil spill in the Arctic, current marine oil spill preparedness across the Region, and identifies the major areas for future development to support a response in the Arctic.

INTRODUCTION

In addition to the development 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 (NSR) is considered to be the most economically viable; the North West Passage, although more difficult to navigate, has recently been successfully used by a major bulk shipping company and could potentially become a viable alternative to the Panama canal 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, and as mining and oil and gas exploration and production activities increase. In response to this, ITOPF has formed an internal Arctic Response Working Group, with the aim of developing our internal knowledge and awareness of Arctic preparedness and response aspects and assisting our members and other stakeholders in this respect.

Although only viable in summer and autumn by most vessels, Arctic shipping routes offer considerably reduced transit distances between Asia and Europe (up to 12,000 km via the Northern Sea Route) and Asia and North America (up to 7,000 km via the Northwest Passage) (Figure 1), which in turn can confer economic and environmental advantages. Shorter voyages result in fuel savings and reduced emissions. Even factoring in the cost of icebreaker assistance, these savings make the Northern Sea Route an attractive alternative to the Suez Canal and its fee structure. Using the Northwest Passage can also allow more cargo to be carried, as although the shoals and archipelagos of Canada’s Arctic waters and cartographic limitations necessitate careful voyage planning, the strict loading restrictions of the Panama Canal can be avoided. However, the relative uncertainty of mid-term ice movements and weather patterns, including during the summer season, means that voyage planning and duration via the northern routes is less predictable than via the traditional routes which can have a bearing on commercial operations.

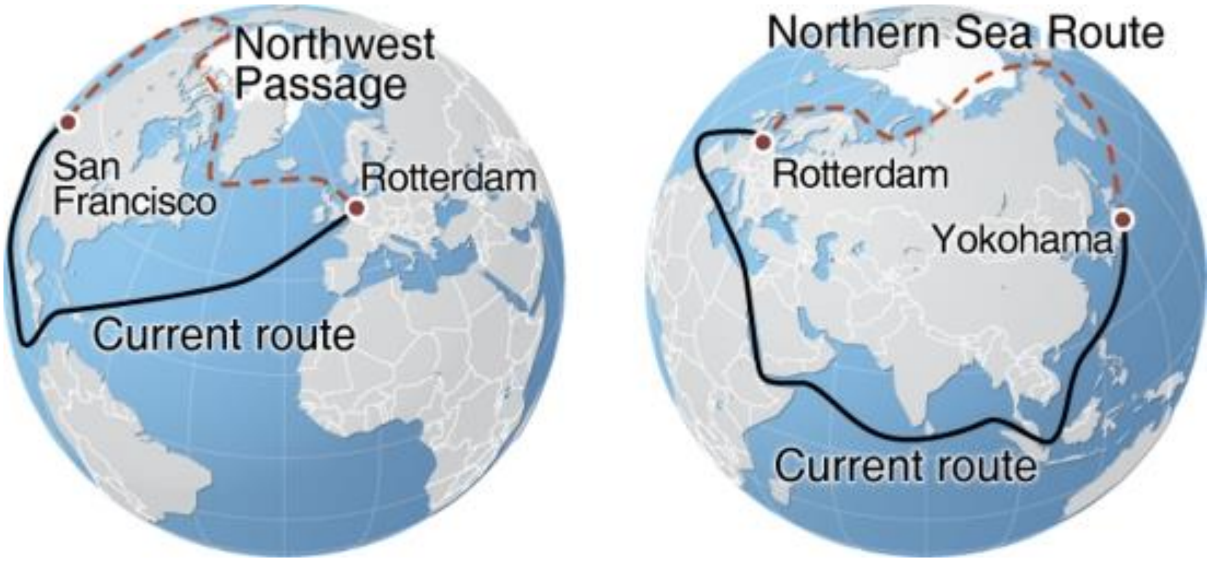

Figure 1: Arctic shipping routes between the Pacific and Atlantic Oceans shown in relation to the current Suez and Panama Canals shipping routes (source: Hugo Ahlenius, UNEP/GRID-Arendal - http://www.grida.no)

OIL FATE & BEHAVIOUR IN ARCTIC CONDITIONS

As largely described in the literature, low 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 window of opportunity to treat or recover the spilled oil, whilst others will hinder the response (Dickins, 2011; Brandvik *et al.*, 2006). The status on fate of weathering of oil in Arctic conditions are summarised in Table 1 below.

Table 1: Status on fate and weathering of oil in Arctic conditions (from Brandvik *et al.*, 2006)

Parameter	In open water	In ice with increasing ice coverage
Spreading	Spreading from thick to thin films. Dependent on oil.	Spreading dependent on ice type and ice coverage. Increasing oil film thickness with increasing ice coverage.
Drift	Oil drift due to wind and current	Current assumption: Ice coverage < 30%, drifting of oil is independent of ice. Ice coverage > 60-70%, the oil will mainly drift with the ice.
Evaporation	Rapid and high due to	Increasing oil film thickness due to

	spreading into thin oil films.	confinement in ice reduces both the rate and degree of evaporation. Diffusion barrier of precipitated wax at low temperature also observed.
Natural dispersion	Dependent on oil types and sea states.	Decreases with increasing ice coverage. Could be very low due to reduced energy conditions in the ice.
Emulsification	Will mainly take place in the presence of breaking waves.	Presence of ice will reduce wave activity and the emulsification will usually decrease with increasing ice coverage.
Water uptake rate	Rapid water uptake. Dependent on oil type.	Water uptake will probably decrease with increasing ice coverage due to wave damping effect and will be slow in dense sea ice.
Viscosity	Increasing viscosity due to increasing water uptake and evaporation	Viscosity increase slower due to slower evaporation and water uptake

'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. 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, 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 2 (from Bobra and Fingas, 1986).

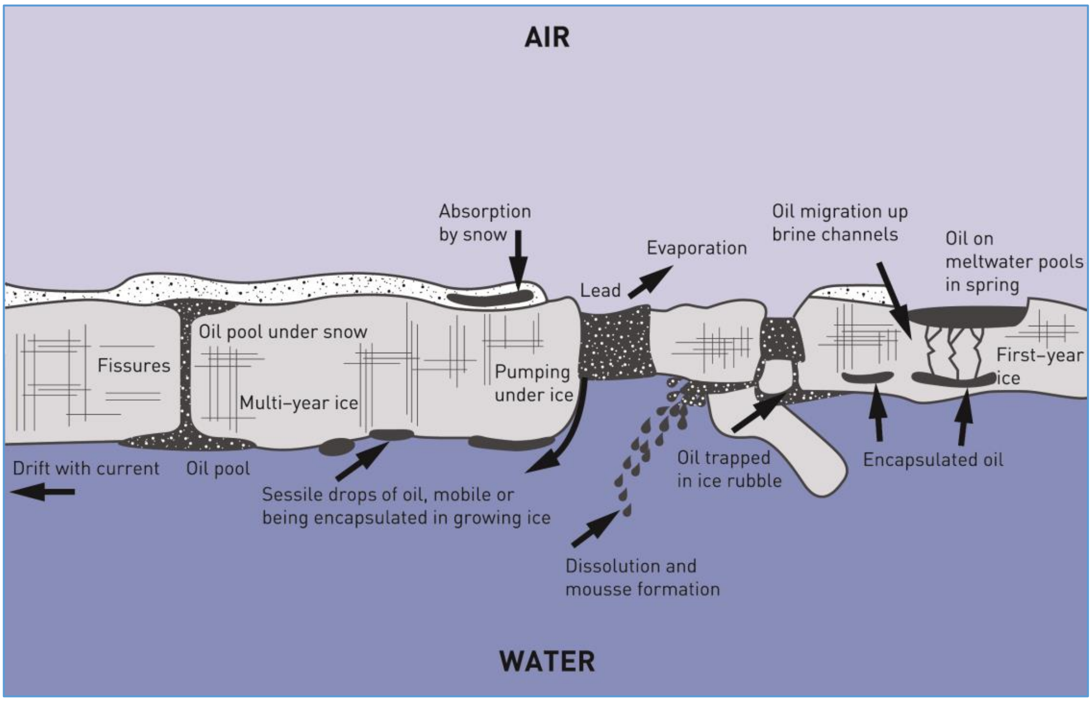

Figure 2: Potential interactions between sea ice and spilled oil

From an operational perspective, it is important to note that to date, the standard oil spill fate and behaviour models commonly used to predict the effect of weathering processes on spilled oils under ambient conditions at lower latitudes do not apply to dense ice cover conditions. The Norwegian institute 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.

DETECTING OIL IN ICE & ARCTIC OIL SPILL TRAJECTORY MODELLING

The detection and tracking of oil in ice is one of the key technological challenges facing the Arctic spill response community and is currently an important area of research and development therefore. 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 might seasonally be hindered in the Arctic by the limited or lack of daylight and/or availability of aircraft with sufficient autonomy. Conversely, open water periods when highest shipping activity is anticipated are also during periods of longest daylight which would benefit the conduct of surveillance and overall response operations. The most developed techniques, and their limitations, are outlined below.

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 footprint of the sensor is smaller than the lead. For satellite SAR data the typical resolution on surveillance mode (wide swath) is 25 m, but this could be improved to 1 m for pre-arranged specific locations (Dickins & Andersen 2009, Dickins, 2010). For airborne SLAR data, the typical resolution is about 1 m. Airborne sensors might however be limited by the regulatory challenges of accessing Arctic airspace, pilot availability, operational health and safety considerations, and a relative shortage of suitably-equipped aircraft in the far north.

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 2.5 cm in thickness, under snow or in/under ice, but is unable to detect thinner oil slicks, or oil trapped under new ice, young ice, first year ice, rafted ice, rubbles or ridges, or ice thicker than 2.1 m (for surface-carried units, or 0.90 m for airborne units) (Dickins *et al.*, 2008; Puestow *et al.*, 2013).

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 and the interaction between the oil and ice, the window of opportunity for this technique can range from hours to days (Hirst and O'Connor, 2010; Puestow *et al*., 2013). 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.

In the context of ice/snow covered grounds and/or shorelines, SINTEF has investigated the use of dogs to detect oil under ice or snow (Brandvik & Buvik, 2009). 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 and logistical considerations as ground personnel.

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 high ice coverage conditions; this is an area of ongoing research (e.g. the Oil Spill Trajectory Modelling in Ice Research Project of the International Association of Oil and Gas Producers Arctic Oil Spill Response Technology Joint Industry Program), 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.

RESPONSE OPTIONS

As in other maritime regions of the world, the main at-sea response options in the Arctic are containment and mechanical recovery, chemical dispersion, and *in situ* burning.

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 and rigid sweeping arms, the extreme cold that may hinder the operation of skimmers and pumps, and the increased viscosity of oil under low temperature 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 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 approximately 30% ice cover, above which mechanical recovery becomes a less practicable response technique. Specialised skimming vessels for oil recovery in ice may however incorporate oil and ice separators in order to screen out ice chunks and reduce the volume of water collected.

In areas where infrastructures are limited and ports far apart, logistical challenges such as the availability of suitable vessels and facilities for the storage and disposal of oil recovered would 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.

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 eventually broken down by naturally occurring micro-organisms; this biodegradation is promoted by the increased surface area of oil exposed to microbial action with smaller droplets. Although biodegradation is known to be slower under cold climates (Margesin and Schinner, 1999), if the water is sufficiently deep (e.g. 20 m), oil concentrations in the water column would 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 thus reducing water mixing 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 (Daling *et al*., 2010). 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 (Daling *et al*., 2010).

As in other regions of the world, chemical dispersion has the potential to be a useful strategy in the Arctic in both open and ice covered waters. However, the well-documented limitations of this strategy would also apply. A number of oils such as high pour point crude oils or heavy fuel oil used as ship fuels in particular are known not to be amenable to chemical dispersion in temperate conditions and would therefore be even less so in Arctic conditions.

It should be noted that the application of chemical dispersants is in general not pre-approved in the respective Arctic Nations territorial 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.

***In situ* burning**

In situ burning of oil (ISB) was used 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. ISB requires a minimum slick thickness of 1 mm for freshly spilled crude oil (or 2–5 mm for weathered crude, diesel oils, and heavy fuel oil) in order to support an efficient and sustainable burn (Buist *et al*., 2013); in the Macondo response this was achieved by containment within fire-resistant boom. In the Arctic, the action of ice to contain oil may allow efficient burns to be sustained without the need for booms. ISB 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% (Buist *et al.*, 2013), a thick and tar-like residue might 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 although they are known to show a high PAH content. Another issue with ISB is that it creates a dense smoke plume, which might restrict burns in close proximity to settlements and sensitive coastal resources. In Arctic conditions, or with more heavily weathered or higher viscosity oils (such as heavy fuel oils used to power large commercial ships), ignition or combustion aids may be required to start and sustain a burn. However, once spilled at sea, a number of oils cannot sustain a combustion efficient enough to allow for a significant removal rate from the water surface and the use of ISB would therefore be of limited benefit. As with the use of dispersants, ISB is generally not a pre-approved response technique in the respective Arctic Nations territorial waters. Also, as elsewhere, 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 ice-covered water locations its use might not be recommended or approved.

Shoreline response

Experience shows that even under optimal conditions for responding at sea, it is unlikely that more than a small percentage of the oil spilled will be recovered or removed from the sea surface. Depending on the location of the spill and the oceanographic conditions, shoreline impact will often be inevitable. In the Arctic, shoreline clean-up will be extremely challenging from both a logistical and a health and safety perspective. The sensitive shoreline types and seasonal variability in the location and vulnerability of coastal resources will likely necessitate a case-by-case net environmental benefit analysis (NEBA) approach to determine if, when, and how it is best to respond. The aim of shoreline clean-up should always be to promote natural recovery, whilst avoiding secondary damage. The environmental conditions at the time of an incident, affecting oil persistence and also the permeability and the load-bearing capacity of the substrate, will dictate the fate of oil on the shore, and therefore the most appropriate response strategy,. For example, oil frozen into coastal sediments may be easier to recover following the spring thaw, when it is more accessible, but in the case of sensitive peat and tundra shorelines, clean-up during the frozen winter months could minimise damage to the substrate.

Waste management

Response techniques that recover oil, oily water (or snow/ice), and oiled substrates can result in large quantities of waste being generated, that will need to be stored, transported, and disposed of. In any spill, waste management has the potential to become one of the more complex and costly aspects of the response, and in remote incidents with limited infrastructure this will be particularly relevant. Response options that treat oily materials *in situ*, careful segregation of waste streams, and separation of oil and water components can help to minimise the quantities of waste generated. At sea, this could be through the use of dispersants or *in situ* burning rather than containment and recovery. Onshore, techniques such as flushing, tilling, and surfwashing, which use the action of tides and waves to accelerate natural cleaning, will be preferable to the removal of beach substrates, but may be limited by the availability of winterised equipment and the prevailing weather conditions. Snow is a natural sorbent; improvised systems to heat oiled snow can be used to both reduce the volume of this waste stream and also allow separation of the water component.

MAJOR CHALLENGES FOR ARCTIC OIL SPILL RESPONDERS

The Arctic represents a unique set of challenges to oil spill responders. The remote location and inhospitable conditions mean that the marine and terrestrial environments have been preserved in a relatively pristine state. Media focus on the Arctic is becoming more intense as climatic and anthropogenic pressures on the iconic fauna, landscapes, and cultures increase. This means that an oil spill in the Arctic is likely to result in widespread scrutiny and demands for a rapid and effective response. At the same time, the very features that make the Arctic so emblematic will impede an emergency response.

Whilst efforts are being made to improve capabilities to respond to an oil spill in the Arctic, it is important to keep in mind that there is a discrepancy between the research and development that has been and continues to be undertaken, and the 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 would be major logistical and health and safety challenges to overcome.

With the exception of a few large ports and industrial centres, infrastructure in the Arctic region is generally extremely limited; ports and airstrips, where they exist, are likely to be operational for only a few months of the year. Gaining access to contaminated sites, which may be very remote, is likely to be very challenging. Specialised equipment and trained personnel must be sourced and mobilised; personnel must be trained not only in oil spill response, but also in extreme environment first aid and survival skills and will require appropriate personal protective equipment. Before personnel arrive on site, plans must be made to ensure their comfort and safety in Arctic conditions which may include 24-hour darkness, extreme cold and exposure, the presence of snow and ice, and potentially dangerous wildlife. Sourcing and mobilising suitable vessels and aircraft (as well as crew and pilots with appropriate training) within a reasonable timeframe would also be challenging.

Incident management and communications in the far north will require careful planning, both for contingency purposes and in the event of an incident. It is conceivable that response operations would be coordinated from a distant command centre and may be carried out over multiple seasons, which would not facilitate control of the response.

In the event of an oil spill in the Arctic or during the contingency planning process, the first question to be addressed would be whether it is possible to respond given the location, the time of year, and the environmental conditions. Should this be the case, the question of whether or not an active response is necessary would need to be addressed, taking into account the sensitive ecological and socio-economic resources at risk and type of oil spilled. If compensation is to be sought under the international oil spill compensation conventions (CLC 92, FUND 92 or BUNKERS 01), the issue of 'reasonableness' would also need to be considered in the context of ship-source pollution. In remote regions, where the logistical challenges facing responders are especially great, and sensitive coastal resources may be very remote from population centres and infrastructure, 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, as well as the threat of a tanker spill. However, over recent years ITOPF has attended more spills of bunker fuels from non-tankers than crude oil spills from tankers, highlighting the potential pollution risk associated with any shipping activity in the Arctic. Heavy fuel oils tend to be far less dispersible than crude oils under any environmental conditions, and although they are designed and produced expressly for combustion, *in situ* burning of residual fuel oils may not be possible under Arctic conditions.

CURRENT RESPONSE CAPABILITY

Historically, response capability in the Arctic has been more focussed on the developing oil and gas exploration and production industry than on national preparedness for a major shipping incident. While oil spill preparedness and response can be viewed on a regional or sub-regional basis in this context, for trans-Arctic shipping route it is vital to consider Arctic-wide preparedness.

As the northern shipping routes open up, the Arctic Council's Emergency Preparedness, Prevention and Response (EPPR) Working Group is addressing this, for example through the recent Agreement on Cooperation on Marine Oil Pollution, Preparedness and Response in the Arctic (http://www.arctic-council.org/eppr/agreement-on-cooperation-on-marine-oil-pollution-preparedness-and-response-in-the-arctic/).

ITOPF's Arctic Response Working Group is continuing to seek further information in regard to preparedness and response in the region, and to follow any regulatory developments. Our current understanding is summarised by region below.

Russia

As Russia moves to exploit the opening up of the Northern Sea Route, search and rescue and emergency response capabilities are being developed further. The Northern Sea Route Administration (NSRA) officially opened in 2013 (see http://www.nsra.ru/en/celi_funktsii/), and issues permits to vessels looking to transit the

NSR, which must meet several criteria according to the ice conditions at the time, the ice class of the vessel, and the experience of the crew.

Icebreaker assistance is rendered by Rosatomflot's fleet of nuclear icebreakers, which carry containment and recovery equipment and trained crews to provide a Tier I response capability, and can also call on shore-based support through the network of search and rescue centres. ITOPF understands that this response capability will be expanded over the coming years to boost capability for larger incidents (Tier II and Tier III). The Northern Sea Route Contingency Plan is available for download from http://www.arctis-search.com/The+NSR+Oil+Spill+Contingency+Plan but the procedures in place for testing and updating the Plan are not currently known to ITOPF.

Finland's Aker Arctic is currently constructing a dual purpose oblique icebreaker, designed to allow ice management and Tier I oil recovery capability in thick first year ice, the first of which is undergoing final trials in the Baltic Sea at the time of writing and due for delivery to the Russian Ministry of Transport in spring 2014. In oblique mode, the 76 m long vessel is designed to cut a wider channel through ice than two conventional icebreakers moving ahead side by side. The vertical hull side is designed to act as a sweeping arm up to 60 m across in heavy waves. The vessels will also feature a skimmer system, including a side door, in-built brush skimmers and collector tanks for oil separation, recovered oil transfer pumps, and a discharge pump.

The use of chemical dispersants in Russian waters is subject to authorisation on a case-by-case basis. The decision to use one of the pre-approved dispersants would be made by the incident commander in agreement with the territorial bodies of Environmental Protection Agency and the Russian Fisheries Agency on the basis of a NEBA (SEA Consulting Group, 2013).

There are currently no national regulations in force regarding ISB in Russia. According to the Russian Maritime Institute, there is some interest in the approval of ISB and consideration is being given to developing new regulations on this strategy with anticipated completion in 2014 (Potter *et al.*, 2013)

Canada

Currently, the vast majority of shipping in the Canadian and Alaskan Arctic is related to the mining, oil and gas industries, and the resupplying of remote communities. Canada's icebreaker fleet, operated by the Canadian Coast Guard, is limited to two vessels, and to ITOPF's knowledge does not provide any oil spill response capability.

In Canadian territorial waters, shipowners of vessels greater than 400 GT, or tankers greater than 150 GT, are required to have a contract with a government-approved response organisation; in the future, additional requirements may be imposed on vessels operating north of 60°N following a review of oil spill preparedness and response capability.

The preferred response strategy in Canadian waters is containment and recovery. Canada has currently no written policy on chemical dispersant use. In case of a spill, the use of chemical dispersants would therefore need to be authorized by the response lead agency after consultation of the REET (Regional Environmental Emergency Team) (SEA Consulting Group, 2013).

A similar situation as for dispersants prevails for ISB, and the expected procedure would be for the spill responsible party to request permission to conduct a burn through the REET (Potter *et al.*, 2013).

Alaska, USA

Under OPA '90, shipowners of vessels greater than 400 GT operating in US territorial waters are required to identify a Qualified Individual, who has full authority to implement oil removal actions, and to identify and ensure the availability of private personnel and equipment necessary to respond to a worst case discharge or substantial threat thereof. The US Coast Guard approves oil spill response organisations (OSROs), but does not guarantee their capability or ability to operate in the Arctic. Oil industry membership organisations such as Alaska Clean Seas provide response capability in the Arctic, but while it is agreed that it is in their members' interests to respond to a shipping incident, there is no guarantee that their services and equipment would be available to non-members.

With respect to the use of chemical dispersants, the Regional Response Team (RRT) and Northwest Area Committee have established pre-approval zones, case-by-case approval zones and no-use zones for Alaskan waters (SEA Consulting Group, 2013).

The State of Alaska has a comprehensive set of guidelines, regulations and authorisation requirements for the use of controlled ISB during a spill event. The guidelines stipulate that before any *in situ* burn can be used, regulatory approval must be obtained through submission of an application and burn plan to the Unified Command (Potter *et al.*, 2013).

Greenland

Shipping in Greenland is also understood to be focussed on the mining and oil/gas industries. Greenland Oil Spill Response provide response capability to their industry members, but again, services and equipment may not be available in the event of a shipping incident.

In Greenland, offshore containment and recovery is the preferred response strategy. In a spill event, permission to use chemical dispersants can be requested using a NEBA based application form from the Bureau of Minerals and Petroleum (BMP) which would be referred to their environmental consultants, the Danish Centre for Environment and Energy (DEC) (SEA Consulting Group, 2013).

ISB is not included as an oil spill response method in the national oil spill contingency plan. It is however in the contingency plan of oil companies operating in Greenland waters with the stipulation that approval would be required from the BMP and would be evaluated on a case by case basis (Potter *et al.*, 2013).

Norway

Containment and recovery is the preferred strategy in Norway. Dispersants are considered to be supplemental or alternative to mechanical recovery depending on the spill scenario. Applications to use dispersant would be based upon a NEBA and subject to approval by the NCA (Norwegian Coastal Authority). All companies involved in oil operations are required to consider and document dispersants as an oil spill response method in their contingency plans (SEA Consulting Group, 2013).

ISB is not considered as a response option in open waters in Norway, however it is under increased focus as the oil and gas industry is moving closer to areas where a spill could reach the ice edge (Potter *et al.*, 2013).

Iceland

Oil spill response in Iceland is coordinated by the Environmental Agency, with assistance from the Icelandic Coast Guard and Maritime Administration. Government equipment is stockpiled in five locations. The primary response strategy is containment and recovery, although it is recognised that sea conditions will often preclude this. Dispersants can be used as a secondary strategy, but the extensive commercial fishing grounds mean that seafood safety will need to be carefully considered. The use of ISB as a response option has not been seriously considered. Although minor spills have been responded to during harsh winter conditions, no major incidents have occurred in Icelandic waters to date.

Baltic States

Whilst not strictly within the Arctic, the Baltic freezes over every winter and poses many of the same challenges to oil spill response. In the Baltic Sea, mechanical recovery is the preferred oil spill response strategy. The EMSA KONTIO response vessel (operated under contract to Arctia Icebreaking) is stationed in Oulu in the winter and Helsinki during the summer, and provides a storage capacity of 2,033 m^3 for oil recovered by 12 m rigid sweeping arms, and weir and brush skimmers. The vessel is also equipped with 500 m heavy duty boom, and a slick detection radar system.

The use of chemical dispersants is allowed as a last resort response option and limited in accordance with the Helsinki Commission relevant recommendations. However, permits to use dispersants can be issued if the situation warrants. Permissions would need to be granted by the relevant authority in the country with jurisdiction on the waters to be treated (SEA Consulting Group, 2013).

ISB is not seriously considered and discouraged given the enclosed nature of the Baltic Sea.

INTERNATIONAL COOPERATION

International cooperation is likely to be a key factor in determining the success of a response to an oil spill in the Arctic. Various regional agreements aim to facilitate and promote cooperation and mutual assistance among Arctic states. The most recent and broadest of these, the Arctic Council's Agreement on Arctic Marine Oil Pollution Preparedness and Response was signed in May 2013 by eight states (Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden and the USA). The Agreement aims 'to strengthen cooperation, coordination and mutual assistance among the Parties on oil pollution preparedness and response in the Arctic in order to protect the marine environment from pollution by oil'. Parties agree to maintain a national system for responding promptly and effectively to oil pollution incidents, and to establish a minimum level of equipment for the assessed risk, training programmes and exercises, and response plans and communications capabilities. The appended Operational Guidelines set out procedures for notification and requests for assistance, command and control in response operations, joint training and exercises, and recommends measures to facilitate effective cooperation. These Guidelines are however non-binding.

Other regional agreements that apply to Arctic territorial waters are summarised in Table 2.

Table 2: Regional agreements among Arctic states with provisions in relation to preparedness and response to oil spills

Agreement	**Signatories**
CANDEN Agreement	Canada and Denmark (including Greenland)
The Convention on the Protection of the Marine Environment of North-East Atlantic (OSPAR)	Denmark, Finland, Iceland, Norway, and Sweden
The Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention)	Denmark, Estonia, Finland, Latvia, Lithuania, Norway, Russia, and Sweden
Copenhagen Agreement	Denmark (including Greenland), Finland, Iceland, Norway and Sweden
Agreement Concerning Cooperation on the Combatment of Oil Pollution in the Barents Sea	Norway and Russia
Agreement Concerning Cooperation in Combating Pollution in the Bering and Chukchi Seas	Russia and USA
Joint Marine Pollution Contingency Plan	Canada and USA
Finnish-Estonian agreement on the cooperation	Finland and Estonia

in combating against pollution incidents at sea	
SWEDENGER Plan	Sweden, Denmark and Germany
Agreement on Cooperation in Combating Pollution of the Baltic Sea in Accidents Involving Oil and Other Harmful Substances	Finland and Russia

In addition to government-led regional initiatives, industry cooperation has also been formalised for the Barents Sea. The Norwegian-Russian (Ru-No) oil and gas industry Barents Project aims to assess the gap between the technology currently available and the technology needed for extracting oil and gas resources in the Barents, Pechora and Kara Seas in an environmentally sound manner, and includes an oil spill response component.

Finally, the IMO has recently adopted a mandatory international code of safety for ships operating in polar waters (the Polar Code), which is intended to cover the full range of design, construction, equipment, operational, training, search and rescue and environmental protection matters relevant to ships operating in the inhospitable waters surrounding the two poles.

REFERENCES

Bobra A. M. and M. F. Fingas. 1986. The behaviour and fate of Arctic oil spills. Water Science & Technology Vol. 18, No 2, 13–23.

Brandvik P. J., Sørheim K. R., Singsaas I. and M. Reed. 2006. Short state-of-the-art report on oil spills in ice infested waters. Oil behaviour and response options. SINTEF Oil in ice JIP report No 1. 63 pp.

Brandvik P.J. and T. Buvik. 2009. *Using dogs to detect oil hidden in snow and ice – Results from field training on Svalbard April 2008*. Report from Joint Industry Programme on oil spill contingency for Arctic and ice covered waters, no. 14. 19 pp.

Buist I.A., Potter S.G., Trudel B.K., Walker A.H., Scholz D.K., Brandvik P.J., Fritt-Rasmussen J., Allen A.A. and P. Smith. 2013. In situ *burning in ice affected waters: a technology summary and lessons from key experiments*. Report from Joint Industry Programme on relevant scientific studies and laboratory and field experiments on the use of in-situ burning in ice-affected offshore environments. 67 pp.

Daling P.S., Holumsnes A., Rasmussen C., Brandvik P.J. and F. Leirvik. 2010. *Development and testing of a containerised dispersant spray system for use in cold and ice-covered area*. Report from Joint Industry Programme on oil spill contingency for Arctic and ice covered waters, no. 13. 61 pp.

Dickins D.F. 2004. *Advancing oil spill response in ice-covered waters*. D.F. Dickins Associates Ltd, prepared for Prince William Sound Oil Spill Recovery Institute, Cordova, Alaska and United States Arctic Research Commission, Arlington, Virginia and Anchorage, Alaska. 18 pp.

Dickins D.F., Bradford J. and L. Steinbronn 2008. *Detection of oil on and under ice: phase III: Evaluation of airborne radar system capabilities in selected arctic spill scenarios.* Final Technical Report. DF Dickins Associates Ltd and Boise State University for US Department of Interior / Minerals Management Service. 56 pp.

Dickins D.F. and J.H. Andersen. 2009. *Remote sensing technology review and screening.* Report from Joint Industry Programme on oil spill contingency for Arctic and ice covered waters, no. 22.

Dickins D.F. (Ed). 2010. *Remote sensing summary report*. Report from Joint Industry Programme on oil spill contingency for Arctic and ice covered waters, no. 30. 46 pp.

Dickins D.F. 2011. Behavior of Oil Spills in Ice and Implications for Arctic Spill Response. Proceedings of the Arctic Technology Conference, Houston, USA. 15 pp.

Hirst B. and S. O'Connor. 2010. *Measurement of methane emissions from oil spill experiments at Svea Test S Svalbard, April 2007*. Oil in ice Joint Industry Programme / Shell International Exploration and Production B.V. Report no. 23. 20 pp.

Margesin R. and F. Schinner. 1999. Biotechnological applications of cold-adapted organisms. Rosa Margesin, Franz Schinner, Editors. Springer-Verlag Berlin Heidelberg: 273-277.

Puestow T., Parsons L., Zakharov I., Cater N., Bobby P., Fuglem M., Parr G., Jayasiri A., Warren S. and G. Warbanski. 2013. *Oil spill detection and mapping in low visibility and ice: surface remote sensing*. Report from Joint Industry Programme to define the state-of-the-art for surface remote sensing technologies to monitor oil under varying conditions of ice and visibility, no. 5.1. 82 pp.

Potters S. G., Buist I. A., Trudel B.K., Walker A. H. Brandvik P.J., Fritt-Rasmussen J. and A. A. Allen. 2013. In Situ Burning in ice-affected waters: Status of Regulations in Arctic and Sub-Arctic Countries. Report from Joint Industry Programme no. 7.2.1. 15 pp.

Sea Consulting Group. 2013. Dispersant use in ice-affected waters: status of regulations and outreach opportunities. Report from Joint Industry Programme no. 2.8. 105 pp.