Paper #8-9

FIELD OIL SPILL RESPONSE EXPERIMENTS AND RELEASES TO TEST TECHNOLOGY, PROCEDURES, AND PRACTICES

Prepared for the

Technology & Operations Subgroup

On March 27, 2015, the National Petroleum Council (NPC) in approving its report, *Arctic Potential: Realizing the Promise of U.S. Arctic Oil and Gas Resources*, also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the study's Technology & Operations Subgroup. These Topic Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters.

These Topic Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents, but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency.

The attached paper is one of 46 such working documents used in the study analyses. Appendix D of the final NPC report provides a complete list of the 46 Topic Papers. The full papers can be viewed and downloaded from the report section of the NPC website (www.npc.org).

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Topic Paper

(Prepared for the National Petroleum Council Study on Research to Facilitate Prudent Arctic Development)

8-9	**Field Oil Spill Response Experiments and Releases to Test Technology, Procedures, and Practices**
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SUMMARY
Industry and federal agencies will need to continue to develop robust oil spill response capabilities that can efficiently operate in Arctic harsh environments. Research into Arctic oil spill response began more than 40 years ago, and significant efforts continue today by industry, either individually or through joint industry projects, academia, and the Federal government. Experimental field releases are a logical key step in the development and validation of oil spill containment, recovery, and treatment equipment and methods, but these field trials are not consistently conducted and as many as 15 years can lapse between tests. A collaborative approach between industry, government, and academic researchers will increase stakeholder confidence in Arctic oil spill contingency plans and allow responders to select the most effective and environmentally acceptable methods for spill response.

Background

As commercial activities increase in the Arctic, industry and federal agencies will need to continue to develop robust oil spill response capabilities that can efficiently operate in harsh environments. Oil spill response researchers in the public and private sectors, and manufacturers have spent many decades developing, testing, evaluating, and refining response tools and methods for Arctic operations, and these efforts have only increased in recent years. Experimental field releases are a logical key step in the development and validation of oil spill containment, recovery, and treatment equipment and methods. Unfortunately, these field trials are not consistently conducted and as many as 15 years can lapse between tests. What is needed is a consistent and collaborative approach to experimental field releases to allow industry and federal agencies to prove oil spill response capabilities in the Arctic, test new response tools, test theory and models associated with oil behavior in the ice environment, and train Arctic responders. A collaborative approach between industry, government, and academic researchers will increase stakeholder confidence in Arctic oil spill contingency plans and allow responders to select the most effective and environmentally acceptable methods for spill response. The knowledge and best practices gained through experimental field releases are a necessary step in the process of continuously improving Arctic spill response plans.

Research into Arctic oil spill response began more than 40 years ago, and significant efforts continue today by industry, either individually or though joint industry projects, academia, and the Federal government (OGP, 2014, Dickins et al., 1981). There have been few actual accidental spills of significant size in Arctic conditions, so the main source of knowledge on oil behavior and spill countermeasures has come from experimental studies in laboratories, test tanks, and field trials. The oil and gas industry and government agencies have a history of safely and successfully completing this research. This research provides a foundation for oil spill contingency planning today.

Experimental field releases started in the 1970's and includes work done mostly in Canada, Norway, and some in the United States. There are a number of reviews and assessments that provide more details on these studies (Fingas and Hollebone, 2002, Brandvik, 2007, SL-Ross et al., 2010, Dickins, 2011). The last Arctic experimental release in the United States occurred at Prudhoe Bay in 1982 (Nelson and Allen, 1982). The last experimental release of oil in ice took place in North America off the Canadian East Coast in 1986 (Buist and Dickins, 1987). Three small releases (200 liters each) took place in ice in the Saint Lawrence Estuary in 2008 (Lee et al, 2011). Norway has since conducted more recent experimental releases, for example in 2006, 2008, and 2009 (Dickins et al., 2008, Sørstrøm et al., 2010). Findings have demonstrated that laboratory and test tank results can be scaled up and applied safely to large-scale field settings. However, experimental releases that provide the essential larger scale validation are scarce. Large wave basins provide the best alternative to field trials but they have significant limitations.

The Bureau of Safety and Environmental Enforcement (BSEE) maintains the world's largest wave tank dedicated to oil spill response research and training in New Jersey. Known as the Ohmsett National Oil Spill Response Research & Renewable Energy Test Facility, it provides near full-scale test capability and is an excellent venue for some research. Ohmsett, however, cannot fully simulate Arctic field conditions. Without climate control features, Ohmsett can simulate cold water and broken ice conditions and has successfully done so while testing mechanical recovery equipment and dispersants, it cannot fully simulate Arctic conditions. As a result, there is a very small time window when it is practical to maintain ice in the tank for a useful test duration.

Considering the recent increases in commercial activity in the Arctic such as shipping and energy exploration, industry and the U.S. federal government need to collaborate on oil spill response research as much as possible, including performing the research with international partners. A critical need for this research is getting reasonable permits and approval of experimental field releases. Further, field trials can also perform an important role in the training of responders. This research will further ensure the robustness of oil spill contingency plans in the Arctic.

Field Release Experiment Objectives

To a great extent, industry conducts and collaborates on oil spill response research. This allows the research to benefit from a broad base of knowledge and expertise. A collaborative approach is even more important for experimental field releases as these activities are complex and costly, and benefit the most from the broadest base of expertise and knowledge. Therefore, the oil and gas industry will continue to attempt to work closely with federal agencies, indigenous people, local residents, other industry, and other stakeholders to conduct experimental field releases. Prior field trials prove that they can be conducted safely and with minimum impact to the environment.

The list below describes some important reasons for conducting experimental field releases:

1) To validate lab and basin scale testing demonstrating the effectiveness of various response strategies (existing, enhancements to existing, and new)
2) To validate lab / basin scale testing and model predictions of the fate and effects of oil in the Arctic environment and to collect data needed to assess environmental impacts and Net Environmental Benefit Analysis considerations ;

3) To demonstrate the technical and operational viability, timeframes, and safety of different techniques;
4) Advancing fundamental scientific knowledge about the Arctic ecosystem;
5) To engage stakeholders and educate responders on the capabilities and trade-offs of different response strategies; and,
6) To provide important training opportunities for Arctic oil spill responders.

In-kind support from government and industry is needed to ensure that resources are utilized as efficiently as possible. By making scientists and researchers available, as well as sharing air, marine, and response assets during an experiment the knowledge can be shared and logistics improved.

There are many concerns and challenges associated with carrying out experimental field releases in any location. These concerns and challenges are even greater in the Arctic. Working with stakeholders and governments at the national, regional, and local level to ensure the studies are carried out in a way that protects the environment and the safety of local communities at all stages from planning to execution is critical. The ultimate goal is to develop Arctic oil spill response tools, strategies, and personnel that are as robust and capable as possible, and the consistent execution of experimental field releases is key to reaching this goal.

Historical Field Release Experiments

Table 1 summarizes most of the medium to large-scale experimental crude oil spills known to have been conducted in sea ice, regardless of location. Also included are two significant shoreline projects involving experimental releases and long term monitoring. There may be other experiments, for example in Russia that are not included because project reports and publications are not available. These studies are reviewed and summarized by SL Ross et al. (2010), Brandvik (2007), Fingas and Hollebone (2002) and Dickins and Fleet (1992). Further information regarding these experimental releases can be found in Appendix A.

Table 1: Summary of Field Experiments in Arctic Conditions

Field experiment	Location	Year
Behavior of Oil Spills in the Arctic	Chukchi Sea	1970
Crude Oil Behavior on Arctic Winter Ice	Beaufort Sea, United States	1972
Interaction of Crude Oil with Arctic Sea Ice	Beaufort Sea, Canada	1975
Oil Behavior Under Multi-year Ice	High Arctic, Canada	1978
Oil and Gas Under Sea Ice	Beaufort Sea, Canada	1979/80
Oil Migration and Modification Processes in Solid Sea Ice	Beaufort Sea, United States	1979/80
Physical Interaction and Clean-up of Crude Oil with Slush and Solid First-year Ice	Beaufort Sea, United States	1980/81
The Baffin Island Oil Spill Project	Baffin Island, Canada	1980, 1983
Emulsions in Ice	Beaufort Sea, Canada	1982
Experimental Releases of Crude Oil in Pack Ice	Nova Scotia,	1986

	Canada	
Marginal Ice Zone Experiment	Barents Sea, Norway	1993
In-situ Clean up of Oiled Shorelines; Svalbard Shoreline Project	Svalbard	1997
Svalbard Experimental Release 2006	Svalbard	2006
Joint Industry Program on Oil Spill Contingency for Arctic and Ice-covered Waters: Oil in Ice Field Experiments 2008 and 2009	Barents Sea, Norway	2008, 2009

Performing Field Experimental Releases

Field experiment releases can be performed to research a variety of technical and operational challenges in the areas of: dispersants, in-situ burning, mechanical recovery, natural attenuation, remote sensing, trajectory modeling, and environmental impacts. Depending on the needs of the different projects, releases could involve oil spilled under ice, in the water between floes or, in some cases, on the ice surface. Justification for why the data can only be collected in the field will be provided for the final suite of studies selected for field research. In addition, specific response strategies and data collection methods will receive prior validation in laboratory or basin tests before going into the field.

Planning and executing a field experimental release can be technically complex. Significant challenges to carrying out this work in remote areas include logistics, planning, and the permitting process. The challenges can be met by:

- Laboratory and meso-scale data to fully confirm the technical feasibility of any response strategy or technology being considered for use in the field
- Meticulous planning with contingencies in priority areas identified through risk analysis and environmental assessment
- Ice and weather forecasting and hindcast analysis to pick the optimum time and place to meet experimental objectives
- Logistics to coordinate multiple marine, air and space assets, including vessels, aircraft, helicopters, satellites
- Early outreach, consultation, and dialogue with agencies, regulators, local community leaders, and other key stakeholders; and continued communications with stakeholders, project teams and field teams.

Before any field experimental release can occur, a sequence of assessment, deliberation, community visits, conversations and formal permit applications needs to take place. The exact order and scope of these activities and expected timing varies by country but at a minimum is expected to include:

- Initial consultation with key agencies, regulators, indigenous and local community leaders/members before committing to a formal application process.
- Initial evaluation to identify geographic areas that meet the necessary criteria
- Initial research scope and definition
- Detailed project planning including logistics, personnel, contractors, securing support-in-kind, response equipment, costing, scheduling etc.
- Interim consultation meeting with key agencies, regulators, Indigenous and local community leaders to discuss project plan
- Necessary permit applications completed and submitted to concerned agencies at national, state and local levels
- Follow-up meetings to answer questions and provide supplementary information

- Provisional go-ahead and agreement in principle
- Final field activity plans and contracts in place to carry out the field experiment research.

Selecting the ideal location for a field research spill depends on a number of critical factors:

- Logistics and availability of ice (type and suitability), weather, sea conditions, climate, including annual variability, timing, etc.
- Access for freight and personnel, vessel operations and air support
- Environmental sensitivities, including local human populations, birds, mammals, fisheries and harvesting activities
- Regulatory constraints and conditions including the ability to secure the necessary approvals at national, regional and local levels
- Expected levels of local support from communities and regulators
- Availability of support vessels
- Ability to test a range of response strategies.

Oil volumes involved in historical releases have ranged from fractions of a cubic meter (a few barrels) to more than 50 cubic meters (315 barrels). Some examples are:

- During the largest release, conducted in fast ice in the Canadian Beaufort, a total volume of 59 cubic meters (371 barrels) was split into nine individual releases over the course of one winter. Eight of these releases were contained within skirts frozen into the ice.
- The largest single uncontained release into a pack ice environment, carried out in Norway in 1993, was 26 cubic meters (164 barrels).
- Most recently, the SINTEF JIP (SINTEF, 2012) involved a total of 17 cubic meters (107 barrels) split into five releases, of which the two largest were contained within fireproof booms; the largest uncontained release was 7 cubic meters (44 barrels).

Measures that can significantly reduce and mitigate risks associated include:

- Oil spill response strategies to remove as much oil as is practical from the marine environment, including flexible options to cope with changing conditions
- Environmental Assessment (EA) conducted as part of the permit application to ensure important environmental sensitivities are identified and taken into account in the project design and spill contingency plan
- Back up plans to deal with a range of outcomes, such as equipment breakdown and changing weather and ice conditions; including parameters of when to stop the test if conditions are not appropriate
- Monitoring Plan to ensure that releases take place away from sensitive wildlife resources and that any residual oil causes no harm
- Having an onboard environmental observer with knowledge of the local area
- Communications plans that maintain full transparency throughout the planning and consultation process and maximize opportunities for key stakeholders to view the releases first-hand if possible.

External stakeholder involvement at the outset of the planning process is critical to ensuring all parties are involved in a conversation about what is being proposed, how it will be carried out and how people can become actively involved. The field releases will afford local communities an opportunity to witness the application of a range of response strategies in their own environment and to gain confidence in industry capabilities. Examples of this involvement may include:

- Planning: Including Indigenous Peoples' traditional knowledge on the marine environment, ecosystems and subsistence harvesting is critical to the environmental assessment process and operational planning.
- Education: The field releases provide a unique opportunity for a dialogue regarding practical and scientific knowledge about the latest Arctic spill response methods with regulators and community groups. The release also provides an opportunity for agency and industry personnel to couple the experiment with training elements.
- Data collection: This could include monitoring sea ice conditions and wildlife using local hunters.

APPENDIX A
HISTORICAL EXPERIMENTAL RESEARCH SPILLS

The following summaries highlight most of the medium to large-scale experimental crude oil spills known to have been conducted in sea ice, regardless of latitude. Also included are two significant shoreline projects involving experimental releases and long term monitoring. There may be other experiments, for example in Russia that are not included because project reports and publications are not available. This review does not include spills in open water, or terrestrial spills focused on oil.

1. Behavior of Oil Spills in the Arctic, Chukchi Sea 1970

A series of small-scale spills (one to two barrels each) was conducted on fast ice in the Chukchi Sea by the US Coast Guard in July 1970. The surface spills (diesel and North Slope crude) quickly drained through a permeable recrystallized upper layer and collected on the melt pools. The crude oil pumped under the ice at two sites rose and collected in the under-ice depressions. The researchers concluded that the presence of ridges and hanging blocks under the ice would be able to contain fairly large oil volumes as long as currents and turbulence in the water column were low (Glaeser and Vance, 1971).

2. Crude Oil Behavior on Arctic Winter Ice, Beaufort Sea, United States 1972

This project is considered one of the "classic" early experiments aimed at understanding the spreading of oil on snow and ice. Much of the work involved developing spreading theories from first principles. Three spills were made with warm North Slope Crude on sea ice. The spreading rates measured in the field generally matched the theoretical predictions and confirmed that only gravity and inertia forces need to be considered. A key observation was that there was no significant penetration into the ice surface by the warm oil. Fresh snow blowing across the oil tended to stick and migrate downward, creating a dry mixture of 80% snow by volume. A heavy snowfall directly on top of the oil compacted the upper snow/oil interface and prevented the new snow from infiltrating the already spilled oil (McMinn, 1972).

3. Interaction of Crude Oil with Arctic Sea Ice, Beaufort Sea, Canada 1975

This was the first large-scale investigation into all aspects of oil in ice behavior, including spreading under ice, encapsulation, and progressive vertical migration as the ice warmed, spreading on surface melt pools in the spring and weathering. A large portion of the oil was removed by in-situ burning on the ice in June some 7 months after the initial spill. A total of 54 m3 (283 barrels) of two different crudes were released in stages throughout the winter of 1974-1975 into containment skirts cut into fast ice within a confined Bay near Cape Parry on the Canadian Beaufort Sea coast. In addition to the contained spills, two additional spills were carried out 30 km offshore, where the oil was allowed to spread freely in the presence of a 10 cm/sec current and movements documented by divers and underwater camera footage. This study demonstrated conclusively that effective removal of oil spilled under ice could be achieved through in-situ burning in the spring. Mechanical removal of the residue completed the successful clean-up. The presence of the trapped oil had no significant effect on the eventual ice thickness, comparing control and oiled sites. As well the presence of oil pooled on the ice surface in the spring had only a minor local effect on the rate of ice deterioration and break-up, advancing the process by a few days to one week (Norcor, 1975).

4. Oil Behavior Under Multi-year Ice, High Arctic Canada 1978

Three small-scale spills of ~3.8 bbl each (0.6m3) of Norman Wells crude were completed at Griper Bay in the Canadian High Arctic in June 1978. An overflight later that summer showed a considerable amount of oil on the surface at two of the spill locations. A field visit in September of the following year found oil in the ice at two of the sites (up to 10%) and very little at the third side, which was bisected by a crack. No oil was found at any of the sites in the fall of 1982, four years after the spill. This is the only known field test involving oil and multi-year ice (Comfort et al., 1983).

5. Oil and Gas Under Sea Ice, Beaufort Sea, Canada 1979-1980

The focus of this unique project was to investigate the fate and behavior of oil released with compressed air (Gas-to-oil ratio up to 300) to simulate a shallow water blowout in 20m of water under stable fast ice. This is the only known project of its kind that comes close to approximating the conditions that would be faced with a subsea release in the presence of gas under ice. Three spills of Prudhoe Bay crude, ~6m3 each, were discharged over the winter of 1979-1980 in December, April and May at a nearshore site in the Canadian Beaufort Sea. Individual spill volumes ranged from 5.9 to 6.8m3. Oil behavior and fate depended largely on the ratio of gas to oil and timing. Early in the season the thin ice sheet was uplifted by the gas, which vented through cracks. Finer droplets were carried further out from the discharge point as gas volumes increased. In all of the spills, the oil was encapsulated by new ice growth within a time frame of 24 to 48 hours regardless of whether there was gas present. The spills later in the winter led to larger pools of oil beneath gas pockets that filled the natural under-ice depressions. An estimated 85% of the spill volume appeared on the ice surface in the spring through ablation of the surface down to the trapped oil droplets and vertical migration of oil from larger trapped oil pools. Approximately two-thirds of the spill was removed through a series of ISB in numerous melt pools. Residue was recovered by teams on the ice prior to break-up (Dickins and Buist, 1981).

6. Oil Migration and Modification Processes in Solid Sea Ice, Beaufort Sea, United States 1979-1980

This paper reports on a series of 18 small-scale spills (1.5 to 18 gal. each) of fresh and emulsified Prudhoe Bay crude and diesel fuel under first-year fast ice during the early part of the winter of 1979-1980. Significant vertical migration quickly occurred when hot crude oil or diesel was injected without any opportunity for new ice to form beneath the oil. The authors noted that abnormally deep snowdrifts present at times could have led to internal ice temperatures more representative of spring than winter conditions. Emulsions injected in the Prudhoe Bay crude tests did not migrate vertically to any extent. The tests were terminated in March 1980 when the oiled ice was cut out of the parent ice and removed to shore (Nelson and Allen, 1982).

7. Physical Interaction and Clean-up of Crude Oil with Slush and Solid First-year Ice, Beaufort Sea, United States 1980-1981

During the winter of 1980-1981, three experimental releases involved spraying 1m3 (6 bbl) of hot Prudhoe Bay crude onto snow to simulate a surface oil well blowout in mid-winter and spring. In the test under cold temperatures with 30cm of hard snow, the oil covered an area of close to 500 m2 and penetrated less than 5cm into the snow surface. In the first spring test in mid-April the oil immediately saturated the snow-slush mixture to a much greater extent. When left for two weeks, the low albedo oil surface gradually subsided relative to the surrounding clean snow. Samples from the oiled snow had water contents in the range 75 to 90%, the equivalent to what would be encountered from mechanical removal of an oiled snow layer (Nelson and Allen, 1982).

8. The Baffin Island Oil Spill Project, Baffin Island, Canada 1980-1983

The Baffin Island Oil Spill (BIOS) Project sponsored multidisciplinary field studies between May 1980 and August 1983 in Canada's eastern Arctic on the northern end of Baffin Island. Forty-five cubic meters of a sweet medium °API gravity crude oil were released in two experimental releases designed to assess and compare the short- and long-term fate and effects of chemically dispersed oil near shore vs. a beached oil slick. The main conclusions of the BIOS Project were: first, the results offer no compelling ecological reasons to prohibit the use of chemical dispersants on oil slicks in nearshore areas; second, the results provide no strong ecological reasons for the cleanup of stranded oil (on certain shoreline types). From these results, the authors concluded that consideration would be given to using chemical dispersants near shore where warranted to protect wildlife or their critical habitat or traditional human land-use sites (Sergy and Blackall, 1987).

9. Emulsions in Ice, Beaufort Sea, Canada 1982

This project involved two spills of crude oil under 1.65m thick, solid fast ice at McKinley Bay, NWT, Canada in March 1982. One hundred nine-two (192) liters of 60% oil-in-water emulsion were injected at two adjacent sites, and the same volume of fresh oil enclosed within a containment skirt was established as a control. The highly viscous emulsion formed a static irregular "lumpy" surface under the ice with no lateral spreading. In contrast the fresh oil formed a more uniform coating within the skirted area. New ice crystals started forming within the emulsion within 24 hours and all spills were encased by a thin skim of new ice beneath the oil within 48 hours. The presence of the oil had no measurable effect on ice growth. The fresh crude started to appear in quantity on the ice surface due to natural migration processes through the sheet by mid-June while the equivalent surfacing of the emulsions did not occur for another 3 weeks. This difference was attributed to the differing oil viscosities affecting the ability of emulsions to flow up the open brine channels in the melting ice. Rather than through migration, the emulsified oil was brought to the ice surface by a combination of melting of the ice from the surface down, and melting of ice above the trapped emulsion layer through solar heating. Eventually, the project estimated that 90% of all oil injected was released from the ice by the time break-up occurred on July 8. The emulsions were stable through the entire project duration and did not "break" (Buist et al., 1983).

10. Experimental Releases of Crude Oil in Pack Ice, Nova Scotia, Canada 1986

This was the first project to involve experimental releases of crude oil in dynamic pack ice. Three discharges of 1m3 each of Alberta sweet mixed blend crude were completed offshore of Nova Scotia, Canada in March 1986. Ice conditions ranged from open drift ice (40 to 60% coverage) to close pack (70 to 80%). The main finding was that high concentrations of slush or brash ice between floes greatly reduced and in many cases stopped the oil spreading. The oil interacted with the ice by saturating the brash ice in the water between the floes and splashing onto the edges of small ice pancakes as the ice pieces ground together. Small volumes of oil were carried under the floes by relative water motion. Oil was rarely transported to the surface of the ice. The experimental results demonstrated that slush and brash ice are not major factors in oil spreading. The spreading of oil in pack ice can be predicted by simple modifications to standard open water equations, to account for the effect of ice concentration. Existing trajectory models such as SINTEF developed to predict spilled oil concentration areas for a spill in snow can be adopted for spreading of oil among slush and brash ice at sea. There was no evidence of emulsification in spite of a water temperature of -1.5°C. There was some evidence of natural dispersion but the oil droplets being created were relatively large and rapidly rose to collect under the ice. Two of the three discharges in the 1986 Canadian experiment were contained in very close ice pack and were successfully burned with efficiencies ranging from 80 to 93%. There were no problems with ignition or sustaining the burn and the residue was easily recovered. The third spill occurred in 4 to 6/10 ice cover and was not naturally contained to a thickness that could sustain combustion; no attempt was made to recover the oil. It was concluded that burning appeared to be the only feasible countermeasure for spills under dynamic pack ice (Buist and Dickins, 1987).

11. Marginal Ice Zone Experiment, Barents Sea, Norway 1993

In 1993, following a series of test tank experiments, an experimental release involving (163 bbl) 26m3 of North Sea crude took place in the Barents Sea marginal ice zone off the coast of Norway. The high concentrations of pack ice kept the oil thick and immobile, which, combined with cold temperatures and limited wave action, significantly slowed the oil weathering processes. Oil spreading and slick thickness were sensitive to relatively small changes in ice concentration: the spill thickness rapidly dropped from 1cm to 1mm as the ice cover opened slightly from 80 to 70% coverage. Most of the oil remained in the slush and openings between floes. Approximately 2-5% of the total volume was smeared around the perimeter of the floes and an insignificant proportion of the spill was transported as small particles under the ice. Attempts to use an oleophilic rope mop skimmer for recovery was hampered by the influence of the vessel opening up the ice cover and allowing the oil to spread – the same effect was noted during the Canadian experiment in 1986. No other effort was made to clean up or recover the oil (Singsaas et al., 1994; Vefsnmo and Johannessen, 1994).

12. In-situ Clean-up of Oiled Shorelines; Svalbard Shoreline Project, Norway 1997-1998

Experimental oil spill studies were conducted on Svalbard to quantify the effectiveness of selected in-situ shoreline treatment options to accelerate natural oil removal processes on mixed-sediment (sand and pebble) shorelines. A total of 5,500 liters of oil was deposited in July and August 1997 along a 3m wide swath in the upper intertidal zone at three sites. Approximately one week after oiling, a different treatment technique was applied to each plot: sediment relocation (surf washing), mixing (tilling), bioremediation (fertilizer application), and bioremediation combined with mixing. One plot at each site was monitored for natural attenuation. The results verified that relocation of oiled sediments significantly accelerated the rate of oil removal by more than one year. The oil mineral aggregate (OMA) formation process was active and was increased by sediment relocation. Oil biodegradation occurred both in the oiled sediments and on the fine mineral particles removed from the sediment by natural physical processes. The biodegradation of oil in sediment was significantly stimulated by simple bioremediation protocols. Mixing (by tilling) did not clearly stimulate oil loss and natural recovery. The treatment techniques did not elevate the toxicity in the nearshore environment to unacceptable levels, nor did they result in consequential alongshore or nearshore oiling (Sergy et al., 1998).

13. Svalbard Experimental Release, Norway 2006

This experiment involved a discharge of 3,400 liters of fresh Statfjord crude oil under 65cm solid fast ice in a fjord on Svalbard on March 27, 2006. The spill was contained within a skirted area of 100m2. Average film thickness was 3.5cm but under ice depressions led to pockets of oil over 10cm deep. The primary objectives of the experiment were to create an under-ice spill as a target for ground penetrating radar and to document the weathering processes of the oil. Oil started to migrate naturally to the surface 24 days after the spill. Most of the oil had surfaced by May 30, just over 60 days following release. The oil was burned with an efficiency estimated at 96% after lying exposed on the ice surface for over one month and having undergone 27% evaporative reduction (Dickins et al., 2008a).

14. Joint Industry Program on Oil Spill Contingency for Arctic and Ice-covered Waters: Oil in Ice Field Experiments, Barents Sea, Norway 2008 & 2009

As part of a large international, multi-disciplinary Joint Industry Program carried out over four years (2006 to 2009) two field projects were conducted in the Norwegian Barents Sea between 78 and 79°N, east of Svalbard, within the pack ice. Two small uncontained spills totaling only 0.8m3 (5 bbl) were completed in 2008 with the purpose of testing the application of oil herders to thicken an oil slick in open pack ice enough to support ISB – the result was a complete success with better than 90% removal effectiveness. This was the first time the combination of herders and burning had been tried in an Arctic field setting. The 2009 project included three uncontained releases (0.5, 2.0 and 7.0m3) into close pack ice (over 80%) to document oil weathering and fate as well as to assess dispersant effectiveness on two spills that were contained within towed boom. Study findings indicated that: burning of thick oil films trapped between floes in pack ice is highly effective (confirming earlier work in Canada and elsewhere); that dispersants are potentially useful to deal with a spill in pack ice as long as sufficient mixing energy is available, and that fire resistant boom can be used in light ice cover to both recover and burn oil at high efficiencies in very low ice concentrations that would otherwise not be ignitable. Measurements of the weathering of oil and the ignitability verified in both lab- and meso-scale studies were used to develop predictive models of the window-of-opportunity for ISB (Sørstrøm et al., 2010).

References

Buist, I.A., S.G. Potter, and D.F. Dickins. 1983. Fate and behaviour of water-in-oil emulsions in ice. Proceedings of the Sixth Arctic Marine Oilspill Program Technical Seminar. Environment Canada. Ottawa.

Buist, I., and D. Dickins. 1987. Experimental spills of crude oil in pack ice. Proceedings 1987 International Oil Spill Conference. American Petroleum Institute. Washington.

Comfort, George, T. Roots, L. Chabot, and Frank Abbott. 1983. Oil behaviour under multi-year ice at Griper Bay, NWT. Proceedings of the Sixth Arctic Marine Oilspill Program Technical Seminar. Environment Canada. Ottawa.

Dickins, D.F.. 2011. Behavior of Oil Spills in Ice and Implications for Arctic Spill Response, Offshore Technology Conference, Houston, Texas

Dickins D.F., Brandvik, P.J., Bradford, J., Faksness, L-G, Liberty, L., and R. Daniloff. Svalbard 2006 experimental oil spill under ice: remote sensing, oil weathering under Arctic conditions and assessment of oil removal by in-situ burning. Proceedings 2008 International Oil Spill Conference American Petroleum Institute. Washington, DC.

Dickins, D.F., and I.A. Buist. 1981. Oil and Gas Under Sea Ice Study: Vols. I&2. Prepared by Dome Petroleum Ltd. for COOSRA, Report CV-1, Calgary, AB, Canada (also published in Proceedings 1981 Oil Spill Conference, Atlanta GA).

Glaeser, J.L. and G.P. Vance. 1971. A study of the behaviour of oil spills in the Arctic. U.S.C.G. Report CG-D-53-74. Washington.

Lee, K., Z. Li, B. Robinson, P.E. Kepkay, M. Blouin, and B. Doyon. 2011. Field trials of in-situ oil spill countermeasures in ice-infested waters. Presented at the 2011 International Oil Spill Conference, Portland, Oregon. American Petroleum Institute, Washington, DC, 16 pp.

McMinn, T.J. 1973. Crude oil behaviour on Arctic winter ice. U.S. Coast Guard Report No. 734108. Washington.

Nelson, W.G. and A. Allen. 1981. The physical interaction and cleanup of crude oil with slush and solid first year sea ice. ABSORB.

Nelson, William G. and A. A. Allen. 1982. The physical interaction and cleanup of crude oil with slush and solid first year sea ice. Proc. Fifth Arctic and Marine Oil Spill program Technical Seminar. Environment Canada. Ottawa.

Norcor. 1975. The Interaction of Crude Oil with Arctic Sea Ice. Beaufort Sea Project Technical Report No. 27, Canadian Department of Environment, Victoria, BC, Canada.

OGP Fact Sheet. 2011. Research in Support of the Arctic Oil Spill Response Technology Joint Industry Programme

Potter, S., I. Buist, K. Trudel, D. Dickins, E. Owens. 2012 Spill Response in the Arctic Offshore, prepared for API and OGP.

Sergy, G. A. and P. J. Blackall. 1987. Design and Conclusions of the Baffin Island Oil Spill Project VOL. 40, SUPP. 1 (1987) P. 1-Q ARCTIC.

Sergy, S.A., Guénette, C.C., Owens, E.H., Prince, R.C. and Lee, K. 1998. The Svalbard shoreline oilspill field trials. Proceedings Arctic and Marine Oilspill Program Technical Seminar No. 21, Vol. 2, pp 873-889. Environment Canada, Ottawa.

Singsaas, I., Brandvik, P.J., Daling, P.S., Reed, M. and Lewis, A. 1994. Fate and behaviour of oils spilled in the presence of ice - A comparison of the results from recent laboratory, meso-scale flume and field tests. Proceedings Arctic and Marine Oilspill Program Technical Seminar No. 17, Vol. 1, pp 355-370. Environment Canada, Ottawa.

Sorstrom, S. E., P. J. Brandvik, I. Buist, P. Daling, D. Dickins, L-G Faksness, S. Potter, J. Fritt Rasmussen and I. Singsaas. 2010. Joint industry program on oil spill contingency for Arctic and ice-covered waters: summary report. SINTEF report A14181. SINTEF. Trondheim, Norway. www.sintef.no/Projectweb/JIP-Oil-In-Ice/Publications/

Vefsnmo, S. and B.O. Johannessen. 1994. Experimental Oil Spill in the Barents Sea - Drift and Spread of Oil in Broken Ice. In: Proceedings 17th Arctic and Marine Oil Spill Program Technical Seminar. Environment Canada. Ottawa.