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EMERGENCY RESPONSE TO ARCTIC OIL SPILLS

Abstract: Development of offshore industry and shipping in Arctic has increased risk oil spills. Such incident would have disastrous effect upon unpolluted Arctic environment and native inhabitants. There are several methods to contain and clean up oil spills. All of them were developed for milder climate operations and with some modifications can be used in Arctic. Biggest challenge for emergency response teams are remoteness of oil spill sites and ice-infested waters.

Keywords: Arctic, Dispersant, Emergency Response, In-Situ Burn, Oil Spill, Skimmer

Introduction

Global warming in changing rapidly Arctic. Receding ice-cover opens Artic waters for shipping and offshore activities. Several oil companies developed oil and gas production facilities to tap rich fossil hydrocarbons resources. New shipping lanes become available for cargo vessels, including tankers carrying oil in bulk quantities. With observed rise in such activities come concerns about risk of major oil spill. The oil spill threat is a grave concern for Arctic states and native people. It is difficult to predict impact of such accident upon fragile Arctic ecosystem. Several clean up strategies have been taken into consideration by Arctic states, including in situ burning as easiest in application in remote areas, see picture below:

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Fig. 1. In situ oil slick burning in presence of ice for test purposes
Source: EPR Guide Oil Spill Response in Snow and Ice Conditions in the Arctic.

For time being no major oil spill has been recorded in Arctic region and most of research regarding oil behavior in such conditions were conducted in carefully controlled conditions when small amounts of oil were released[2]. Purpose of this experiment was thorough research of oil spill spreading behavior in ice conditions and evaluation of fate of oil spilled in Artic conditions. During several test spillages extent of spreading oil slick was recorded by airborne cameras installed on board of helicopter. Researchers concentrated mainly on dynamics of slick spreading, oil evaporation rates, emulsification and dispersion and interaction with ice. It helped to determine processes affecting oil spills in Polar conditions as shown below:

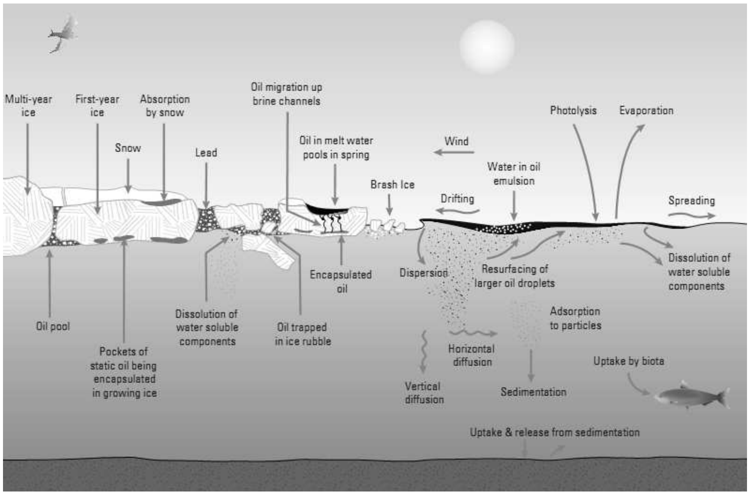

Fig. 2. Environmental processes that affect oil behaviour and weathering in open water and in ice
Source: Committee on Responding to Oil Spills in the U.S. Arctic Marine Environment.

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2 I.A. Buist, F.D. Dickins, *Experimental Spills of Crude Oil in Ice Pack,* Proceedings of 1987 Oil Spill Conference, Baltimore, Maryland, 1987, p. 373.

General conclusion drawn from numerous small scale experiments and training exercises is that difficult environmental conditions Arctic conditions can work to oil spill response team advantage. Low temperatures are slowing down evaporation and emulsification of oil thus making it easier for setting it alight. Ice can work like natural booms corralling oil and preventing further spreading of slick. Freezing ice is trapping oil which can be burnt in the spring in melt-water basins. Mechanical recovery of spilled oil could be more difficult for typical equipment widely used in milder climatic conditions. Recovery of oil trapped underneath ice requires assistance of icebreaker to release it. Accordingly these conclusions several oil clean-up strategies have been proposed and taken into consideration by Arctic states.

1. In-situ burning

In-situ burning (ISB), sometimes called controlled burning, had been used first time as countermeasure during oil pipeline leak in the Mackenzie River, Canada, in 1958[3]. Successful operation paved way to fast removal of large quantities of spilled oil. Method was tested during several large scale experiments and was found applicable for clean-up operations both in open and ice infested waters. For open waters and ice concentration below 10% oil slick should be contained by fire-resistant booms (see Fig.1) and ignited within 2-3 days since occurrence to avoid excessive oil weathering. Higher ice concentration provides containment for oil spill in leads and polynyas and use of booms is not required. Large ice concentration is also slowing down process of oil weathering and extending period of time when oil can be easily ignited. Minimum slick thickness necessary for oil burning depends of type of oil and can be summarized as below[4]:

- 1 mm oil thickness for light crudes and gasoline.
- 2-5 mm oil thickness for weathered crudes and middle-distillates (diesel and kerosene).
- 10 mm oil thickness for residual fuel oils and emulsified crudes.

Graphic below presents basic heat and mass transfer processes during in situ:

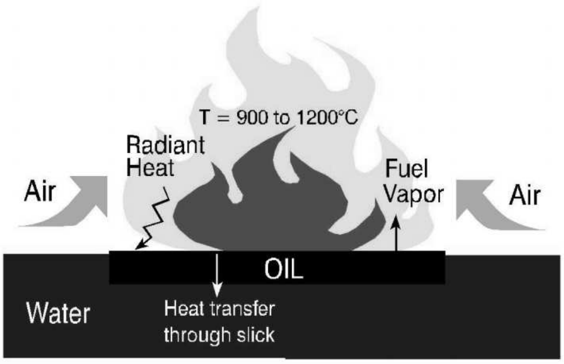

Fig. 3. Basic heat and mass transfer processes during in situ burning.
Source: Arctic Response Technology-In Situ Burning in Ice-Affected Waters.

[3] EPPR, 2015. *Guide to Oil Spill Response in Snow and Ice Conditions Emergency Prevention, Preparedness and Response (EPPR)*, Arctic Council, Tromsø, 2015.
[4] *Ibidem*.

Oil can be ignited only if sufficiently thick oil layer isolates slick surface from cold water and prevents temperature drop below its Fire Point, below which the burning stops. When burning oil on calm water or on top of melt pools temperature of underlying water may rise to boiling point. Resulted steam throws oil droplets into the flame increasing burning rate. This phenomenon is called vigorous burning phase and never happens with towed booms as water surface stays below boiling point due to continuous replacement. Strong wind affects oil burning process and for successful operation wind speed should be not higher than 10 to 12 m/s. Weathered oil tends to form stable water-in-oil emulsion and can be ignited only if water content doesn't exceed 25%. Under favourable conditions efficiency of in situ burning may reach 90% of original volume. In calm ice-infested Arctic waters often booms can be replaced by herders. Development of this kind of surfactants has begun in 1970s for offshore industry but with limited success[5]. Herders work well only in calm waters which is a disadvantage for operation in open waters but not for calm Arctic waters. Herding agent spreads on water surface in monomolecular layer due to high spreading pressure and reduces surface tension of water surrounding oil slick. It results in reduction of forces spreading oil on water surface and allows oil slick to contract and increase its thickness to burnable limit. IBS has raised several questions regarding its impact upon environment. Main components of air emission are water and carbon dioxide as shown on graphic below:

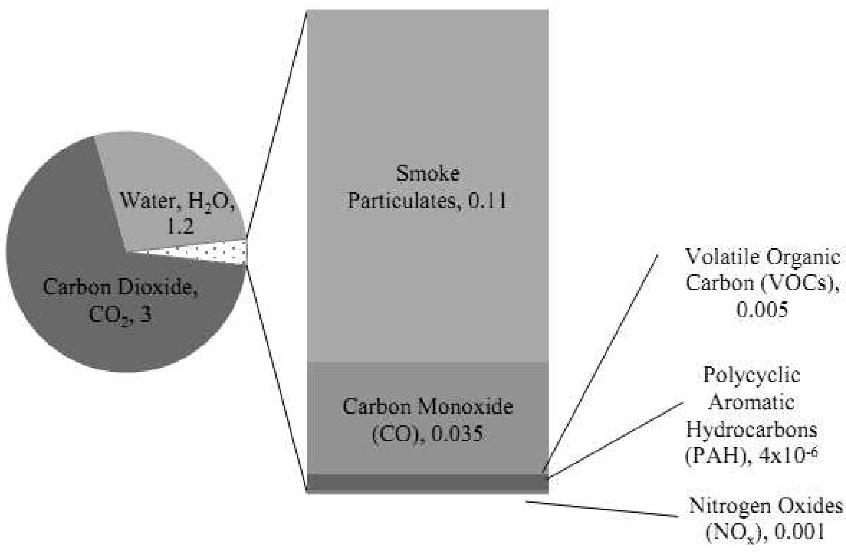

Fig. 4. Main components of a smoke plume from an in situ burn
Source: Arctic Response Technology-In Situ Burning in Ice-Affected Waters.

5 Arctic Response Technology, *Research Summary: Herding Surfactants Contract and Thickens Oil Spills for In-Situ Burning in Arctic Waters,* London, 2015, p. 13.

Exact proportions of burning process components emitted to the air depend on kind of crude oil. Third, most important, component is sooth which may amount to 2-20% of oil burned but quickly dissipates with range from the burn site. Burnt remains of oil usually sink to the bottom where they are scattered on limited area as charred lumps.

2. Dispersants

Oil spilled into water is subjected to the process known as dispersion. Mixing energy provided by waves and wind overcome surface tension and breaks oil into small droplets of varying size. Large droplets float to the surface where they coalesce in form again a slick. Small droplets form with water stable emulsion and will remain suspended in water column. Emulsion is quickly diluted by water below toxicity level. Small droplets with size less than 100 microns eventually will biodegrade. Purpose of chemical dispersants is to enhance natural dispersion and speed up process of oil microbial degradation. Modern dispersants mixture of surface active agents (surfactants) and solvents. Solvent reduces viscosity of surfactant for easier application with spraying booms and helps to penetrate oil slick. Surfactant molecule has two parts: oleophilic and hydrophilic. At water-oil interface oleophilic part goes into the oil and hydrophilic part of surfactant molecule goes into the water. This creates reduction in surface tension and promotes breaking away small oil droplets with help of mixing energy. Dispersants are manufactured for optimum efficiency in seawater which means that low or excessive salinity may weaken their action. Another important factor affecting their efficiency is type of crude oil being treated. Dispersants can be applied by boat or aircraft. Large offshore spills are best attended by large multi-engine aircrafts, while helicopters are more suitable for near-shore smaller spills. Use of chemical dispersants has raised safety concerns regarding their harmful impact upon environment. Regarding their toxicity, Environment Canada has found that modern dispersant are less toxic than household cleaners[6].

3. Mechanical recovery

Mechanical recovery of oil from water surface has an advantage of physical removal of pollutant which can be stored and safely disposed. Method is being used for cleaning small large scale spillages. It is safest method from environmental safety point of view as doesn't require chemicals and doesn't release combustion products into atmosphere. Currently in use are four main types of skimmers for oil recovery:

– Typical mechanical skimmers with conveyor belts or grab buckets picking up water contaminated with oil and transferring it into storage tanks. They very well suited for very viscous oils but their usefulness is very limited in ice-infested waters.

[6] S. Potter, I. Buist, K. Trudel, D. Dickins, E. Owens, *Spill Response in Arctic Offshore,* Cape Charles VA, 2012, p. 60.

– Vacuum skimmers using air movement to lift oil from water surface. They are not well suited for heavy oils and cannot be used on volatile oil for safety reasons. Vacuum cleaners are seldom used because the can be inefficient by recovering more water than oil.
– Weir skimmers work principle depends on oil passing over the weir which separates oil from water. They work satisfactory both on light and heavy oils but can recover considerable amount of water which requires large storage space. Weir skimmer is deployed at apex of floating boom or inside boom corralling oil slick. Popular among emergency response teams due to their compactness and simple method of deployment. Their efficiency is rated lower than oleophilic type skimmers. Can be used for oil recovery in waters with low ice concentration.
– Olephilic skimmers rely on adhesion of oil to ropes, brushes, disks or drums made of material with oleophilic properties. Oil is being scraped off from working element to containment chamber from where is pumped into storage container. Such skimmers generally work best on light and medium viscosity oils but brush type can handle even very viscous oils. They are widely regarded as versatile and efficient equipment. This type of skimmers well suited for oil recovery in ice-infested waters.

It is difficult to mull over all types of skimmers and their particular technical solutions but analysis of research results of group called Arctic Response Technology-Joint Industry Programme[7] points to brush type skimmer and rope mope skimmer. Example of first type is depicted below:

Fig. 5. Brush type oleophilic skimmer in ice-infested waters
Source: J. Rytkönen, *Mechanical Oil Recovery in Ice*.

Brush skimmers are built as remote recovery units when skimmer is being deployed by crane and as internal unit placed inside hull of icebreaker. First of such vessel has been launched and sails icebreaker 'Baltika'. She is the first Arctic class

[7] Arctic Response Technology, *Mechanical Recovery in Ice, Summary Report,* London, 2015, p. 11.

vessel featuring internal brush skimmer and asymmetric hull lines. Another type of perspective skimmer is based on rope mope unit which is built only as remote equipment. Example of skimmer is shown below:

Fig. 6. Oleophilic rope mope skimmer for ice-infested waters
Source: Arctic Response Technology, Mechanical Recovery in Ice.

Conclusion

Oil spills in Artic are contained and cleaned up basically with the same methods which were developed for milder climate operations. However, Arctic conditions require that existing methods need some modifications to suite them better to new environment. Main problem for existing technologies lies in ice-infested waters.

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Abstrakt

Usuwanie skutków rozlewów ropy naftowej w Arktyce

Rozwój przemysłu offshorowego oraz zwiększenie natężenia żeglugi w Arktyce spowodowały wzrost poziomu zagrożenia rozlewem ropy naftowej. Taki wypadek miałby katastrofalne skutki dla nieskażonego środowiska naturalnego Arktyki oraz jego mieszkańców. Istnieje wiele metod ograniczania i usuwania skutków rozlewów ropy naftowej. Wszystkie metody były opracowane dla operacji przeprowadzanych w cieplejszym klimacie, ale po pewnych modyfikacjach mogą być zastosowane w warunkach arktycznych. Największym wyzwaniem dla ekip usuwających skutki awarii są duże odległości oraz zalodzenie wód morskich.

Słowa kluczowe: Arktyka, rozlew olejowy, środek dyspersyjny, wypalanie kontrolowane, zbieraczka oleju