Research on Oil Spill Response Technology in Cold Water Condition
- State-of-the-art of the recent studies-

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Abstract

This oil spill in cold water conditions study started in 2017 to collect information and review various researches on spill response technology. A large amount of scientific research and testing has been conducted in the past 50-years to improve equipment and methodologies available to respond an oil spill in cold water condition. This paper describes the past oil spill events: Exxon Valdes in 1989 and Deepwater Horizon in 2010, and also presents a part of the current progress of oil spill research on the prediction of spilled oil behavior in the Sea of Okhotsk and by Joint Industry Programme (JIP).

Key words: oil spill, sea ice, cold ocean.

INTRODUCTION

There are some unique considerations to address when considering operations in the Arctic, including prolonged periods of darkness, extreme cold, distant infrastructure, presence of sea ice offshore, unique ecological system, and a higher cost of doing business.

In cold ocean environments with sea ice present, oil-spill cleanup is technologically difficult since spilled oil remains under/between sea-ice cover. Up-to-date information of spilled oil drift is indispensable for the development and implementation of an effective response.

PAST OIL SPILL EVENTS

Exxon Valdes on March 24, 1989, Alaska

The tanker Exxon Valdez grounded on Bligh Reel in Alaska's Prince William Sound, rupturing its hull and spilling nearly *11 million gallons* of Prudhoe Bay crude oil into water. Prior to the 2010 Deepwater Horizon oil spill, it was the largest single oil spill in U.S. coastal waters. Figure 1 shows the geography of Alaska and the oil spill location[1].

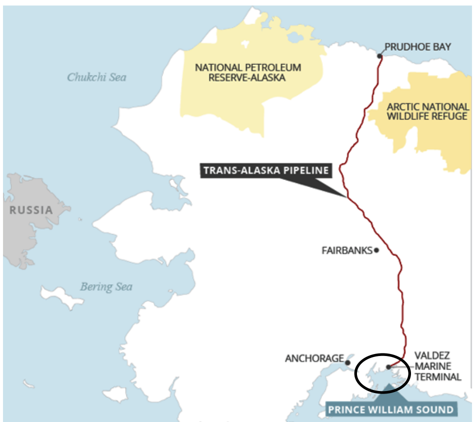

Fig.1 The location of the oil spill in 1989.

Deepwater Horizon on April 20, 2010, GOM

The oil drilling rig Deepwater Horizon, operating in the Gulf of Mexico, exploded and sank resulting in the death of 11 workers and the largest spill of oil in the history of marine oil drilling operations. *210 million gallons* of oil flowed from the damaged well over 87-days period, before it was finally capped on July 15, 2010. The location of the oil spill is shown in Fig. 2[2].

Fig.2 Location of the oil spill in 1989.

The oil budget of the Deepwater oil spill accident is shown in Fig.3 which is based on calculation made July 2010[3]. The seven categories generally fall into three groups:

- *Human intervention*: direct recovery from the well (17%); in situ burning (5%); skimmed (3%); chemically dispersed (16%).
- *Natural Processes*: naturally dispersed (13%); evaporated or dissolved (24%).
- *Other (22%)*: refers to the oil remaining after subtracting the above estimates from the total estimated release; possible fates include remaining in the water column, settling to the sea floor, mixing with sediment, ingested by microbes, or collected during shore cleanup activities.

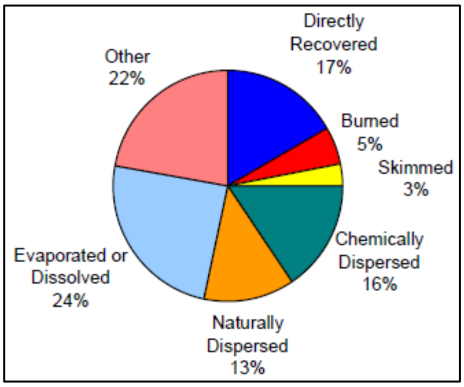

Fig.3 Oil budget of the Deepwater oil spill.

RECENT RESEARCHES

Prediction of Spilled Oil Behavior in the Sea of Okhotsk

The exploitation of gas and oil fields in areas offshore of Sakhalin Island, estimated to contain 45 billion barrels (TOE), has continued since the 1990s. Sakhalin I and II projects are already producing oil and gas commercially. The locations of the Sakhalin I and II project elements are shown in Fig. 4.

The Engineering Advancement Association of Japan (ENAA) started a six-year program, "A Study to Predict Spilled Oil Behavior in the Okhotsk Sea Under Sea Ice Conditions," in 2003 that was sponsored by the Ministry of Economy, Trade, and Industry (METI) of Japan. The University of Tokyo (Prof. Hajime Yamaguchi) and Hokkaido University (Prof. Kay I. Ohshima) joined the project to work on the numerical modeling of the ice-spilled-oil rheology and the ocean circulation, respectively, of the Okhotsk Sea[4, 5].

Up-to-date information of spilled oil drift is indispensable for the development and implementation of an effective response. Shorter computation times would be advantageous for timely implementation of oil-spill cleanup procedures. Predictions using data sets for 2003 and 2005 are shown in Figs. 5 a) and b), respectively.

Fig.4 Schematic of the Sakhalin I and II Project elements.

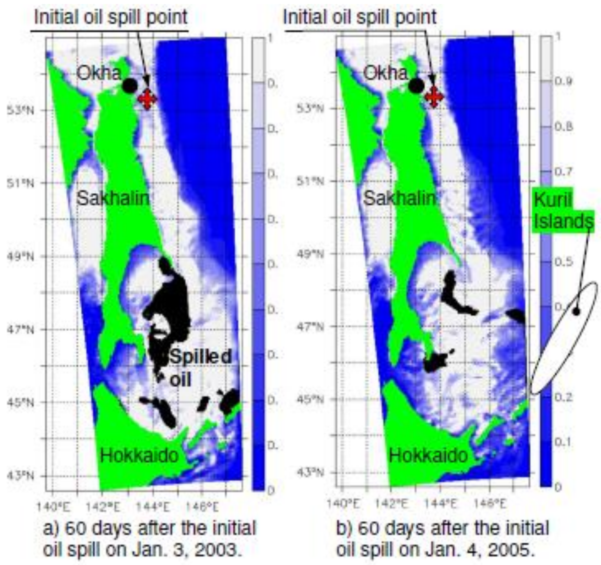

Fig.5 Predictions of the behavior of oil spilled in the oil production field offshore northeast Sakhalin, using data sets for 2003 and 2005.

Joint Industry Programme (JIP)

The Arctic Oil Spill Response Technology Joint Industry Programme (JIP) was initiated in 2012 and terminated in 2017. It represents a collaboration of ten international oil and gas companies (BP, Chevron, ConocoPhillips, Eni, ExxonMobil, Gazprom-neft, North Caspian Operating Company, Shell, Statoil, and Total) that have come together to further enhance industry knowledge and capabilities in the area of Arctic spill response as well as to increase understanding of potential impacts of oil on the Arctic marine environment[6].

The program is managed by the International Association of Oil and Gas Producers (OGP) and focused on six key areas of oil spill response:

- Mechanical containment and recovery,
- In-situ burning,
- Dispersant application,
- Detection and mapping including remote sensing,
- Trajectory modelling, and
- Environmental effects - Net Environmental Benefit Analysis (NEBA).

Figure 6 shows the graphic the six different JIP research areas[7].

Fig.6 Graphic showing the six different JIP research areas.

One example of the six key research areas, in-situ burning is a response technique proven very effective for removal of oil in ice-affected conditions, especially in snow and dense sea ice. Oil on water or between ice floes can be disposed of quickly, efficiently and safely by controlled burning. This technique works most efficiently on thick oil layers, so the oil is contained by fire-resistant booms or ice. Through burning, on average, about 80-95% of oil volume is eliminated as gas, 1-15% as soot and 1-10% remains as a residue. Controlled burning has been proven to work in the Arctic[8]. Figure 7 illustrates controlled in-situ burning system in broken ice condition[7].

Fig.7 Illustration showing controlled in-situ burning in broken ice.

Research Activities in Europe

European countries have been historically conducting researches on arctic response techniques. Finish Aker Arctic continues to develop spilled oil recovery vessels and equipment. In 2006 the dry cargo vessel *MS Runner* sank in the Estonian waters of Gulf of Finland, and oil spilled 30-50 tons. The main tools used in this accident were the bucket brush skimmers as shown in Fig. 8[9]. As a result, some 15 tons of oil was collected and most of the oil was pumped out from the wreck later in the following summer by diving systems. New technologies are being developed in Finland as shown in Fig. 9[9].

Fig.8 The spill response task by the vessel (left) and the oil recovery bucket in operation (right) in Finland.

Fig.9 Finland's newest oil spill response vessel *MS Louhi* (left) and oil recovery bucket (right).

CONCLUSION

Oil spill prevention is a top priority for the oil and gas industry and becomes one of the first concern to pertinent organizations especially after the Exxon Valdez oil spill accident was experienced.

Since any oil spilled in the Sea of Okhotsk may drift to the coastal areas of Hokkaido and cause damage to the marine environment and economy of this area, continuous studies and information collection of current progress of oil spill research are indispensable for us.

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REFERENCES

1 NOAA official homepage, accessted in January 20, 2018.
2 "DEEP WATER, The gulf Oil Disaster and the Future of Offshore Drilling," Report to the President, National commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling. January 2011.
3 "Deepwater Horizon Oil Spill: The Fate of the Oil," CRS Report for Congress, December 16, 2010.
4 Yamaguchi, H., K. I. Ohshima, and N. Nakazawa (2011): Numerical Prediction of Spilled Oil Behavior in the Sea of Okhotsk Under Sea Ice Conditions. OTC 22123, *Proc. Offshore Technology Conference 2011, Houston, USA, 2011*.
5 Nakazawa, N., J. Ono, H. Yamaguchi, K. I. Ohshima, A. Kurokawa (2012): Numerical Prediction of Spilled Oil Behavior under Sea Ice Conditions: Modification of the 2011 Model. OTC 23801, *Proc. Offshore Technology Conference 2012, Houston, USA, 2012*.
6 "Summary of Current Oil Spill Response Research Activity (Industry and Government)," Working Document of the NPC Study: *Arctic Potential: Realizing the Promise of U.S. Arctic Oil and Gas Resources*, Made Available March 27, 2015.
7 "Arctic Oil Spill Response Technology Joint Industry Programme Synthesis Report," May 3, 2017.
8 Mullin, J. (2012): The Oil and Gas Industry's Commitment to Responsible Arctic Operations: An Innovative Arctic Oil Spill Response Technology - Joint Industry Programme. OTC 23800, *Proc. Offshore Technology Conference 2012, Houston, USA, 2012.*
9 Wilkman, G., E. Ritari, A. Uuskallio, M. Niini (2014): Technological development in oil recovery in ice conditions. OTC 24592, *Proc. Offshore Technology Conference 2014, Houston, USA, 2014.*

Summary in Japanese

和文要約

氷海域における流出油対策技術
ー近年の研究レビューー

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北極海における海底資源の賦存確認による同海域での石油や天然ガスの開発、また、海氷の減少により北極海航路が現実味を帯びてきたことに伴い、氷海域での油流出事故の発生が懸念されている。1989 年に発生したエクソンバルディーズ号の座礁による原油流出事故以来、流出事故の防止と回収技術の研究が進んだものの、氷と混在する流出油の回収は多くの困難を伴う問題である。

本稿では、上記流出事故と 2010 年にメキシコ湾で発生した Deepwater Horizon 爆発事故による原油流出事故を振り返るとともに、近年の国内外の流出事故対策の研究を紹介する。