Annual Progress Report Form - Oil Spill Recovery Institute

An electronic copy of this report shall be submitted by mail, or e-mail to the OSRI Research Program Manager wspegau@pwssc.org and Financial Office poswalt@pwssc.org

Mailing address: P.O. Box 705 - Cordova, AK 99574 -

Deadline for this report: This report is due 30 days prior of the anniversary of the effective date of the grant. In the projects final year the annual report will be replaced with a final report.

Today’s date: June 5, 2009

Name of awardee/grantee: University of Alaska

OSRI Contract Number: 08-10-13

Project title: Oil in Ice: Transport, Fate, and Potential Exposure

Dates this progress report covers: July 1, 2008 to May 31, 2009

PART I - Progress Report on Activities

The progress report must include the following elements.

1. Non-technical Abstract or summary of project work to date that does not exceed two pages and includes an overview of the project. The abstract should describe the nature and significance of the project and progress made toward realizing project goals. It may be provided to the Advisory Board and could be used by OSRI staff to answer inquiries as to the nature and significance of the project.

2. Brief review of the objectives as described in original proposal and progress report related to these objectives.

3. Describe problems or roadblocks encountered in project implementation.

4. Highlight accomplishments, whether or not they were part of the original proposal.

5. Conclusions to date.

6. Appendix including copies of all written reports or publications completed or in progress, resulting from the project work. This also includes abstracts of papers presented at conferences. Please note the acknowledgment of OSRI support stated in Section 10.3.4 of the Grant Policy Manual.

1. Abstract

The pore structure of sea ice provides space for the entrainment of oil and water-soluble contaminants. Both can be released to the ice surface and into the ocean during the initial entrainment phase and spring warming; the release, its timing and rate affect remediation strategies and the potential biological impact of oil spills in sea-ice covered waters. The aim of this project is to provide relevant information on microstructural constraints on oil entrainment and mobilization, simulate movement of water-soluble compounds (WSC) released from entrained oil, and contribute a small-scale module to the development of a model of larger-scale dispersal of oil and oil-associated compounds in sea-ice environments. The study is part of an overarching effort that examines specific aspects of entrainment and release of oil and oil-associated compounds in sea ice.
Appendix J – OSRI Grant Policy Manual

The work is divided into two parts. One aspect of the study focuses on microstructural controls of oil and WSC entrainment and mobilization. This is achieved through a series of laboratory experiments focusing on physical mechanisms and relevant boundary conditions for entrainment and release. Furthermore, we are contributing to the design and microstructural sample analysis of ice column experiments conducted at SINTEF in Norway, with the aim of quantifying the microbiological and chemical aspects of oil and WSC entrainment and mobilization.

The second component of our study employs a fluid dynamics model developed to simulate brine movement in and under growing sea ice at high spatial resolution (mm- to cm-scale). This model is used to quantify fluxes of fluid and WSCs through the porous ice matrix as a function of depth in the ice and relevant boundary conditions (ice growth rate, temperature and porosity distribution). In conjunction with release rates obtained from SINTEF experiments and other work, these simulations will allow quantification of the fluxes of potentially harmful water-soluble substances into the water column. In conjunction with the ice growth experiments, the work will also help delineate the time frame over which such mobilization can occur in growing ice before further ice growth effectively immobilizes the oil until the onset of melt.

To address the question of potential mobilization of oil and WSCs during the melt phase, laboratory experiments will be carried out and analyzed in conjunction with existing field data and a porosity-permeability model to assess potential release of WSCs later in the season.

The work will provide information on the timing of WSC and oil movement and mobilization that can help with the assessment of potentially harmful effects on sea-ice and under ice fauna and flora, as well as provide guidance to planning of spill clean-up operations with respect to windows of opportunity for effective spill response.

2. Objectives and progress made

This work contributes to the project “Oil in Ice: Transport, Fate, and Potential Exposure” coordinated by the NOAA Coastal Research and Response Center. The objectives of this overarching program relevant to our work and progress made in addressing these are as follows:

(i) Conduct transport/exposure laboratory studies to determine how ice growth conditions affect transport and fate of entrapped oil in ice and to collect quantitative data on the partitioning of oil components (bioavailable fractions) into brine inclusions and channels and rates of vertical transport.
• A series of experiments has been completed in the Geophysical Institute cold lab to examine oil entrainment and movement in relation to pore microstructure, temperature and porosity. The dependence on oil viscosity was also studied.
• Analysis of data from these experiments is underway and is yielding important insights into penetration depths of oil into ice, microstructural constraints on oil mobilization and heterogeneity in oil distribution at the mm- to cm-scale.
• Detailed microstructural analysis in support of ice column experiments at SINTEF demonstrated the validity of the experimental approach in simulating growth of quasi-natural sea ice in the lab. Lab visits and study of the experimental set-up also led to improvements in experimental design.

(ii) Develop an oil-in-ice sub-model.
• Implemented the bulk of the physical component of a joint fluid dynamics code but halted development
Appendix J – OSRI Grant Policy Manual

after collaborators became unavailable; decided to change the focus of the fluid dynamics modeling strategy to work with an existing model;
• Based on the fluid dynamics modeling and the aforementioned laboratory studies, a parameterization scheme or simple model will be developed to allow integration into the large-scale oil spill model operated by SINTEF. This model will describe fluid exchange and entrapment as a function of temperature, ice growth rate and other relevant parameters.

3. Describe problems or roadblocks encountered in project implementation

The project has been impacted by delays in the schedule of the overarching Oil in Ice program. Moreover, a planned visit and thesis work by a graduate student at the University of New Hampshire (UNH) was cancelled on short notice. This impacted work that had already been completed in preparation for this collaboration and required a revision of the overall fine-scale modeling strategy. Based on discussions at SINTEF in January 2008 a fluid dynamics simulation was to be developed that would account for physical redistribution and biochemical dissolution–reaction kinetics of dissolved hydrocarbons in sea ice. Our task was to provide the physical fluid dynamics framework in a clear and well-documented form that could be modified and extended by others. The code was to be extended by a graduate student from UNH to include the biochemical module of dissolution and reaction kinetics. The graduate student would have developed the analytical approach to the biochemical model prior to visiting us at UAF and get introduced to the code base during a visit to Fairbanks. At this stage and based on feedback from the student it was planned to make modifications to the physical module to facilitate the addition of the biochemistry module. Model validation and simulations in the framework of the JIP would have been performed as a joint approach led by the student. After the participation of the graduate student was cancelled in March, we decided to rest the code development as we did not have the resources to develop the biochemical approach and perform the model validation and evaluation of simulation results ourselves. Instead we consulted with collaborators at UNH and NOAA and decided to focus on results we could gain from the existing (physical-only) fluid dynamics model.

4. Accomplishments

• Successfully completed laboratory experiments on oil entrainment and mobilization
• Two site visits at SINTEF led to refined experimental design and trained SINTEF employees in microstructural analysis
• Stratigraphic and microstructural analysis demonstrated that SINTEF ice column experiments produce columnar sea ice representative natural sea ice
• Made significant progress with data analysis of laboratory experiments to aid with interpretation of SINTEF experiments and model development
• Graduate student (Jonas Karlsson) working on the project presented a poster summarizing first results from experiments at IPY Symposium in March 2009 and was recognized with an award for runner-up in the student poster competition
• Results of laboratory experiments provided crucial insights in the partitioning of oil within the pore space in both cold and warm sea ice.

5. Conclusions to date

• Ice grown in SINTEF ice column experiments is representative of natural conditions and yields reproducible textures and microstructures.
• The bulk of oil released under growing sea ice penetrates the bottommost centimeters of the ice column, the so-called skeletal layer.
• Entrapment and penetration depth are governed by the porosity profile of the ice and hence the boundary conditions controlling the latter, including ice growth rate and under-ice currents.
• North Slope Sweet Crude exhibits deeper penetration into brine channels during the entrapment phase because of its substantially lower viscosity as compared to North Sea oils used in SINTEF experiments.
• In warm sea ice, individual brine channels can sustain significant flow and control the bulk, macroscopic flux of oil and WSCs through the ice matrix.
• In warm ice, mobilization of oil through free or forced convection can result in substantial heterogeneities in oil distribution at the cm to dm-scale.
• Upward migration and pooling of oil at the ice surface proceeds differently in differently sized compartments of the pore space, resulting in a phased mobilization and migration of oil (and by implication, WSCs).
• While oil is encapsulated predominantly in the inter-lamellar pore space in cold ice during the growth phase, it penetrates both inter-lamellar pore space and brine channels in warm ice.

Planned work for the next year:
• Complete analysis of lab experiments (to be presented at the 20th IAHR Symposium on Ice in Finland, June 2010)

• Develop parameterization to account for potential contamination due to oil entrapped in sea ice during the growth period of ice. We will build on our existing fluid dynamics code to investigate the ice–ocean interface flux during the growth phase, and in particular its dependence on distance from the interface. This will build on our experience with depth-integrated ice–ocean exchange. We expect that this work will involve defining a model grid scale that is fine enough yet allows us to simulate growth for a large ensemble of boundary conditions in a reasonable amount of time (approx. 2 days per simulation). The grid spacing will probably be of the order of 5 mm. Simulations will be performed to establish if the model results depend numerical characteristics of the simulations (e.g. domain size, grid spacing). We will deduce a heuristic parameterization that is based on the simulations; it will likely be possible to define a simplified physical description that will allow us to suggest proper scale dependence. This parameterization will then be made available to SINTEF for integration into their large-scale model.

6. Appendix

A. Report on microstructural and stratigraphic analysis of ice grown in SINTEF columns (attached)

B. Poster presentation by Karlsson et al., “Laboratory experiments on entrapment and movement of oil in sea ice”, given at INRA IPY Symposium “Lessons from Continuity and Change in the Fourth International Polar Year”, Fairbanks, AK, March 4-7, 2009 (attached)

Appendix J – OSRI Grant Policy Manual

Part II - Annual Financial Statement

Please complete the attached Excel spreadsheet (GPM-Appendix I – Fin Rpt Form).

See attached document.