Project information

Keywords
Oil In Ice
Project title
Net Environmental Benefit Analysis Tool to Assess the Environmental Effects of Arctic Oil Spills and Oil Spill Response Technologies -NEBA
Year
2016
Project leader
Lionel Camus
Geographical localization of the research project in decimal degrees (max 5 per project, ex. 70,662°N and 23,707°E)
77°53′54″N 16°43′21″Ø
Participants

Jasmine Narhgang, UiT-The Norwegian Arctic University

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Flagship
MIKON
Funding Source

The International Association of Oil and Gas Producers

The Innovation Fund Denmark

COWIFonden

Akvaplan-niva

Summary of Results

There were two main research objectives which we have addressed in this project: What are the impact of three mitigation techniques which were natural attenuation, chemical dispersant application and the residues of burnt oil, on the 1) sea ice biological communities and 2) the oil biodegradation processes and persistence in the sea ice.

Concerning the biological impact, the study on the plankton communities was performed *in situ* in the mesocosms which were deployed for 6 months in the pack ice and also in microcosms in the laboratory. The study on the sea surface microlayer was performed *in situ* using microcosms. Finally, the polar cod study was performed in the laboratory.

Key findings were as follow:

- In the mesocosms, the different treatments had no discernible effect on sea ice growth and thickness.
- The oil alone or with dispersant prevented light penetration through the ice while residues of burnt oil let a little bit of light to penetrate the sea ice.
- The controls exhibited a very low penetration of light, which is presumably due to the absorption of light by the opaque walls of the mesocosms which may have implication on primary production.
- None of the treatments had any discernible impact on the exchange of nutrients between the brine channels of sea ice and the underlying water
- Most taxonomic groups of sea ice protists exhibited low species richness with the exception of pennate diatoms, which had the highest

number of species, followed by dinoflagellates and choanoflagellates

- Overal the residues of burnt oil treatment had a lesser ecological impact on ice algae than natural attenuation or dispersant application

- No major effects were observed on the pelagic plankton community. While there were some significant effects on microplankton, but the potential indirect effects on the higher trophic levels was not investigated.

- Zooplankton were not affected by the levels of exposure in this study, although some post-exposure effects were observed on nauplii malformation and development.

- No significant difference in microbial abundance between sea surface layer and underlying water as well as between various treatments was observed. In contrast, differences between the surface layer and the underlying water was observed on a microbial community level and these differences were less apparent amongst treatments.

- No long-term effects on survival, growth or reproductive investment were revealed in polar cod exposed to mechanically dispersed oil, chemically dispersed oil or residues of burnt oil. The latter may however have led to increased interruption of maturation in female fish but this needs to be further investigated.

Concerning the oil biodegradation and persistence the project focused on the assessment of the persistence and biodegradation of oil, under natural conditions, following different response options, including natural attenuation, in situ burning (on water and on ice) and chemical dispersion (i.e., addition of oil plus dispersant without mechanical mixing), as well as natural attenuation on different types of shoreline (rock and sediment). Reminder, this project does not focus on the efficiency of response techniques (i.e. dispersant option or in situ burning option). Clearly, this project does not address the relevance of these response options for the Arctic environment, but focus only on the fate of the oil after the response (i.e. fate of dispersed oil and fate of *in situ* burning (ISB) residues).

- Concerning the experiment performed with mesocosms, the oil was trapped at the surface of the icepack. A low dissolution kinetic of the lightest compounds from the oil slick was observed, followed by a diffusion of these compounds through the ice cores. This diffusion process explains the concentration of dissolved Polycyclic Aromatic Hydrocarbons (PAHs) measured in the water column under the ice in all mesocosms. Nevertheless, the kinetic of these phenomena was higher for the oil + dispersant treatment. In addition, and for the oil trapped in the top section of the ice pack, biodegradation of light alkanes was observed for oil + dispersant and oil treatments. The microbial communities were found to be different at different ice-layer depths and significant changes between communities from ice and seawater were found. Nevertheless, Arctic microbial communities were found to shift in response to an oil spill within the first month of exposure. Arctic microbial communities potentially able to biodegrade oil compounds are present and active in the sea-ice layers in the event of an oil spill even during the winter months. Investigating the active portions of the bacterial community has shown that some changes are more visible on the activity of organisms rather than on the total population. From the hydrocarbon degradation incubation experiments, we conclude that bacteria present in sea ice were able to respond to and degrade petroleum hydrocarbons within weeks. This microbial activity showed a strong seasonable influence. During the April incubations, the observed microbial growth and degradation rates were less pronounced than in May.

- Concerning the bacterial community in the sea water column, their structure analysis showed a significant difference in the “oil + dispersant” mesocosms compared to the “control” or other treatments. The bacterial community shifted towards very high numbers of *Colwellia* organisms as well as a higher activity of *Oleispira* genus. Members of these genera have been identified in crude oil contaminated seawater in Greenland and are known to include many oil degrading species. These results indicated that oil may have leaked through from the ice layer to the seawater, where it was actively degraded by microorganisms. The biodegradation potential of bacteria present in seawater was confirmed by the short term incubation experiments.

Master and PhD-students involved in the project

PhD:

Kirstine Toxvaerd, Danish Technical University and COWI

Morgan Bender, UiT-The Arctic University of Norway

Master

Marina Pancic, Danish Technical University

Pil H. Hansen, Danish Technical University

Jean-Sébastien Côté, University of Laval (Canada)

For the Management

The ultimate objective of the project is to provide data that will be used by a tool that has been developed to perform a net environmental benefit analysis to manage oil spill in the Arctic. The tool has been developed along this project by the project partner Rambol. However, during a workshop during summer 2016, it appeared that the tool needs to be further optimized and validated before new data can be used. Also, our data need to be scientifically approved through a peer review publication process before thy can be used for management purposes. We are now in the process of writing a serie of papers that will be published in a special issue of Marine Environmental Research. We are also in communication with the Norwegian coast guards which are the responder to oil spill in Norwegian waters and also the Norwegian environmental protection agency (miljø direktorat) which is the norwegian regulator to inform them about our findings and the vast amount of data set which will be available once published.

Published Results/Planned Publications

all the papers are in preparation, here is a list which indicates topics of the papers and authors:

1 introduction paper by Camus & Smit (Akvaplan-niva and Shell)

2 oil biodegradation and persistence by Le Floch et al (Cedre)

3 OSR impacts on Arctic microbial populations by Boccadero et al (IRIS)

4 seasonal ecology in Arctic seas and exposure potential by Wiedmann et al (Akvaplan-niva)

5 OSR effects on key arctic zooplankton by Toxvaerd et al (Danish Technical University and COWI and UNIS)

6 Acute and chronic effects of spills on population dynamics – Calanus by Jak et al (IMARES)

7 Long term resilience of polar cod by Bender et al (Akvaplan-niva & UiT)

Communicated Results

At Arctic Frontiers, Tromsø, January 2016:

Talk

Lionel Camus, Jack Word, Robbert Jak, Stephane Le Floch, Christophe Aeppli , Catherine Boccadoro, Eric Comerma, Jean Sebastien Côté, Helene O. Eide, Marianne Frantzen, Pil H Hansen, Maja Hatlebakk, Morten Hjorth, Eva Koehler, Zach S Leavit, Eva Leu, Patricia Matray, Jasmine Nahrgang, Torkel G Nielsen, Marina Pančic, Stig F Petersen, Kjetil Skagerup, Janne Søreide, Kirstine Toxværd, Jean Eric Tremblay, Magnus Wiedmann. Net Environmental Benefit Analysis support Tool to Assess Oil Spill Response Technologies and the Environmental Effects of Arctic Oil Spills

Posters

Helene O. Eide, Janne E. Søreide, Torkel Gissel. Nielsen, Morten Hjorth, Pil H. Hansen and Kirstine U. Toxværd. Effects of crude oil, chemical dispersed oil, and in-situ burning on Arctic zooplankton reproduction.

Marianne Frantzen, Jasmine Nahrgang, Stephane Le Floch, Lionel Camus. Long-term resilience in polar cod exposed to dispersed oil and burned oil residue

Jean-Éric Tremblay, Jean-Sébastien Côté and Jonathan Gagnon. Light penetration, nutrients and ice-algal growth in experimental mesocosms exposed to oil and dispersants

Stéphane Le Floch, Nolwenn Le Cuff and Fanny Chever. Environmental effects of arctic oil spills: oil biodegradation & persistence

Kirstine Toxværd, Pil Hagenbøl Hansen, Eva Koehler, Marina Pančic, Maja Hatlebakk, Helene Overaa Eide, Janne E. Søreide, Torkel Gissel Nielsen, Morten Hjorth. Effects of oil spill responses on key Arctic zooplankton species

Robbert Jak, Jacqueline Tamis, Pepijn de Vries, Lia Hemerik. Acute and chronic effects of oil spills on the population dynamics of *Calanus hyperboreus*

Christoph Aeppli, Paty Matrai. Effects of Oil and Dispersants on Microbial Community and Oil Weathering in Arctic Sea Surface Layer

At SETAC Orlando, November 2016

Three Posters:

Kirstine Toxværd, Pil Hagenbøl Hansen, Eva Koehler, Marina Pančic, Helene Overaa Eide Maja Hatlebakk, Janne E. Søreide, Torkel Gissel Nielsen, Morten Hjorth1 Effects of oil spill responses on key Arctic zooplankton species

Marianne Frantzen, Jasmine Nahrgang, Stephane Le Floch,Morgan L. Bender, Jocelyn H. Palerud, Lionel Camus Long term resilience in polar cod exposed to dispersed oil and burned oil residue

R.G. Jak, P. de Vries, J.E. Tamis, M. Hjorth, L. Camus & L. Hemerik Matrix models for Arctic Calanus species: scaling up from experimental toxicity for oil components on individuals to population level effects

One talk:

Boccadoro, Austerheim, Maeland, Ramanand, Lefloch, Chevet, Aeppli, Camus Impact of oil and spill treatments on arctic sea ice and seawater microbial populations

Interdisciplinary Cooperation

This project required the cooperation accross several disciplines such as: chemistry, microbiology, biology and finally engineering.

Budget in accordance to results

The budget allowed to disseminate the scientific findings in peer reviewed journal and to also communicate with stakeholders such as the Coast Guard (the responder to oil spill in Norwegian waters) and the Norwegian Environmental protection Agency (the Norwegian regulator).

Could results from the project be subject for any commercial utilization

No

Conclusions

An unprecedented data set has been produced to understand better the long term impact of oil spill and response technology on the sea ice communities. Also, knowledge in oil weathering and microbial activities has been generated throughout the entire lifetime of the sea ice from ice formation to ice melting. This data expands the knowledge base that is needed to perform a NEBA by the stakeholders in order to identify the best response option to mitigate an oil spill in ice.