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1.0	draft	27th February 2019	Kim Gustavson Janne Fritt-Rasmussen Susse Wegeberg	Kim Gustavson, WP4 leader
2.0	final	28th February 2019	Kim Gustavson Janne Fritt-Rasmussen Susse Wegeberg	Steering group

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Executive summary

D4.15 includes abstracts on manuscripts in preparation for publication in peer review journals, as well as abstracts on platform presentations at international conferences. Results that will be communicated in manuscripts are all from experimental work conducted at arctic condition in Greenland 2017 and 2018. Topics in manuscripts and presentations includes: 1) rates of natural removal and degradation of stranded oil on rocky surfaces; 2) effect of oil smothering on the tidal macroalgae in both an aspect of self-cleaning potential, as well as effects on its photosynthetic activity; 3) effectiveness and potential for shoreline in situ burning of oil spills – a Greenland field pilot study and; 4) environmental effects coastal in situ burning of oil spill;– a Greenland field pilot study.

Manuscript for peer review scientific journals:

Oil, tide and tiles – Testing natural degradation and removal rates of crude vs heavy fuel oil along rocky shorelines in the Arctic

Kim Gustavson[1], Sophia V. Hansson[1], Janne Fritt-Rasmussen[1] and Susse Wegeberg[1]

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Abstract

Due to a northward shift in offshore activities, including increased shipping traffic and oil and gas exploration there is a growing risk of oil spills in the arctic, potentially reaching and affecting nearshore arctic ecosystems. In order to estimate the rate of natural removal and degradation of stranded oil on rocky surfaces in the Arctic, we simulated oil spill events at two locations along the west coast of Greenland (i.e. in low and middle Arctic climatic regimes). Two types of oil, crude oil (Naphthenic North Sea crude oil) and a heavy fuel oil (HFO; IFO 180), were applied to tiles mimicking rocky shore substratum, and then placed in different height levels of the tidal zone (i.e. low tide, high tide, above shorline facing sun/precipitation exposure, and above shoreline shielded from sun/precipitation exposure). Oiled tiles (n = 28 for each tidal level) were installed to ensure that natural removal rates of the oil, in relation to different water cover regimes and air exposure times, were obtained. The experiment was performed under 4 months (May-September 2017) during which oil remains were sampled continously and chemical analysed. Already on day one of the experiment, visual observations of oil remians on the tiels indicated large differences in removal rates between the two oil types (Crude oil>HFO), as well as between locations in the tidal zone (low tide>high tide>above tide exposed>above tide sheilded). These observeations were later on confirmed by analysis throughout the experiment; i.e. the crude oil was washed off more readily and at a faster rate than the HFO, which is ascribed to differences in physical characteristics of the oil types (i.e. HFO has a higher content of wax and asphaltenes and hence a higher pour point and higher viscosity). We therefore conclude that the self-cleaning potential of a rocky shoreline coast following a stranded oil spill event is considered high if 1) the high tidal amplitude ensures two daily passing of seawater wash of the shoreline, and 2) if the spill entails a lighter oil type. However, if the oil spill is of HFO type the natural removal and degradation is expected to be significantly slower and the self-cleaning potential less efficient. Such knowledge of natural self-cleaning potential is key for establishing strategies for future oil-spill response in Arctic coastal areas and seas.

Submission date July 2019

Smooth or smothering? The self-cleaning potential and photosynthetic effects of Arctic macroalgae *Fucus distichus* following an oiling event

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Abstract

Due to an increasing economic and political interest to exploit offshore oil and gas reserves facilitated by the receding sea ice extent and improvements in sea transport), the Arctic is facing an unprecedented risk of marine oil spills. Any potential shoreline landing of oil spill could lead to acute and chronic impacts on the intertidal ecosystems. However, comprehensive knowledge on direct effects of oil spills on macroalgae in general, and in Arctic ecosystems specifically, is still lacking. This study therefore assess the effect of oil smothering (i.e. oiling) on the tidal macroalgae *Fucus distichus* in both an aspect of self-cleaning potential, as well as effects on its photosynthetic activity. Oiling from four oil types (ANS, Grane, IFO30 and MGO) were simulated by exposing oil emulsions to tips of *Fucus distichus*, after which the self-cleaning potential of the macroalgae was tested by wash in sea. The longest measured half-life for sea wash was four days, indicating that oiling from most oil types is washed off by seawater within 14 days. Depending on oil type, oiling may also inhibit or stimulate photosynthetic activity in *Fucus distichus*; i.e. Grane appears to inhibit photosynthetic activity whereas ANS, IFO30 and MGO appears to stimulate photosynthetic activity. Results indicate 1) that the removal rate of oil smother on seaweed is relatively fast as most oiling from all four oil types tested was washed off by the sea within a matter of days; 2) that effects of oiling on photosynthetic activity depends on the oil type tested, which can have either inhibitory or stimulating effects; and 3) that the photosynthetic activity of macroalgae continues to be effected by oiling, even if oil on the tip surface is almost or completely washed off.

Submission date June 2019

Effectiveness and potential for shoreline in situ burning of oil spills – a Greenland field pilot study

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Abstract

In situ burning is a well proven offshore oil spill response technology, latest used during the Deep Water Horizon oil spill in the Gulf of Mexico. The use of in situ burning near the coast is less investigated, as the method is generally not recommended close to land due to the smoke formation and potential impact of inhabitants and animal congregations. However, in the Arctic, a shoreline in situ burning operation may be a possibility due to the remoteness and scarce populated areas. Hence, a shoreline in situ burning field pilot study took place in Greenland in summer 2017. 600 L of a North Sea crude oil was released into a Pyroboom, ignited and burned. The burning efficiency was high and in line with what has previously published for field burns. A bucket skimmer system was tested to collect the burn residue after the burn. The environmental impacts on the coastal community was also investigated and the impacts was identified as either smothered, heated and/or burned in the place of the burn. Overall, the method proved to be not very complicated and with a high operational potential, however more oil types should be tested to fully investigate the potential of the method.

Submission date July 2019

In situ burning of large-scale experimental oil spill in Greenland waters

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Abstract

In summer, 2017 an in situ burning large-scale field experiment took place in a close fjord in Greenland. The purpose of the experimental work was to: 1) investigate the possibility of collecting the residue after the burn, 2) investigate the environmental impacts from such an operation to a cold environment and 3) conduct a large-scale in situ burn including a heavy fuel oil. 1000 L of IFO180 was released in a Pyroboom that was dragged by two vessels, the oil was ignited and burned for approximately 40 minutes. The Pyro boom was disconnected and a skimmer trawl system was connected for testing the possibility of collecting the burn residue. The trawl system proved to be useful, however the detachment of the Pyroboom was not suitable for the operation due to lack of control of residue. Approximately 20 kg was collected by the trawl and the burn efficiency was estimated to be in line with other large-scale burns. The environmental samples are about to be analyzed and will be included in the final version of the manuscript.

Submission date August 2019

Tidal zone community impact from coastal in situ burning trial in Greenland

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Abstract

A trial of coastal in situ burning (ISB) of an experimental oil spill was performed in 2017 in the vicinity of Færingehavn, south of Nuuk, Greenland, in a selected bay with suitable coastline. For monitoring environmental effects of the coastal in situ burning, a baseline of the tidal community was performed in the area for the coastal in situ burning test and in a reference area. The baseline was established by sampling of all tidal community organisms in 2017 (e.g., Ascophyllum nodosum, Fucus distichus, F vesiculosus, Littorina saxatilis) except Semibalanus balanoides, within a square of 25 × 25 cm. Coverage of fucoids and barnacles in the squares was estimated. The same sampling was performed in 2018, next to the squares sampled in 2017 with sufficient distance to avoid edge effects. After the burning, samples were taken of the smothered Fucus spp. and Ascophyllum nodosum, along the impacted coastline and in three different tidal levels, to be analyzed for the degree of smothering by oil and burn residue from the burning operation. Impact on Fucus spp. and Ascophyllum nodosum was estimated (heated, burned, smothered). All together, a pattern appeared where only the organisms in the highest tidal level and at the sampling points most directly impacted by the in situ burning operation were diminished by the coastal in situ burning operation. Furthermore, as part of monitoring the environmental effects of the coastal ISB, silicone sheets and mussels were placed in different depth beneath the burning and collected the fourth day after the burning operation. The data for total hydrocarbon (THC) concentration in the silicone sheets showed that the lighter fraction (C5-C9) were measureable in the silicone sheets beneath the in situ burning operation, but not in the silicone sheets placed in the reference bay indicating spreading of the these lighter fractions to the water column during the first 4 days after the burn.

Submission date September 2019

Conferences contributions

SETAC Europe 28th Annual Meeting Rome May 2018

Effects of oil spill on coastal seaweed in the Arctic (platform presentation)

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Abstract

In case of an acute oil spill response operation, decision making regarding the operational response strategy and prioritizing biology at risk must be resolute. For that a Net Environmental Benefit Analysis, NEBA, is often performed to achieve the optimal environmental benefit with respect to choice of oil spill combat methodology and biology at risk. To provide data for assessing beaching oil spill impacts in the Arctic areas, the effects of oil smothering of the macroalgae *Fucus distichus*, which is a dominant species in the intertidal zone of the coasts in the Arctic, as well as its self-cleaning potential by wash in sea, were studied. Effects of four different oil types were tested, including crude oil types, bunker oil and marine diesel. Different oil types have varying properties depending on the origin of crude oil and refinery process, and hence may have different effects due to their physical and chemical characterizations. Photosynthetic activity was measured as proxy for effect on growth and the self-cleaning potential was tested by wash in sea for oil smothered tips of *F. distichus* over a period of 2 weeks. The removal of the oils from the seaweed surface was considered as relatively fast ($T_{1/2}$ ~ 3-4 days). Depending of oil type, the oil inhibited or stimulated photosynthetic activity. Marine diesel inhibited photosynthetic activity, whereas the three other oil types stimulated the activity. Thus, in general, the results indicated 1) that oil smothering was relatively fast washed off in the sea water; 2) that, depending on the oil type, photosynthetic activity were stimulated or inhibited; and 3) that the photosynthetic activity was still affected (stimulated or inhibited) even after 14 days, although oil on the tip surface was completely or almost completely washed off.

Oil spill combat and effects in the Arctic coastal environment; self-cleaning potential and in situ burning (poster presentation)

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Introduction

What is the environmental effects of a beaching oil spill in the Arctic, how well will the shoreline potentially be able to clean it-self from such an oil spill, and will combating the oil by in situ burning at the coast just do more harm to the communities in the tidal zone?

It has been reported, in connection with oil beaching on sheltered rocky coasts, that the intertidal macro algal cover was affected due to oil smothering and/or shoreline cleaning efforts [e.g., 1]. However, it is also expected that (some) oil smother on the coast and coastal organisms may be naturally washed off or degraded [2]. Knowledge about the potential for removal and degradation of beached oil is an important parameter in the planning and choice of oil spill response, based on a Net Environmental Benefit Analysis, NEBA, which often is performed to achieve the optimal environmental effect with respect to choice of oil spill combat methodology and biology at risk [2]. In situ burning is a potential methodology for combating oil spill. The use of in situ burning operations along the shore is novel, and knowledge on the effects on the coastal organisms is important input to the NEBA.

Hence several studies have been performed at the west coast of Greenland to support such a net environmental benefit analysis, and an integrated synthesis will be presented of; 1) removal rate and eco-toxicological effects of oil smother on seaweed (Fucus distichus), which is a dominant species in the intertidal zone of the coasts in the Arctic; 2) self-cleaning potential of a coast line, including natural removal by seawater wash and physical degradation; as well as 3) effects on the tidal communities after combat of a beaching oil spill by in situ burning.

Materials and methods

To provide data for assessing beaching oil spill impacts in the Arctic areas, the effects of oil smothering of the macroalgae Fucus distichus, as well as its self-cleaning potential by wash in sea were studied in semi-field studies at Disko Island at the west coast of Greenland. Four different oil types were tested, including crude oils, bunker oil and marine diesel (Table 1). Different oil types have varying properties depending on the origin of crude oil and refinery process, and hence may have different effects due to their physical and chemical characterizations [e.g., 3]. Oil emulsions were chosen for the smother experiments to simulate oil beaching in the tidal zone after some hours of weathering in the sea. Photosynthetic activity was measured as proxy for oil smothering response on growth, and the self-cleaning potential was tested by wash in sea for oil-smothered tips of F. distichus.

Oil	Type
ANS	Crude Oil
Grane	Crude Oil
IFO30	Heavy Fuel Oil
Marine Gas Oil (MGO)	Diesel

Table 1. Oil types tested.

For estimating the rate of natural removal and degradation of stranded oil on rocky surface in the Arctic, a study was performed at three locations along the west coast of Greenland at low Arctic, middle Arctic and high Arctic climatic regimes. The study included natural removal of a crude oil and a heavy fuel oil from tiles mimicking rocky shore substratum and was run in the period from May- September 2017 (day for set-up of experiment = day 0) and sampled continually. The tiles were placed in different height levels of the tidal zone, and hence natural removal and degradation rates in relation to different water cover regimes and air exposure times were obtained. The oil remains on the tiles were analyzed for chemical and biological compositions.

Furthermore, to test efficiency and environmental exposure of coastal in situ burning, a pilot scale costal in situ burning operation was performed during summer in a bay in western Greenland with a crude oil (burning operation day = day 0).

Results and discussion

The removal rate of oil smother on seaweed (Fucus distichus) surface was considered as relatively fast, with half-time periods (T1/2) ranging from 2 to 4 days. The eco-toxicological effects of oil smother depended on oil types Marine diesel inhibited photosynthetic activity whereas the three other oil types stimulated the activity.

It is expected that natural removal of crude oil and HFO show clear difference with respect to wash by seawater. By visual observations on day 1 for the experiments, differences in remaining oil on the tiles was obvious. The crude oil was washed off more readily than the HFO, which is ascribed the different physical characteristics of the oil types; HFO has a higher content of wax and asphaltenes and hence has a higher pour point and is more viscous. Analyses of chemical composition of the remaining oil on the tiles as well as composition of bacterial flora will indicate the fraction of oil degraded by physical processes and the biodegraded fraction.

The effects on the tidal communities after a coastal in situ burning operation showed heat and smother effects on tidal seaweed from oil and burning residues (Fucus spp.) (Figure 1).

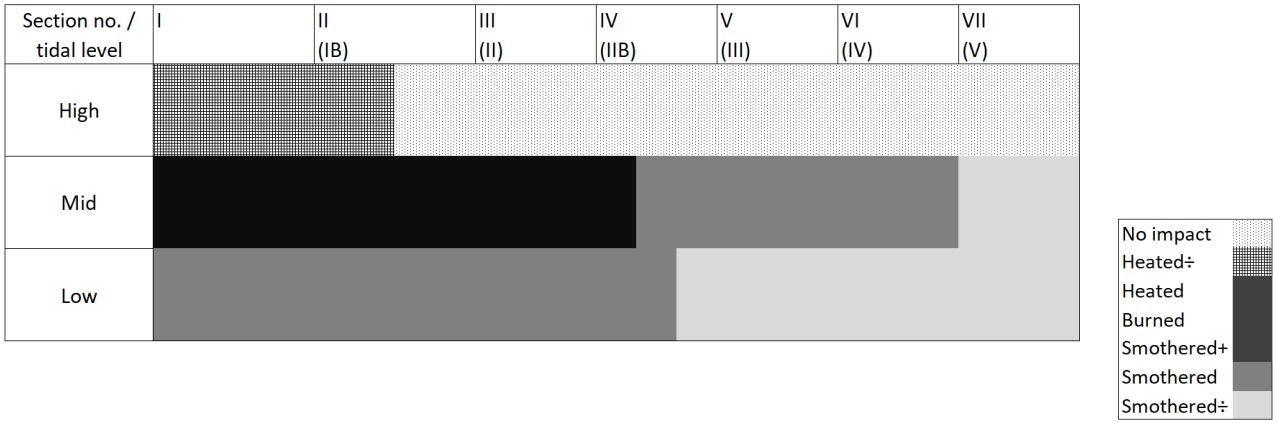

Figure 1. Impacted coast from in situ burning. The burn was restricted to the area section I-III.

From visual observations day 4, smother was significantly reduced and heat effects were limited to the outer part of the Fucus canopy layer. Short-term exposure rate to oil and burn residue smother will be estimated from quantification of oil components per weight of Fucus biomass. Long-term effects will be estimated from a qualitative and quantitative monitoring programme.

Conclusions

As a preliminary conclusion, the self-cleaning potential of a coast with a relatively high tidal amplitude, which ensure two daily seawater wash of the coast, is considered as potentially high. However, if oil spill is of HFO type the natural removal and degradation is expected to be significantly slower than for a lighter oil type. Effects from oil smother and coastal in situ burning operations on Fucus spp., is expected to be relatively short-term and the coastal in situ burning methodology appears promising for combating of oil spills in remote areas.

It is assessed that the results from the research experiments will provide valuable information for decision makers regarding oil spill response options to include in the net environmental benefit analysis (NEBA) for oil spill response strategy and capacity building in the Arctic seas.

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[3] Fritt-Rasmussen J, Brandvik PJ, Villumsen A, Stenby EH. 2012. Comparing ignitability for in situ burning of oil spills for an asphaltenic, a waxy and a light crude oil as a function of weathering conditions under arctic conditions. Cold Region Science and Technology, vol. 72, pp.1-6.

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MOSPA 2018 Oulu 7-8 March, Oil Spills in Arctic Areas –seminar (platform presentations)

Combat of oil spill in coastal arctic waters – effectiveness and environmental effects –field experiments 2017

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Abstract

The 2017 field campaign of the EU H2020 project GRACE work package 4 (WP4) is presented.

The main objective of WP4 is to improve the knowledge base for combating oil spills in icy and cold waters, and includes research to increase knowledge on environmental fate of stranded oil; natural degradation and combat of the oil spill by in situ burning.
The rate of natural removal and degradation of stranded oil on rocky surface was investigated. Natural removal of North Sea type crude oil and a heavy bunker fuel oil on tiles has been studied in the period of May- September 2017. The tiles were placed in different height levels of the tidal zone, and natural degradation in correlation to different water cover regimes and air exposure times, and the study was performed in low arctic, middle arctic and high arctic climates at the West coast of Greenland. The oil remains on the tiles has been analyzed for chemical compositions.

For operational and environmental research, a pilot scale oil spill experiment was conducted in an enclosed arctic water basin in Greenland including offshore in-situ burning experiment of a heavy bunker fuel oil (IFO 180). Subsequent the in situ burning operation, collection of burn residue was performed by a specialized residue collection trawl system developed by DESMI A/S.
Environmental effects and exposure of the marine environment was monitored using blue mussels.

Moreover, a pilot scale onshore in situ burning operation was performed in a bay with a North Sea type crude oil for testing efficiency and environmental exposure. Subsequent the onshore in situ burning operatoin, the Lamor mechanical oil spill response unit, named Bucket skimmer was tested for collection of burn residues. Environmental side effect of the onshore in situ burning operation was monitored on macroalgae, winkles and blue-mussels, and long-term effect on onshore macroalge communites will be monitored in 2018.
Approval for field test is given by the Greenland authorities (Ministry of Nature, Environment and Energy) in permit of September 30, 2016.

It is assessed that the results from the research experiments will provide valuable information for decision makers regarding oil spill response options to include in the net environmental benefit analysis (NEBA) for oil spill response strategy and capacity building in the Arctic and Baltic sea.

The project was funded by the European Commission Horizon 2020 programme.

Strategic Net Environmental Benefit Analysis (sNEBA)

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Abstract

The concept of a strategic Net Environmental Benefit Analysis (sNEBA) will be presented.

sNEBA is a planning tool for decision making on design of an appropriate and fast national oil spill strategy combining the right mix of countermeasures for a region based on relevant oil spill scenarios. The selection and mix of oil spill combat techniques must be a balance between presence and oil spill sensitivity (short and long term, recovery rate) of organisms in the oil slick trajectory, in the water column, on the sea surface and on the shoreline potentially impacted by beaching oil. For inclusions of different combat techniques in, e.g., national oil spill contingency plans, an assessment of environmental pros and cons of these combat techniques in particular areas / regions can be obtained from the sNEBA.

The sNEBA is based on 1) knowledge on local / regional biology, ecology as well as the sensitivity, including tolerance and recovery rate, of ecosystem key components to oil spill including ecotoxicological data and knowledge and also 2) modelling of oil spill scenarios; oil spill trajectories and dispersion. The sNEBA synthesizes the knowledge for each of the spatial compartments; water column, sea surface, sea bed and coast, focusing on the key species / ecosystems characterizing these spatial compartments and the potential environmental impacts of oil spill, dispersed oil and burned oil.

Performing sNEBA for national areas / regions of concern will reveal the potential and possible effects of the response methods and hence support decisions on whether or not to include in situ burning, use of dispersants, bioremediation or mechanical recovery in the national oil spill response strategy as well as the need for capacity and expertise building in the national emergency countermeasures.

A sNEBA will hence support:

- Decisions on inclusion of combat techniques in oil spill contingency plans
- Capacity building and where to optimally place the equipment
- Integration of scientific knowledge with community and relevant regulative and operational governmental bodies
- Development of national response guidelines and approval procedures
- Cross-border and trans-boundary co-operation and agreements on oil spill response.

In case of an acute oil spill response operation, decision making regarding the operational response strategy must be resolute. For that, national contingency plans and international / trans-boundary agreements are essential.

Work Package four (WP4) of the EU Horizon 2020 project GRACE will provide a tool for performing sNEBA based on cases from the northern part of the Baltic Sea and the Disko Bay area in Greenland. A case from Store Hellefiskebanke, West Greenland, where a sNEBA was performed, will be presented.

The project was funded by the European Commission Horizon 2020 programme.

42nd AMOP Technical Seminar on Environmental Contamination and Response, June 4-6, 2019, Halifax, Nova Scotia, Canada (Platform presentations)

Strategic Net Environmental Benefit Analysis (SNEBA) – from conceptual framework to tool

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Abstract

A Strategic Net Environmental Benefit Analysis (SNEBA) is a planning tool for optimizing oil spill response preparedness. The overall aims of the analysis are to identify the most environmental beneficial methods for combating an oil spill in a specific sea area; location or region. SNEBA compiles information and data on, e.g., 1) sensitivity of important organisms and/or organism groups in the selected sea area, 2) estimates for distribution and fate of oil spills in the selected sea area. The SNEBA is based on oil spill scenarios, published as well as expert knowledge on the environment in the area in question according to the marine spatial compartments; sea surface, water column, seabed, and coast, and for the four seasons. Pros and cons of the major available oil spill response techniques are evaluated; mechanical recovery, chemical dispersion of oil and in situ burning , but also doing nothing, and leave the oil to be natural dispersed and degraded, may be an (only) option.
The SNEBA conceptual framework developed for assessing the oil spill response potential in connection with oil exploration options on Store Hellefiskebanke in Greenland will be presented as well as the SNEBA tool. The SNEBA tool consists of a number of successive steps; compilation of data and information, calculations and assessments for score systems as well as decisions trees for each oil spill and dissemination of results. The steps are supported by information boxes with data / scoring tables. Relation to existing concepts, such as Net Environmental Benefit Analysis (NEBA) and Spill Impact Mitigation Assessment (SIMA), will be included in the presentation.

Oil spill response, effectiveness and environmental effects - Experimental work performed in Greenland waters

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Abstract

This presentation introduces and gives an overview of different projects conducted as part of the EU Horizon 2020 research project GRACE (Integrated oil spill response actions and environmental effects). The main objective of the projects was to improve the knowledge base for combating oil spills in Arctic waters. Hence, the projects focuses on developing, comparing and evaluating the effectiveness and environmental effects of different oil spill response methods in an Arctic climate.

The presentation will include results of experimental work perform in Greenland coastal waters in the following subprojects:

1) In situ burning field trials in Greenland coastal waters 2017. Two burns were completed, offshore and near the coast. Focus will be on environmental impacts from the burns and lessons learned with respect to increased usability of in situ burning.
2) Studies on natural removal of stranded oil on rocky coast in two different Greenland climate regimes. Focus will be on the removal of oil from rocky coast with respects to oil types, biodegradation, physical degradation and wave wash.
3) Study on investigations of the efficiency and environmental impacts of combating oil spill at shoreline and shoreline clean-up on rocky coastline. This will be an introduction to work that are planned to be completed in Northeast Greenland summer 2019.