Project title: Evaluation of natural bioremediation potential of Arctic beaches
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Rationale: This project falls within the framework of a four-year multi-partner research initiative between McGill University and the Department of Fisheries and Oceans called the Ocean Protection Plan. Determining *in situ* fuel biodegradation capacity of fuel spills washed up on beaches in Canada is a key aspect of developing relevant fuel spill remediation approaches for Canada. This is especially true for the Canadian Arctic Ocean where global warming is resulting in the opening of the Northwest Passage to a broad and sustained increase in anthropogenic activities (ie. shipping traffic from both Canada and Internationally) and the exploitation and transportation of offshore Arctic fuel reserves to the Canadian high Arctic. All these elements are putting marine areas in and around the Northwest Passage at an elevated risk of a fuel spill. Inevitably, some of these fuels will wash up on Arctic beaches, potentially putting both marine and terrestrial systems at risk. Our knowledge of the natural attenuation potential of hydrocarbons in marine Arctic beach sediments is severely lacking at an international level and especially in the Canadian context. Essentially, we do not currently know if hydrocarbon biodegradative microbial populations exist in typical Northwest Passage beaches and how they will respond to a fuel spill. In southern latitudes, the addition of fertilizers can stimulate the natural microbial community to degrade hydrocarbon more efficiently, but it is not know. if this will happen under Arctic conditions. Past studies on this topic were limited in their ability to study the microbial community on Arctic beaches. The field of microbial ecology has been advancing very rapidly. In contrast to earlier studies, we now have the ability to use next-generation sequencing technologies to precisely determine the microbial community composition and how it will respond to the presence of shipping fuel. Data on the microbial community will be complimented by GC-MS data on the changing chemical composition and toxicity of the fuel over relevant time frames to mimic an accidental fuel spill.

The Objectives of this research program are to determine:

1. If biodegradative microbial populations are present in the beach sediments.
2. If the biodegradative populations can degrade fuel contaminating tidal beach sediments under *in situ* Arctic conditions.
3. If the bioremediation treatments (additional of fertilizers) enhance hydrocarbon biodegradative activities and to what extent.
4. If the concentrations of hydrocarbon contaminants decrease in the beach sediments over time, to what extent, and at what rates.
5. How the toxicity of the fuel changes over time.

Progress to Date

We have contacted the Resolute Bay Hunter and Trappers Association about our research plans. Following discussions with Phillip Manik and Uluriak Amarualik (who discussed earlier versions of our research proposal with the Hunter and Trappers Association Board members) it was made clear to us that our research must not interfere with the summer hunting season, and that the community is not comfortable with any fuel being released to the environment in the Resolute area. We will therefore not be releasing any fuel to the environment, and all experiments have been designed to proceed without interfering with community hunting activities or limiting access to the beach in any way.

We are eager to meet with the community in summer 2019 to learn about local boating practices and local knowledge of what currently happens when fuel is accidentally spilled in the marine environment, as well as informing the community about how our research will benefit Resolute Bay.

We have contacted the Nunavut Arctic College to enquire about hiring an indigenous student from the Environmental Technology program to join our team as a paid research assistant.

Sediment samples collected in Resolute Bay in 2018 have been analyzed to determine total bacterial load, and DNA has been extracted from the sediment for analysis of key hydrocarbon degrading organisms and genes. We are in the process of planning optimal sediment incubation conditions in the laboratory, to mimic the environment of an Arctic beach.

Several different types of shipping fuels have been chosen as most relevant for this project, including low sulfur fuel, Bunker C, and marine diesel oil.

Methodology: In the first year of this research program (summer 2019), the Arctic field research will take place over a two-month period, with sampling chambers put into place in beach sediment in the vicinity of Resolute Bay in early July, and retrieved for analysis in late August. At the same time, sediment samples will be collected for laboratory microcosm column incubations at McGill University. These sampling chambers are approximately the dimensions of a small school ruler (2cm x 10cm), and contain an adsorptive material coated in 0.1 mL of shipping fuel. The total amount of fuel contained in all sampling chambers will be less than 10 mL. Sampling chambers will be buried in the sediment of a beach in the Resolute Bay area in early July, and will be retrieved in late August. It will not be noticeable that the sampling chambers are in the beach, meaning the beach will remain fully accessible to the community. After the two-month incubation, we will retrieve the sampling chambers and extract nucleic acids for microbial community analysis. All residual fuel traces will be removed together with the sampling chamber, resulting in no negative impacts on environment, wildlife, or people.

Also in summer 2019, sample of beach sediment will be collected from beaches in the Resolute Bay area. This sediment will be incubated in our laboratory at McGill University together with various types of fuels and fertilization treatments to determine the efficiency with which the natural microbial communities can degrade these contaminants. Sediment will be incubated in microcosm columns set up to mimic the natural environment of an Arctic beach, in which sea water levels increase and decrease like natural tidal patterns. Samples will be taken from these microcosms at regular time intervals for GC-MS analysis (to determine how the chemical composition of the fuel changes over time), and microbial genomics analysis.

Native microbial biodegradative populations of sediment samples from beaches will be detected and monitored through several genomics methods including quantification of representative hydrocarbon-biodegradative genes for different classes of hydrocarbons existing within the fuel (alkanes, aromatics, PAHs, etc.) by digital PCR. Beach sediment microbial community responses to fuel with and without nutrient amendment (a slow-release fertilizer rich in nitrogen and phosphorous) will be monitored by 16S rRNA gene profiling; this will identify which microbes may be enriched for in the sediments. State-of-the-art metagenomic sequencing analyses will detect and characterize the hydrocarbon biodegradative pathways enriched for in the contaminated sediments; genome-binning will be attempted on metagenome sequences to obtain genomes of biodegradative microorganisms, allowing for high-level characterization of Arctic beach sediment microorganisms. Metatranscriptomic analyses will determine which microorganisms are actively responding to the fuel contamination in the beach sediments through identification of mRNA transcripts involved in hydrocarbon biodegradation. Hydrocarbon biodegradative activity will also be assayed in sediment microcosm assays using representative 14C-labelled hydrocarbons to determine the extent, rates, and activities of hydrocarbon biodegradation. In parallel, chemical and toxicology analyses of the contaminated beach sediments will determine if the global levels of hydrocarbons residing within the beach sediments and their toxicity over the life time of the project.

Data management:

Data will initially be stored on the personal research computers of the research scientists on the team, and immediately shared between team members using a shared Google Drive. Analyzed data and results will be made publicly available through publication in open-access scientific journals. A non-technical summary of our research will be written as an article for Nunavut News to inform the public of our results. We will also give annual progress updates to the local community of Resolute Bay.

Research outputs:

Ultimately, we plan to compile a catalogue of hydrocarbon-degrading bacteria present in Arctic beach sediment and identify the key bacterial species responsible for fuel-degrading activity. We will identify which Arctic beach sediment microbes are associated with the degradation of different fuel components, and determine the optimal bioremediation treatments for fuel-contaminated northwest passage Arctic beaches. The data generated during this study will be used to produce a predictive fuel degradation kinetic model for Arctic Marine beaches, to inform public policy for remediation treatments of hydrocarbon-contaminated Arctic Marine beaches in the event of a fuel spill in the Northwest passage.

At the end of the four-year research program, a comprehensive report will be prepared for the Department of Fisheries and Oceans to inform policy decisions in the event of an accidental fuel spill in the Canadian Arctic.

This research will form the basis of the theses of one Masters student and one PhD student, and will contribute to the professional development of two postdoctoral fellows. Research outputs will be published in open-access scientific journals. Furthermore, as the Whyte lab research group is in Resolute every year, we will give annual presentations to the community on the importance and progress of our experiments.