

Dispersion of Oil Spills in Ice-Infested Waters



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Arctic Oil Spill Countermeasures

- Challenges in the Arctic include ice coverage, cold temperatures, isolated locations, and limited day-light hours during the winter
- Traditional tools such as booms and skimmers were developed for open water conditions
- Availability of oil spill response personnel and the logistics of waste containment and disposal is an issue in the Arctic
- Consideration of the sensitivity of Arctic species and habitat



Response Option of Choice?

- There is no single response technique that is suitable for all circumstances
- Contingency plans should consider all clean-up methods (*Use the right tool*)
- To establish operational guidelines, research is needed to identify efficiency, operational limits and biological effects of various clean-up strategies
- Local knowledge and cooperation is required to ensure the application of oil spill countermeasures in an efficient and environmentally responsible manner

Response Option of Choice?

Containment and Mechanical Recovery

- Booming and skimming

Burning

- In-situ burning

Bioremediation

- Biostimulation
- Bioaugmentation

Enhanced dispersion

- Chemical oil dispersants
- OMA formation

Natural Attenuation

- Monitoring natural recovery



Fate of the Oil: GOM spill

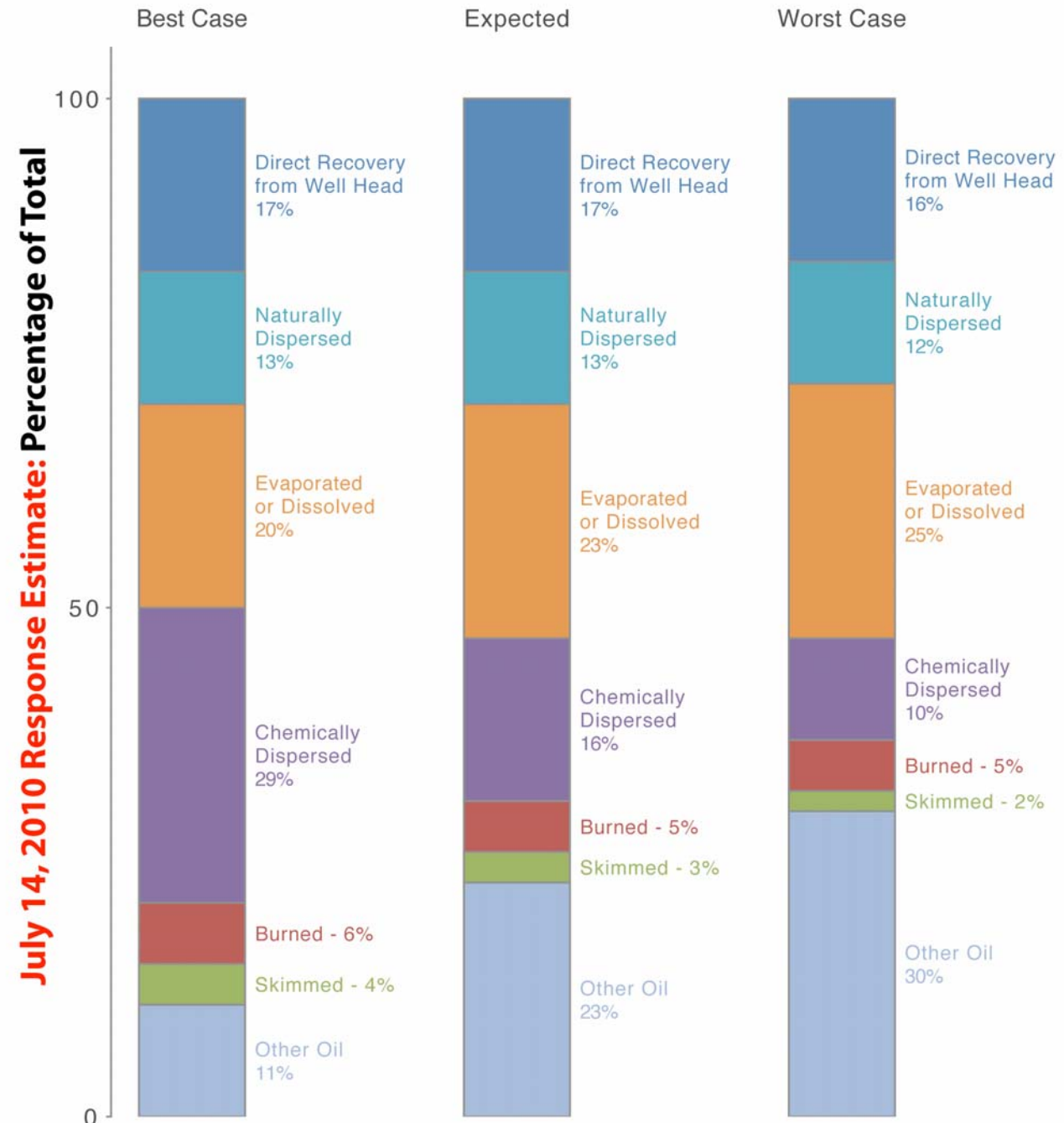
Response estimates expressed as % cumulative volume of oil discharged in the best, expected, and worst cases

Oil Budget Calculator

October 2010

NOAA (National Oceanic and Atmospheric Administration)

Other: Remaining oil is at the surface as light sheen or weathered tar balls, biodegraded, or already came ashore



Enhanced Dispersion for Oil Spill Response

- Based on the concept of transferring oil from the sea surface into the water column, as small oil droplets
- These are diluted by natural processes to concentrations below toxicity threshold limits
- Dispersed oil droplets are degraded more rapidly by natural bacteria
- Achieved with **chemical oil dispersants** and/or **OMA formation**



**Hydrocarbons are not new to the
marine environment**

Gas Sampler



**Natural seepage accounts for 0.2 –
6.0 x 10⁶ metric tons/year**

**Natural bacteria have adapted to
tolerate and utilize them as a carbon
and energy source**

Bacteria



Scott Inlet, Baffin Island – 600m depth

Chemical oil Dispersants

- Dispersant use following the Gulf of Mexico Oil Spill prevented significant oiling of sensitive shoreline habitats
 - The ability to effectively deploy and monitor an unprecedented dispersant response was based on the past decades' improvements
- New low-toxicity formulations developed for low temperature/Arctic conditions and high viscosity oils
- Methods of application from surface vessels (e.g. SINTEF JIP), aircraft and sub-sea injection are being improved

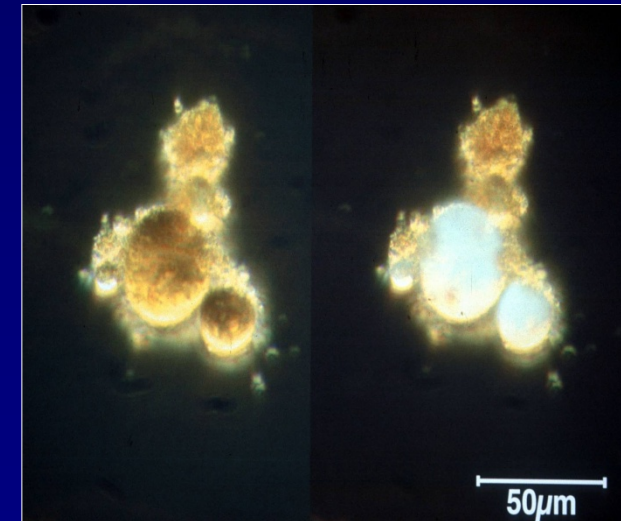
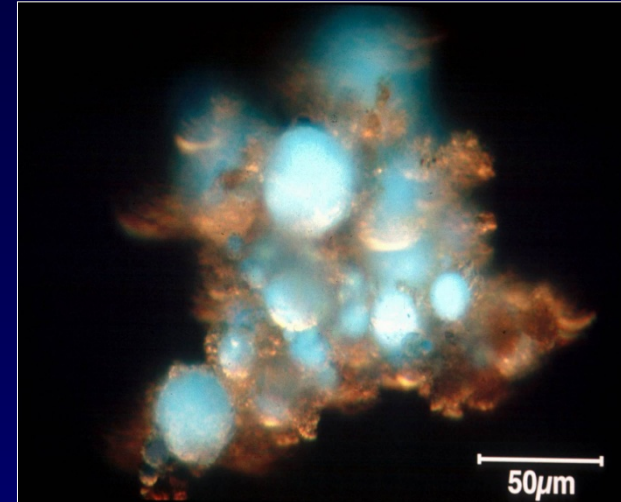


Arctic Oil Dispersant Research Priorities

- **Develop and improve application methods for surface and subsurface (e.g. deepwater blowout) spill response**
- **Evaluation of acute/chronic biological effects of oil dispersants on benthic and pelagic biota fish and develop improved Environmental Effects Monitoring (EEM) protocols**
- **Development of analytical methods for the quantification of chemical dispersants applied at sea**
- **Monitoring dispersant and oil degradation and habitat recovery**
- **Evaluation of emerging dispersant formulations**
- **Develop predictive numerical models to support chemical dispersant applications under Arctic conditions**
- **Resolve key regulatory issues**

Oil-Mineral Aggregate (OMA) Formation

- Naturally produced in high particulate estuarine and near shore waters
- OMA occurs with naturally occurring suspended particles
 - Mineral fines and associated organic fractions
- OMA changes fate and transport and effects of oil
 - Biodegradation rate
 - Horizontal and vertical transport
 - Biological effects



OMA Formation as a Spill Countermeasure

Oil mineral aggregate formation “clay oil flocculation” may be the cause of “natural self-cleaning” of shorelines affected by past oil spills.

- Baffin Island Oil Spill (BIOS) Project - Natural cleansing was as effective as other tested countermeasures
- Laboratory studies with oiled sediments from the *Exxon Valdez* spill revealed that “micron-sized mineral fines, seawater and weathered oil” interact to form “clay-oil flocs”
- The mechanism was responsible for the natural cleaning of sheltered shorelines in Prince Williams Sound observed a year after the spill

St. Lawrence Estuary Field Trial: DFO Science/CCG



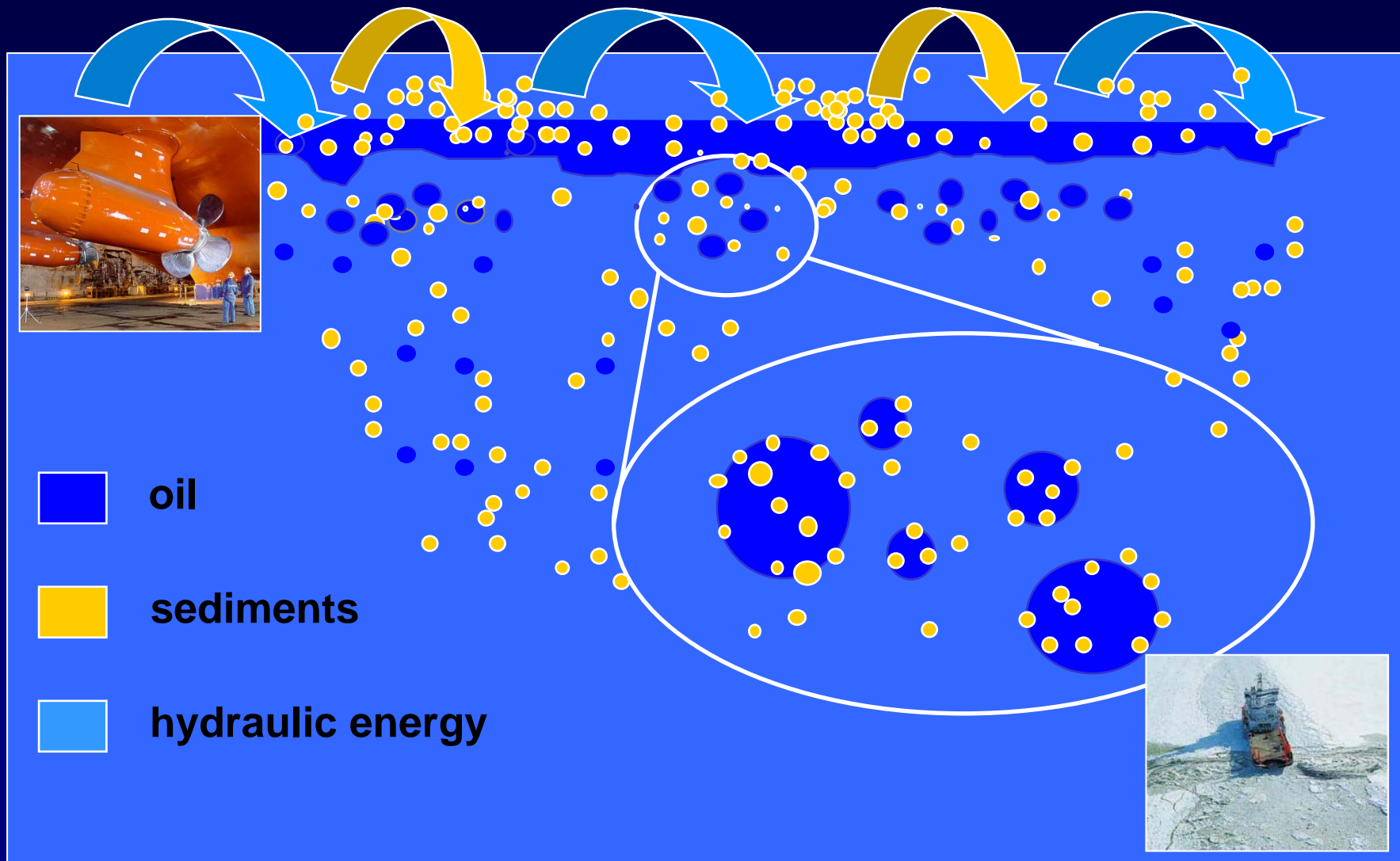
Test effectiveness
OMA formation as
a oil spill
countermeasure

Fill the gap
between lab and
real-world
application

Gain operational
experience for
larger scale field
trials

* **Controlled release of oil**

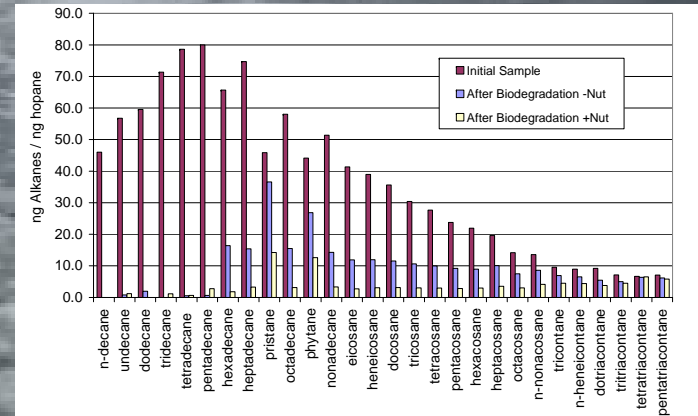
Conceptual Model of Enhanced OMA Formation





OMA Application and Mixing Treatment

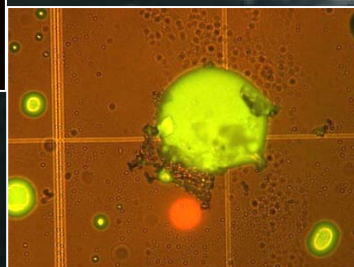
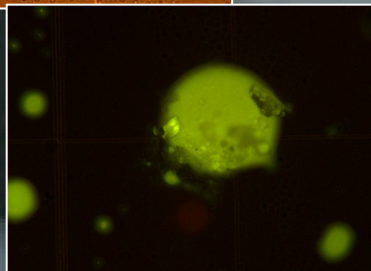
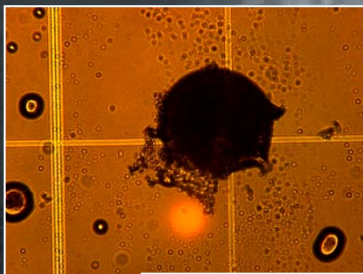
Dispersion Efficacy with OMA



Oil Degradation

50 days at 0.5°C:

- 60% total Hydrocarbons
- 75-88% total alkanes
- 55-65% PAHs



OMA Formation

Resurfacing of Oil without OMA



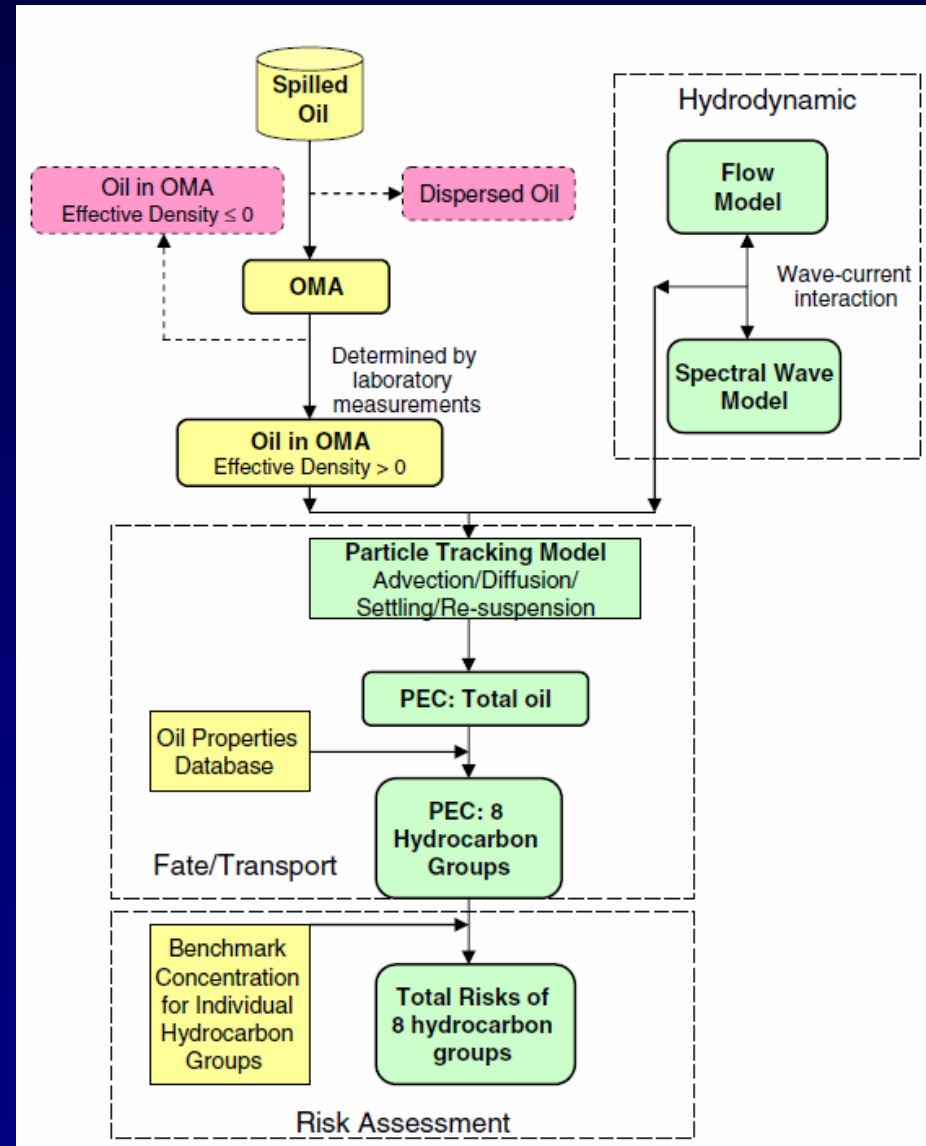
Sampling for Determination of Dispersion Effectiveness

- Samples recovered from the water column for laboratory biodegradation study to monitor the persistence of oil at cold temperature
- Water samples were collected every 30 min for 2 hours from different depths (surface, 1m, 5m and 10m)
 - GC-FID analysis of TPH distribution
 - Epi-fluorescent microscopy
 - UV-Fluorometer analysis
- In-situ instruments used to monitor OMA
 - Underwater video camera
 - Laser in-situ scattering and transsiometry
 - Turbidometry



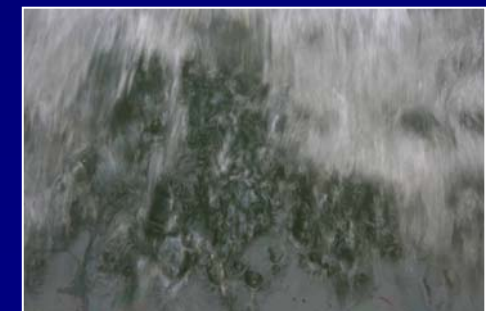
Modeling the Fate/Risks of OMAs

A hydrodynamic model that considers the interactions between waves and currents has been integrated with a fate/transport model that can simulate the advection/diffusion, settling and re-suspension of OMAs to study the potential impacts of oil on benthic organisms



Feasibility of OMA as a Countermeasure

- Oil spilled on ice-covered waters effectively dispersed by OMA formation
- Propeller wash provides sufficient mixing energy
- Significant oil biodegradation under ambient low temperature conditions
- Ongoing wave tank and numerical model studies are focused on the influence of factors such as mixing energy, type of mineral fines, chemical dispersants and toxicity issues



Natural Attenuation

Response strategies are not 100% effective

To support decision-making regarding oil spill contingency, response plans and damage assessment we need to improve knowledge on:

- Levels of microbiological diversity to estimate both the capacity of the system to clean itself (of treated and/or untreated oil) in case of accidental spills
- Persistence of the contaminants based on biodegradation rates obtained from the field

Natural Attenuation

What's the environmental impact of the residual fraction that is not accounted for following clean-up operations?

- **The interaction of biological, physical and chemical processes are responsible for the progressive loss of these and other contaminants within the marine environment**
- **New evidence from advances in biotechnology (e.g., metagenomics,) suggest that oil in Arctic waters may be degraded at higher rates by indigenous organisms than previously thought**

How clean is clean?

- **Development of monitoring protocols for operational end-points**

The Way Forward



Government of Canada's Northern Strategy Framework promotes northern science and research, reinforce circumpolar cooperation, strengthen partnerships, and environmental protection

- Most of what we know about oil spill behavior and response to spills in ice comes from laboratory, experimental test tank studies, and a few historical large-scale field experiments
- The operational effectiveness of numerous “new” oil spill clean-up technologies and response strategies is unknown
- Proof-of-concept and operational guidelines must be established before they are accepted by the oil spill response community
- Conclusion of numerous scientific symposia on Arctic oil spill response - **Field trials with oil are absolutely essential to make real progress**

Knowledge Gaps for Future Field Studies

- Remote sensing systems to detect, monitor and map the transport and spreading of oil in ice and below ice
- The weathering of oil in cold water/Arctic conditions
- Development and verification of oil-in-ice drift and fate models
- Improved mechanical response equipment (skimmers, pumping systems for viscous oils, and the removal of oil from ice and water)
- In-situ burning in broken ice (development of fire booms, chemical herding agents, and ignition systems)
- Oil dispersion enhancement by chemical dispersants/enhanced oil mineral aggregate formation (focus on effectiveness, identification of controlling factors and development of application guidelines)
- Bioremediation of oil stranded on shorelines
- Characterization of water soluble components and biological effects (toxicity) on Arctic species
- Development of operational end-points for spill clean-up operations