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AMOP - THE ARCTIC AND MARINE OILSPILL PROGRAM

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INTRODUCTION

The AMOP began in April 1977 and initially the focus was on the southern Beaufort Sea. Studies triggered by an oil industry proposal to undertake offshore exploratory drilling there had concluded that few proven countermeasures were available to deal with a blowout or any large oil spill in arctic waters. The AMOP is still an active program, and its primary objective continues to be to improve the knowledge base and technology for combatting arctic and marine oil spills.

Many of the AMOP studies have been supported by industry and organizations in the United States, especially the U.S. Minerals Management Service (MMS). The program has included projects at the laboratory and pilot scales, and sometimes involved large-scale field work such as the $7-million Baffin Island Oil Spill (BIOS) project in the Canadian Arctic, and the sea trials of treating agents and oil-containment booms that were performed off Canada's east coast in 1987.

Environment Canada's River Road Environmental Technology Centre (RRETC) is responsible for the overall management and direction of the AMOP, but joint projects are managed and directed by committees including representatives of the funding agencies involved in joint projects. Similar co-operative arrangements are also used to promote development of improved techniques for responding to chemical spills. Results of chemical spill projects are also disseminated through the Spill Technology Newsletter, technical reports (about 200 of them), and at seminars and conferences - including the annual *Technical Seminar on*

The Arctic Marine Oilspill Program (AMOP) is Environment Canada's program for oil spill research and development. This issue is a condensed version of a program review covering past, present, and planned projects. The original article was written by Dave Thornton, Merv Fingas, Harry Whittaker, and Gary Sergy.

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Chemical Spills organized by RRETC.

AMOP PROJECTS

Detection and Tracking

Because of the remoteness of much of Canada's coastal areas and the added complications of ice and darkness in the Arctic, a considerable effort has been expended to evaluate and develop equipment to locate, identify, and track oil spilled at sea.

Tracking Buoys. One of the first devices to be developed was the slick-tracking buoy by Orion Electronics Ltd. in Nova Scotia. Sea trials of this floating battery-powered radio transponder have shown that its drift closely approximates that of oil.

Remote Sensing. Work on remote sensing systems has given us a good understanding of the strengths and weaknesses of the various techniques available, including the use of satellite imagery. Each has its limitations and a recommended outfit includes a synthetic-aperture radar, an infrared-ultraviolet linescanner, a laser fluorosensor, an annotated colour camera, and onboard real-time display equipment. Remote sensing projects have included:

- acoustic studies,
- development of prototype systems by RRETC,
- sensor evaluation for oil loss detection,
- development of laser fluorosensors, and
- development of an oil-thickness sensor.

Properties, Behaviour, Effects, and Modelling

A prerequisite for the development of effective countermeasures for arctic oil spills is a sufficient knowledge of the conditions under which the measures must work and the effect those conditions have on the properties and behaviour of the oil. The acquisition of that knowledge has proven to be a major and ongoing task of the AMOP.

The Baffin Island Oil Spill (BIOS) Experiment. The almost $7 000 000 BIOS experiment was by far the largest component of the properties, behaviour and effects work. This 4-year international co-operative undertaking by government and industry has provided previously unavailable data on the short- and long-term fate and effects of crude oil stranded on an arctic shoreline - compared to that of the same type of oil when chemically dispersed in the nearshore arctic environment. Data on the effectiveness of selected shoreline cleanup techniques have also been acquired in addition to the increased knowledge about the physical, chemical, and biological processes operating in common arctic marine ecosystems.

Stranded Oil Fate and Persistence. AMOP-funded studies have improved methodology for the characterization of surficial oil, improved the capability to predict self-cleaning rates and to understand complex processes which influence oil movement and character.

Subsea Blowouts. AMOP studies have shown that it is technically feasible to capture escaping oil near the seabed if conditions are sufficiently favourable. However, because the probability that such conditions will exist is so low and the cost of having a system available is so high, RRETC does not consider subsea containment to be a practical countermeasure.

Ice Influence. Various AMOP studies have examined the influence of ice on the physical fate and behaviour of oil. They range from the compilation of available information on ice type and extent in an arctic atlas, the determination of ice dynamics from satellite imagery, and experiments in laboratories and test tanks, to field experiments involving the release of oil in ice-covered waters.

Photo-oxidation. Apart from a small study at the University of Manitoba that looked at ways to enhance the degradation of oil by ultraviolet light, the effect of photo-oxidation on spilled oil behaviour has not had sufficient priority to be pursued further until recently. In the course of seeking a better understanding of the factors governing oil dispersion it became apparent that one of the keys might be the change in natural surfactant content resulting from photo-oxidation. That aspect is currently being explored at RRETC.

Water-in-Oil Emulsification. A study on the formation of water-in-oil emulsions was conducted in co-operation with the U.S. MMS. The cause of emulsification was determined to be the precipitation of asphaltenes and resins in non-aromatic solvents or compounds.

Oil Catalogue. The Canadian oil industry has supported the compilation of a catalogue on the properties of oils that could be spilled in Canada or adjacent waters. Data and representative samples of frontier oils are provided as they are discovered, common pipeline blends, imported cargoes and various products. The annually up-dated catalogue combines the data from industry and others with experimental data obtained at RRETC.

Remedial Measures

Environment Canada has been working to improve spill countermeasures for 20 years and one of the first decisions was to focus attention on the problems peculiar to cold climate operations and to make maximum use of technology developed for spills elsewhere. Another initial decision was to tackle the essentially ice-free and complete ice-cover situations first and to defer the problem of removing oil under intermediate ice conditions.

Arctic Oil Skimmers. Prior to the AMOP, most of the effort devoted to remedial measures had been expended on performance evaluations either in enclosures set up adjacent to wharves or in open water. That work had shown that three types of skimmers being manufactured in Canada were potentially effective under near-freezing conditions, but that all required modification to correct problems. Initially, the objective was to develop and prove the necessary modifications to each type and to derive an arctic oil recovery vehicle on that basis. However, after the first year or so, it was concluded that special-purpose skimming vessels able to operate safely in the Arctic at reasonable distances from the few and widely separated support bases were possible but too costly. Work to that end was abandoned in favour of devices that could be deployed from offshore support ships or other vessels of opportunity such as barges.

Conventional Booms. Nothing was done to further the development of conventional booms for several years because of the decision to focus on open-water situations and because of the substantial effort being expended by Norway and others to develop booms for offshore use. The AMOP did not venture into that aspect of oil spill countermeasures development until the Canadian Coast Guard (CCG) specifically requested a scaled-up version of the river model of the Bennett self-inflating "Zoom-Boom" to evaluate as an open-ocean replacement for their Vikoma SeaPacks.

A section of the boom performed well in the OHMSETT test tank. However, when the full length was subsequently deployed at sea off Newfoundland in conjunction with the trials of the Bennett/Versatile arctic skimmer, the CCG decided that it was not a suitable replacement for their Vikoma system.

Fireproof Booms. Work at Balaena Bay, North West Territories (NWT) during the Beaufort Sea studies had shown that oil floating in melt pools on the surface of sea ice could be burned-off *in-situ*. One of the first projects under the AMOP, therefore, was to determine the feasibility of constructing a fireproof boom to provide the necessary confinement in the absence of sufficient ice or other natural features. A variety of materials and approaches were considered and small-scale tests indicated that fire-resistant booms were indeed feasible and that floating nets were ineffective.

Waterjet Barrier. A Canadian inventor proposed a novel concept of using a horizontal array of high-pressure waterjets to oppose the movement of oil on water. Some exploratory showed that the airflow induced by high-pressure waterjets in the proposed arrangement does effectively move oil on water. The presence of waves that made conventional booms ineffective had little effect on the ability of the jet-induced wind to move oil.

A preliminary assessment of the waterjet barrier as a fireproof boom showed that the induced wind or influence of the sprayed water does significantly reduce the amount of smoke that is characteristic of oil-pool burns.

Boom Test Protocol. The largest experimental oil spill in Canadian waters was released

off Newfoundland in the late summer of 1987 in co-operation with the CCG and the U.S. MMS. The primary purpose was to gain a realistic assessment of the capability of the CCG's booms and skimmers to function in offshore sea conditions and the containment and recovery effort was one of the most successful on record. Nevertheless, the tests confirmed that the equipment was not ideally suited for offshore recovery of waxy crude oil. It was also confirmed that, under wind, current and wave conditions which are marginal for oil slick containment and recovery, the best results can be obtained by "going with the sea", rather that working into the sea and wind. A secondary objective, successfully achieved, was to take advantage of the opportunity to deploy booms with oil in a pre-planned situation in order to validate a protocol developed by the OHMSETT Interagency Test Committee (OITC) for assessing the capability of offshore booms to contain oil without having to spill it. Such a protocol is important because of the demonstrated limits of adequately assessing offshore booms in the confines of a test tank and the need to avoid the deliberate stressing of the environment by spilling oil at sea.

Oil Slick Igniters. Another project directly resulting from the aforementioned Balaena Bay experiment was one to develop a means of igniting the oil floating in melt pools from the air. An igniter that could be dropped from a helicopter or slow-flying fixed-wing aircraft was developed with the cooperation and assistance of Canada's Defence Research Establishment at Valcartier, Quebec, after tests had shown that the existing devices developed for fighting forest fires did not produce sufficient heat to ignite oil that had been subjected to the amount of weathering that could be expected.

Laser Oil Slick Igniter. Although air-dropped incendiary devices have been proven capable of igniting pooled oil, they are still not an entirely satisfactory solution to the problem because of the associated logistics. The igniters have a shelf-life of five years, there are only a few places in North America that are equipped and approved to make such devices, and the production capacity is limited even in an emergency situation. There are also transportation restrictions to further complicate the task of getting a sufficient number to the right place in time. Upon learning that Physical Sciences Inc. in Andover, Maryland had achieved some success igniting pooled oil with a laser in their laboratory, they were awarded an AMOP contract to establish the design criteria for such a system. They were successful in doing so, as was demonstrated in a small-scale trial under typical late-winter conditions. An engineering study has shown that an operational system could be installed in a helicopter using existing technology, and a functional system could be built if needed.

In-situ Burning. Environment Canada has joined the U.S. MMS and the National Institute for Standards (NIST) in studying *in-situ* burning as an oil-spill countermeasure. Focus has been placed on the emissions to the air. Tests have shown that oil burning is an acceptable oil-spill countermeasure in many circumstances. One of the major concerns with the technique was the potential production of poly-aromatic hydrocarbons (PAH). The studies showed that the concentrations of PAH in the residue and soot were comparable in magnitude to those found in the original oils. No other exotic or highly toxic compounds were measured at significant levels.

Other tests also included the use of Ferrocene as a smoke suppressant. The chemical worked very well and, at certain application levels, completely eliminated smoke.

Spill-treating Agents

Some studies have been done through AMOP on a variety of spill-treating agents, but most work has focussed on use of chemical dispersants.

Chemical Dispersants. Environment Canada has issued national guidelines on the use of chemical dispersants for treating oil spills. As a result, RRETC audits dispersants which enter the Canadian market to check their effectiveness and toxicity in relation to the national guidelines. Dispersants which meet or exceed the effectiveness and toxicity criteria are included on the list of dispersants accepted by the department for potential use in Canada. Actual dispersant-use decisions, however, are made on a case-by-case basis by factoring

in the particular circumstances of the specific spill situation.

Other Spill-treating Agents. AMOP has supported work on a variety of spill-treating agents such as sinking agents, herding agents, oil-spill combustion enhancers, and oil biodegradation enhancers. Work is underway to develop standardized tests and criteria for assessing the performance of 10 types of spill-treating agents. So far, tests have been developed for testing the effectiveness of recovery agents ("elasticizers"), solidifiers, emulsion breakers, and surface-washing agents.

Disposal

Burial and incineration are two methods of disposal for recovered oil and oiled materials that have been addressed under the AMOP.

Burial. Despite the recognized problems of operating land vehicles in the Arctic and the long-term terrain damage that can result, it was deemed prudent to be prepared for situations where there might be no other practical alternative along the shores of the southern Beaufort Sea. Selection criteria were established and possible burial sites were identified from aerial photographs.

Incineration. A number of projects have been undertaken to develop a capability for incinerating oil in the Arctic and in other remote areas of Canada where it would be very expensive to transport oil and oil-contaminated materials to incinerators elsewhere. Simple wicking devices to collect and burn oil floating on melt pools were found to be impractical. A prototype device has been developed, however, that makes use of ultrasonic energy to herd, lift, and atomize floating oil and it has burned-off emulsified crude oil under calm conditions with virtually no smoke. An air-transportable pit incinerator has been developed for disposing of oiled combustibles. A rotary kiln assembled from readily available materials (e.g., used oil drums and car wheels) has been built and tested in co-operation with the Canadian oil industry. The design of this kiln is being re-evaluated, in an attempt to broaden the range of materials which can be treated.

CURRENT R&D PLANS

RRETC uses a co-operative approach to identifying R&D needs and for planning and implementing projects. A series of specialist advisory committees are used to help identify technical shortfalls and to promote research co-operation and co-ordination. Specialist advice is sought from the government, private and academic sectors in Canada and the United States and from experts overseas. In addition, managers from co-funding agencies and spill-response organizations are involved in the project selection and the process of delineating priorities. Over the years, this collegial approach has resulted in a significant level of joint-project agreements and cooperative work with a range of agencies inside and outside Canada.

The following is a summary of AMOP and hazardous material spill-response R&D projects which are planned by RRETC for the 1992-93 fiscal year (the initiation in FY1992-93 of those marked by an asterisk* is dependent on additional funding):

Detection and Tracking

Work continues on developing and testing:

- **Person-portable Analytical Equipment** -to measure contamination levels at spill sites.
- **Vehicle-mobile Analytical Systems** -to develop super-critical extraction techniques for high priority substances and GC-MS methods for on-site analysis.
- **Fluorosensor** -to develop an operational airborne laser fluorosensor for oil-spill remote sensing.
- **Slick-thickness Sensor** - to participate in a joint effort to develop a dual-laser oil-slick thickness sensor.
- **Model Helicopter** - to commercialize the remote-controlled air-sampling model helicopter.
- **Oil-under-ice Detection** -to co-sponsor development of a prototype acoustic system.
- **Spill-response Vehicles** - to study the design and optimum configuration of vehicles for response to chemical spill incidents.

- **New Radar*** - to develop a Synthetic-Aperture Radar (SAR) specifically for oil spills.
- **Airborne Sampler*** -to participate in the development of an air-deployable slick sampler for obtaining legal samples.
- **Beach Probe*** - to conduct a feasibility study on the development of a probe to detect and quantify the amount of oil sunken into contaminated sediments.
- **New IR/UV*** - to develop a new infrared/ultraviolet system for oil-spill remote sensing.
- **Oil Identification*** - to review and update methods for oil spill identification for legal purposes.
- **New Sensors Evaluation*** - to evaluate the most promising new remote-sensing concepts for application to oil spill response.

Properties, Behaviour, and Modelling

Work will be conducted on:

- **Oil Analysis** - to improve analysis for environmental purposes.
- **MAP Extraction** - to commercialize the application of MAP technology for chemical extraction (minimizing waste products and energy use).
- **Manual for Spills of Hazardous Materials** - to develop a new manual containing more data and chemical listings.
- **Artificial Intelligence System** - to complete a prototype and to do testing on the Spill Modelling Artificial Reasoning Technology (SMART) System.
- **BOSS (Behaviour of Oil SpillS) Project** - to continue literature reviews and data collection to produce a volume of findings on oil-spill behaviour.
- **Oil Behaviour** - to initiate laboratory studies on oil spill behaviour.
- **Oil Catalogue** - to measure the properites of oils and petroleum products.
- **Oil Spill Model** - to participate in the consortium to develop the "World Oil Spill Model" for predicting the fate of marine oil spills.
- **BLEVE** - to continue to participate in a study for understanding BLEVEs (Boiling Liquid Expanding-Vapour Explosion).
- **Stranded Oil Fate and Self-cleaning Rates** - to focus on oil fate and persistence, interactions and processes, natural removal rates, and development of models for surficial and subsurface oil stranded on various types of shorelines.
- **Monitor Oil Spill Sites** - to revisit the *Arrow* and *Kurdistan* oil spill sites to report the status of residual contamination, long-term fate, effects, and recovery, and to evaluate the long-term results of the cleanup actions taken.
- **Toxicity Methods Development** - to develop and standardize methods for laboratory spill-substance toxicity testing and assessment.
- **Water Uptake*** - to plan a study on the uptake of water by oil spills - with and without oil-in-water emulsion formation.
- **Energy Measurement*** - to develop a procedure using laser turbulence probes to measure energy in laboratory shakers and in test tanks.
- **LNG Literature*** - to review and summarize the literature on the spill-related aspects of Liquified Natural Gas (LNG).
- **Oil Analysis*** - to compile analytical methods for oil spill work in one report.
- **Oil Characterization*** - to develop high technology procedures for the characterization of oil spills.
- **Soil Penetration*** - to participate in a study of chemical penetration rates in soils.
- **Long-term Weathering*** - to study further the long-term weathering of oil spills. Significant laboratory data have been obtained under conditions simulating oil on open water and oil which has

sunk. It is proposed to focus the additional studies on emulsions and their long-term fate.

- **Spills-of-Opportunity*** - to conduct a study on oil sedimentation using a spill-of-opportunity, if a suitable opportunity arises.

- **Toxicity Primer*** - to prepare a toxicity primer pamphlet to cover marine and non-marine spills of hazardous materials.

- **Fate and Effects Bibliography*** - to assess and install the computerized fate and effects bibliography developed jointly with the Department of Fisheries & Oceans.

Remedial Measures

Studies on remedial measures will continue on:

- ***In-situ* Burns** - to participate in the multi-year study of burning slicks contained by fireproof booms.

- **Chemical Spill Countermeasures Manual** - to update, verify the existing entries and survey the Chemical Spill Countermeasures Manual.

- **Shoreline Cleanup Manuals** - to prepare manuals to advise on environmentally sound assessment procedures, cleanup criteria, practices, and policies for coastal oil spills.

- **Environmental Assessment of Spill Countermeasures** - to develop further the design of the Spill Countermeasures - Performance & Effects (SCOPE) Project that will use experimental discharges of oil to evaluate countermeasures and cleanup technologies for coarse-sediment shorelines.

- **Soil Cleanup Criteria** - to monitor the results from the National Contaminated Sites Remediation Program and use relevant information to develop improved environmental quality and cleanup criteria for spilled substances in soils.

- **Boom and Skimmer Evaluations** - to evaluate new and improved boom and skimmer concepts and equipment.

- **Sorbent Evaluations** - to evaluate new and existing sorbents using updated protocols and criteria developed in conjunction with the American Society for Testing & Materials (ASTM) and the Canadian General Standards Board (CGSB).

- **Waterjet Barrier** - to test the high-pressure, low-volume waterjet barrier in the St. Lawrence River and the OHMSETT test tank in the Fall of 1992.

- **Pump Evaluations** - to examine pumps used in various phases of oil-spill cleanup in a multi-year project.

- **OHMSETT Revitalization** - to contribute approximately 1/10th the cost involved in commissioning and operating the OHMSETT test tank in Leonardo, New Jersey. The tank is managed by the U.S. Minerals Management Service with support from the U.S. Coast Guard. RRETC has a representative on the committee with oversees and plans the programs for the facility.

- **Tanker Self-help Workshop** -The Canadian and U.S. Coast Guards carried out studies on this topic last year. RRETC organized a workshop in Toronto in April, 1992, to examine the conclusions from the studies and to determine if any practical R&D could be done on this issue. The report from the workshop will be available in late 1992.

- **Emulsion-breaking Systems** - to continue to work on a system involving ultrafiltration, solvent addition, and pervaporation that has shown promise in breaking very stable water-in-oil emulsions at bench-scale and follow with pilot-plant-scale work.

- **ASTM Standards Development** - to co-operate with the ASTM Committee F-20 (which deals with Hazardous Materials and Oil Spill Response and which is currently chaired by the Chief, Emergencies Engineering Division, RRETC) to develop standards for oil-spill response equipment testing and performance.

- **Micro- and Ultra-filtration** - to continue bench- and pilot-scale work on an energy-efficient method that uses micro- and ultra-filtration and water-soluble polymers to remove heavy metals from water.

- **Steam Stripper Evaluation** - to conduct further trials to demonstrate the capability of the RRETC prototype mobile steam stripper to cleanup groundwater contaminated by a spill of methylene chloride.

- **Membrane Technology Evaluation** - to evaluate the capabilites of new membranes recently developed for spill cleanup.

- **Pesticide Residue Treatment** - to study the need to concentrate or destroy pesticide residues resulting from pesticide warehouse fires and container recylcing programs.

- **Butane Stripper Evaluation** - to evaluate the two refurbished pilot-scale prototype mobile units developed by RRETC which use liquid butane and pervaporation, respectively, to remove chemicals from ground- and surface-water.

- **Cleanup of Contaminated Soil** - to conduct bench-scale work on various soil matrices for a solvent extraction system that uses hexane or natural gas liquids for the removal of hydrocarbons and other organic chemicals from soils.

- **Microwave-Assisted Process (MAP)** - to investigate the applicability of the DOE-patented MAP extraction technology to treat spills of organic chemicals in soil including hydrocarbons.

- **Basics of Chemical Spills Book*** - to complete the *Basics of Chemical Spills* book as the companion to the *Basics of Oil Spill Cleanup* volume.

- **Corralling Oil Slicks in Rivers*** - to assess a technique for coralling oil slicks in fast currents.

- **Treatment of Sinkers*** - to investigate a procedure for countermeasures for spills of dense liquids in relatively shallow waters.

- **Freeze Crystallization*** - to plan a small field trial for recovering metal salts from a spill using freeze crystallization.

Spill-treating Agents

Studies on spill-treating agents will cover:

- **Guidelines** - to develop guidelines for spill-treating agent performance.

- **Treating Agent Tests** - to develop and use tests to evaluate the performance of treating agents.

- **Dispersant Development** - to continue working on the chemistry and physics of dispersant use under a joint U.S. MMS - Environment Canada project.

- **Spill-treating Agent Performance** - to test chemical dispersants for auditing compliance with Environment Canada toxicity and effectiveness guidelines.

Disposal

Studies on disposal include:

- **Incineration of Oil-spill Debris** - to study emission and equipment performance data at bench-, pilot, and full-scale.

- **Enhanced Oxidation** -to study the use of titanium oxide as a catalyst in the RRETC prototype mobile enhanced oxidation unit used for chemical destruction.

- **Enhanced Oxidation in Non-aqueous Solvents** - to continue bench-scale work and construct a moblie pilot unit for continuing solvent extraction and enhanced oxidation to improve destruction efficiencies for organic compounds in soil matrices.

- **Destruction of Chlorinated Alkanes** - to investigate alternative destruction technologies for chlorinated alkanes and compare enhanced oxidation in bench-scale work.

- **Vapour Phase Enhanced-Oxidation Studies** - to study an enhanced oxidation process

used for destruction of compounds in vapour phase.

CONCLUSIONS

Some of the deficiencies in oil-spill countermeasures technology have been recognized recently in North America as a result of damage caused by the EXXON VALDEZ tanker grounding in Alaska, and the NESTUCCA barge incident off the west coast of Canada. As a result of this realization, numerous U.S. and Canadian organizations have entered, re-entered, or accelerated their work in the marine oil-spill R&D arena. In order to gain full benefit from this increased activity, it is important that the players take considerable care not to duplicate previous or ongoing work, and that existing and new R&D efforts are efficiently co-ordinated.

The AMOP will continue to focus on marine and cold-climate oil-spill problems, and has a track record of co-operation with agencies inside and outside Canada. New initiatives in the area of cold-climate and marine oil-spill research and countermeasures technology development should build on the expertise and knowledge which have been developed through the AMOP. Ideally, new work should be co-ordinated through the existing linkages and management mechanisms - adapted as necessary to accommodate the legitimate interests of organizations entering or re-entering the field.

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The Spill Technology Newsletter was started with modest intentions in 1976 to provide a forum for the exchange of information on spill countermeasures and other related matters. We now have over 2000 subscribers in over 40 countries.

To broaden the scope of this newsletter, and to provide more information on industry and foreign activities in the field of spill control and prevention, readers are encouraged to submit articles on their work and views in this area.