TECHNICAL AND RESEARCH PROGRAMS BEING IMPLEMENTED IN JAPAN AND FRANCE CONCERNING SUBMERGED OIL MONITIRING.

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ABSTRACT

The transportation at sea of persistent and heavy oils is on the rise and concerns about the associated risks have recently increased in many countries.

A succession of accidents has demonstrated that submerged and sunken oils are a much common occurrence than previously thought and that it is almost impossible to track them in many cases. This is due to the lack of adequate tools both for their detection and the drift prediction, underneath the sea surface or on the sea floor.

From this conclusion experimental and research programs are being implemented in France and Japan. In this country the NMRI is developing specialised tools to detect slightly submerged oil slicks and tests are taking place to determine how deep the UV fluorosensor is effective. In addition the use of a new Lidar using a blue green laser should increase the penetration in sea water and provide seamless geographical data of the coastal area. On an other hand an Ocean Surface Current Radar has been developed to measure the distribution of currents and sea states near the shore.

In France efforts are concentrated on the monitoring of heavy oil slightly submerged or sunken on the sea floor through different projects funded by post Erika comprehensive actions. A new AUV dedicated to pollution and wreck monitoring is developed and will undergo testing at sea. In parallel the assessment of specific sensors is to be completed together with experiments taking into account heavy oils.

In both countries these technical and research projects have the common objective to improve the responders capacity to eventually predict when and where submerged oil will strike the coastline or sensitive areas.

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INTRODUCTION

The transportation at sea of persistent and heavy fuel oils is increasing and will still increase in the future. On the other hand spills of such oils are among the most polluting products and are very difficult to combat because of a high viscosity. But beyond this difficulty the submerged and sunken parts of those heavy oils are an additional concern. The sinking to the sea bottom or the slight submergence of heavy oil is a much more common occurrence than generally recognised. The changes that lead to this sinking are often not well understood especially after some two or three days of weathering or from the beginning when the product is a residual, a cut or a mixing. Because of these facts, submerged oil monitoring is a challenging problem in many respects.
The NAKHODKA and ERIKA spills are good examples of this challenge for in both cases the heavy fuel oil had been spilled far from the shores and the product had been drifting for many days in rough seas and had caused a widespread contamination.
Previous incidents in Europe, many years ago, involving large quantities of oils had already lead to important submerged pollution: the GINO and TANIO (France) and the HAVEN (Italy). Every incident is peculiar because of the product involved and because of the environmental conditions. This point is also of great importance and partially explains the difficulty to derive appropriate experience.

THE JAPANESE CONTEXT

A massive oil spill, which was caused by the fracturing of the hull of the tanker NAKHODKA occurred on 2 January 1997 in rough seas of about 6 m in wave height. The drifting bow section was confirmed the following day. Daytime observations were conducted using helicopters of Japan Coast Guard (JCG, at that time the Maritime Safety Agency) and airplanes of the Maritime Self Defense Forces to gather information. But it was extreamly difficult to observe the total image of oil slicks in the turbulent seas. After the storm, unexpectedly appeared big discs of oil spill, sometimes larger than 100m in diameter.

While there is a wide range of oil recovery systems available, all suffers limitations in the rough sea conditions prevalent in winter in the Sea of Japan. There will always be a major problem of emulsion with heavy fuel oil, which is not amenable. The oil of the tanker NAKHODKA loaded at Shanghai, had viscosities of 137 cSt at

Tokyo 181-0004 Japan

50°C (6,000 cSt at 10°C). But the drifting oil sampled on 5 January had viscosities of 1,232,000 cSt at 12°C. It was very difficult to recover oil in offshore.

Although some dispersants were tested by Maritime Disaster Prevention Center(MDPC), they were turned out not so effective to this weathered oil slick. Dispersant action will be initiated only where it is likely to be effective and in the judgment of experts, there is a significant threat of damage to birds or marine life on the coast, or where an offshore operator considers it necessary for safety reasons. If oil disperse into small droplets in the water column it would be difficult to locate and to evaluate the effects by any means other than in-situ sampling.

Ten days after the stern of NAKHODKA had sunken, drifting spilled oil was detected near the incident point where the depth is about 2000m. The investigations were conducted by unmanned remotely operated vehicle (ROV) of Japan Marine Science & Technology Centre (JAMSTEC). At first, a submersible sonar equipment was employed to sound wrecks and the surrounding sea bottom, then ROV DOLPHIN-3K confirmed ship's name, "Nakhodka" and carried out detailed inspection of ruptured surfaces and also observed a slow raising of oil seep whose rate was estimated 3-4kl/day. JCG has conducted a patrol of the seas for five year, it does not seem that the situation has greatly changed but its rate is considered in decrease. The fate of seep is not yet clarified

THE FRENCH CONTEXT

On December 12, 1999, the Maltese tanker ERIKA, loaded with 30,000 tons of heavy fuel oil and sailing from Dunkirk (France) to Livorno (Italy), broke up into two parts in bad weather and sank 40 miles off the Brittany coast in the northern part of the Bay of Biscay. The very first assessment of the situation revealed that between 5,000 and 7,000 tons of Fuel Oil n°6 (20,000 cSt at 10°C and over 100,000 cSt when emulsified) had been released into the sea. In fact almost 20,000 tons had been spilled, generating the most dramatic black tide since the 223,000 tons released by the AMOCO CADIZ tanker, 21 years before.

One of the main problems underlined by the ERIKA spill is the overall tracking of the oil slicks. In addition to the characteristics of the heavy fuel oil involved in this spill, the behaviour of the weathered slicks has been influenced by the bad weather and the near shore conditions. These slicks of heavy oil have been only partially detected and the efficiency of the airborne sensors has been subject to discussion. Because these aerial means did not performed well in this case, the ability to track all the slicks has been considerably reduced. In addition there is a clear possibility that some heavy oil has been submerged and has travelled without being detected in some circumstances. For example in the vicinity of the Loire estuary the heavy oil slicks have most probably lost buoyancy when coming into contact with the large river plume or when some sediment has been mixed to the oil. From these facts the necessity to improve the ability to detect heavy oil when submerged either slightly under the sea surface or deeper in the water column and on the sea floor has been identified as a major topic by the French authorities.

Less than three months after the ERIKA oil spill that has heavily polluted a large part of the French Atlantic coastline, an inter-ministerial committee (CIADT) has announced a first package of major decisions to improve pollution prevention and management. The CIADT has decided among others the creation of a R&D Network for the development of the expertise needed in various fields. This network called RITMER (Réseau de Recherche et d'innovation Technologiques concernant les pollutions Marines accidentelles et conséquences écologiques) aims at promoting projects that could improve the detection and the intervention means as well as the protection and restoration of the various ecosystems. This Network should involve research institutes and private companies working in the field of pollution fighting. It may also include marine professionals (fishermen, …) and marine companies. The R&D project proposals are first technically reviewed before being funded by the relevant ministry, most of the time the Ministry for Research. In fact the proposed projects may also be dedicated to the spreading of specific knowledge or to the organisation of thematic seminar.

Other post Erika actions are based on the French petroleum industry through a consultative committee under the authority of the Ministry of Industry. This committee, called CEPM, examines, assesses and classifies research projects presented by the French industry in the petroleum exploration and production sector. A partial funding of the selected projects is set up by the above mentioned Ministry.

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A EUROPEAN COOPERATION

In December 2000 the European Parliament and the Council set up a Community framework for cooperation in the field of accidental or deliberate marine pollution. The Directorate General / Environment made a call for proposals in 2001 to support and supplement national and regional efforts in that field. This call was encompassing several topics from Bioremediation and Response in cold waters to Response to submerged oil spill, this last topic including “analysis of techniques, means of detection”

THE TECHNICAL PROGRAMS

In Japan

From incidents of Nakhodka and chemical tankers, we learn that it is necessary to improve the following techniques so that information at a spill site can be provided rapidly with the precision and accuracy needed for both tactical operations and strategic planning:

- to detect submerged oil or chemical pollutions in the subsurface layer
- to measure distribution of oil droplets in the water for evaluating effects of dispersants
- to observe seep from wrecks more easily

The current problem of detecting objects located within a body of water will be overcome by the use of a gated imaging lidar system. Lidar system is capable of reproducing images from the surface to some depths. The major physical constrains responsible for the propagation light through water are absorption and scattering. The depth to which light penetrates varies with wavelengths; shorter wavelengths are normally absorbed at shallow depths.

The compact imaging lidar system developed by National Maritime Research Institute (NMRI) is a rather simple one without scanning capability. The laser is mounted next to the receiver telescope. The receiver consisted of a lens that collects the scattered light onto CCD image detector through an image intensifier. An interference filter is placed in front of the detector to limit interference from background light. The detector is triggered to begin each measurement at surface and useful signal is received during gate opening time. The detector output is digitized and stored in the computer.

In homogeneous water, the return signal from a lidar will experience an exponential decrease with propagation distance that is in addition to the geometric loss. For each lidar pulse, the return waveform is analyzed to obtain the optical properties of the water, especially the measured beam attenuation parameters.

There are several problems to be drawn from the field research. The lidar attenuation coefficient is highly correlated with in-situ measurements of the optical properties of the water. The fluctuations in the lidar signal are primarily because of the refractive effects of surface waves. The irregular movement of platform reduces the accuracy of gate operation that relates to the resolution. The temporal width of the laser pulse of several nano-seconds also limits the resolution of the lidar. NMRI has started new experiments at the tower of 19m above the basin to evaluate how deep the instrument is capable to measure fluorescence of oil and to detect objects in the water column.

Monitoring techniques combined with accurate drift computer model forecasting are the primary strategic tools used for environmental response planning.

Here are two important projects concerning under water sensing and observation of ocean current supported by national research organizations.

JCG announced that a new airborne lidar bathymeter will be operated in 2003 to meet its shallow-water coastal surveying needs to provide seamless geographical data of the coastal area. Also it will serve to countermeasure various natural disasters with rapid deployment and to survey shallow-water. It could help for monitoring submerged oil.

An ocean surface current radar (OSCR) has been developed by Communications Research Laboratory (CRL) to measure the distribution of ocean currents and sea states near the shore using backscatter echoes from ocean waves. The system utilises VHF radio frequency to map surface current patterns over a large area up to 200km from the coast. The shore-based radar system in Okinawa has started operation consisting of two stations deployed two islands about 100km apart. Each station makes independent measurements of current speed along radials emanating from its phased-array antenna system. The data are then combined to produce accurate vector currents.

In Japan, a variety of technologies have been developed to cope with accidental marine pollution supported by governmental and non-governmental organizations.

These researches of remote sensing methods, satellite image analysis and prediction of drift have varying degrees of success in operational expectations, and thus is not yet fully integrated into national, regional and area response plans and operations.

Cooperated experiments to evaluate capabilities of variety techniques to cope with marine pollution are highly expected in the future.

In France

A state of the art concerning the underwater detection of oil slicks has been performed by Cedre in the year 2000 subsequently to the ERIKA spill. This review has shown that there is almost no convincing experience at sea for off-the-shelf underwater devices in the whole world although underwater pollution by heavy oil is not so unusual. This situation may be due to much varied marine conditions together with no certainty about the feasibility of underwater surveys although sonar and echo-sounders are routinely operated for the offshore petroleum industry. From this review the major conclusion was that the tracking and detection of submerged oil is a challenging question and very few research and development efforts had been committed up to now.

Therefore the recommendation to the French authorities has been the following:

- implementation of an evaluation project concerning existing tools supposed to be relevant for adequate underwater surveys
- improve expertise concerning new aerial means to detect slightly submerged slicks through international co-operation in the development of new tools (for instance: Lidar Induced Fluorescence technology)
- development and testing of new underwater sensors

Therefore three projects were proposed, the first of them is a project initiated by ECA, an industrial leader in the field of mine warfare vehicles and offshore technology, aiming at developing an Autonomous Underwater Vehicle (AUV) dedicated to accidental pollution monitoring. The scope of its missions is ranging from detailed mapping of wrecks to pollutants identification with adequate or specialised sensors. This project, called MARIE and co-ordinated by ECA, involves several partners (IFREMER/COMEX/Cedre) and is funded through the CEPM. This project has started in 2001 and should end in 2003. It will enable to test a new vehicle at sea and to test its ability to map a ship wreck, to make a photo-mosaic of this wreck and also to make a survey of a large area to record the current and salinity pattern. This last survey is intended to give a valuable input to a 3D drift model so as to predict the impact of the pollutants leakage in areas where the currents are not well kwown. In a later stage this will be completed by the use of new sensors for the determination of the product involved in the pollution, this could be based on the results from the third project described hereunder.

The second project concerns the evaluation of existing acoustic tools to detect heavy oil slicks on the sea floor. This project, named “Expérimentation de Capteurs Acoustiques pour la détection de Pollutions Immergées” (EXCAPI), is mainly based on experiments through the use of a large sea water basin with an artificial sandy sea floor . It aims at giving the Authorities better advises as for the selection of the best available sonar according to the specific conditions prevailing on each site that is polluted or supposed to be by underwater oil slicks. This project is already labelled by the RITMER and should start quite soon. The main partners are Cedre, IFREMER and GESMA. The latter is a research group having a strong expertise in underwater acoustics and combat systems within the French defence organisation. The other partners are university research laboratories specialised in acoustics.

A third project has been proposed according to the European call (EESD framework) and is complementary to the previous ones because it encompasses all kind of sensors, being recent or under development. It aims at assessing the performance of those sensors according to the operational needs. This includes not only the reliability and sensitivity but also the ability to use them on different underwater vehicles and in varied conditions. There will be a French-Italian partnership, the partners being ICRAM/IFREMER and Cedre, to conduct this project that will possibly includes some laboratory experiments in addition to a detailed evaluation.

A follow up project should be dedicated to the experiment of the most relevant sensors in actual situations such as a polluted area in the Mediterranean sea.

CONCLUSION

The NAKHODKA and ERIKA accidents that occurred in Japan and France entailed new developments because of the important problems that had to be faced due to the heavy oil characteristics. Among others the monitoring of submerged and sunken oil is a technical challenge which implies the development and testing of a variety of technologies. Some of this work is already initiated but a lot more is surely needed to cope with this type of pollution. Thus more international co-operation is highly expected to significantly improve the monitoring of heavy oil slicks.

BIOGRAPHY

François PARTHIOT graduated from Ecole Centrale de Lyon in 1971 and from Ecole Nationale Supérieure de Techniques Avancées in 1973, specialising in naval architecture and ocean engineering. He worked within CNEXO on the exploration of polymetallic nodule fields in the Pacific Ocean for two years, then in a consulting company on various topics concerning harbour and coastal development. From 1983 within IFREMER he has been successively in charge of the underwater intervention on deep wrecks then of the development of new deep underwater systems for sea floor surveys and mapping. He joined Cedre's delegation for the Mediterranean Sea in the year 2000 and is involved in oil detection both with satellite and underwater tools.

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NMRI (Japan) NAKHODKA-ERIKA technical lessons Cedre (France)

TECHNICAL and RESEARCH PROGRAMS

being implemented in Japan and France

concerning

SUBMERGED OIL MONITORING

GINO / CYANA- 1982

NMRI NAKHODKA-ERIKA technical lessons Cedre

NAKHODKA / ERIKA accidents: many similarities

* heavy fuel oils: high viscosity (+10 000 cSt)
* vessels broke in 2 parts (one sinks/one is towed)
* wreckages occurred 100/50 km from the shore
* slicks impacted large portions of shoreline +500 km
* after several days of drifting
  (6 and 12 days / first arrivals)

NMRI NAKHODKA-ERIKA technical lessons

First lesson:

It is necessary to improves techniques

so that information concerning the spill can be provided rapidly and accurately

for strategic planning and tactical operations

NMRI NAKHODKA-ERIKA technical lessons

CORRESPONDING NEEDS THAT WERE DERIVED:

* detect submerged oil in subsurface on large scale
* measure distribution of droplets in water column
* observe seepage from the wreck more easily
* detect oil slicks on the sea floor

NMRI NAKHODKA-ERIKA technical lessons

NEW TECHNIQUES CONSIDERED IN JAPAN:

* compact fluorescence Lidar :performance / depth of pollutants
* lidar bathymeter: to provide data on the coastal area
* ocean surface current Radar / up to 200 km from coast

THESE TECHNIQUES ARE DEVELOPPED / TESTED BY:

NMRI (National Maritime Research Institute)
JCG (Japan Coast Guards)
CRL (Communications Research Laboratory)

NMRI NAKHODKA-ERIKA technical lessons

TECHNICAL ACTIONS in FRANCE:

* acoustic sensors (multibeam sounder, imaging sonar…)
* fluorimeter, laser fluorosensor, spectrometer, …
* light supportvessels
* dedicated underwater vehicles (ROV/AUV)

NMRI NAKHODKA-ERIKA technical lessons

ACTIONS FUNDED THROUGH POST-ERIKA PROGRAMS:

RITMER a R&D network initiated by the French authorities involving research institutes, private companies,..

CEPM committee under the authority of the Ministry of Industry that assesses and classifies projects related to offshore petroleum industry

EUROPEAN COMMISSION- Directorate Gen. Environment: cooperation against accidental or deliberate marine pollution

NMRI NAKHODKA-ERIKA technical lessons

RITMER FUNDED PROJECT: EXCAPI

experiments in a large seawater tank (9 000 m3)

several oil patches on a sandy floor (20 cm)
several heavy oils

assessment of existing acoustic sonars:
side scan sonars
panoramic sonars

NMRI NAKHODKA-ERIKA technical lessons

CEPM FUNDED PROJECT: MARIE

development and testing at sea of a new AUV design to:

map the ship wreck

make a detailed photo mosaic of the wreck and vicinity

survey a large area / currents / salinity / temperature

survey for pollutant detection and mapping

NMRI NAKHODKA-ERIKA technical lessons

E.C. FUNDED PROJECT: DENIM
(expected)

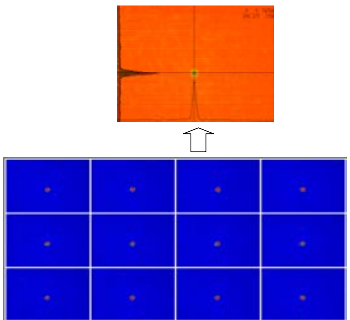
assessment of new sensors: fluorosensors, spectrometers
(reliability, sensitivity, accuracy)

ability to be operated at sea in severe conditions

interfacing with different underwater vehicles

Sequence of laser spot images obtained from 1000ft

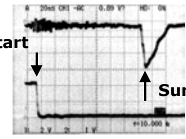
Fluorescence lidar boarded on Beach Craft observed the Lake Biwa. (NMRI)



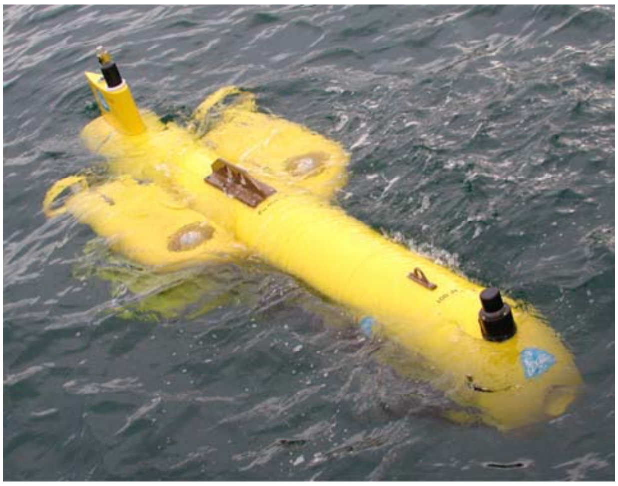
Images of spot on the water surface(0.9m in dia.)

Lidar experiments from the tower

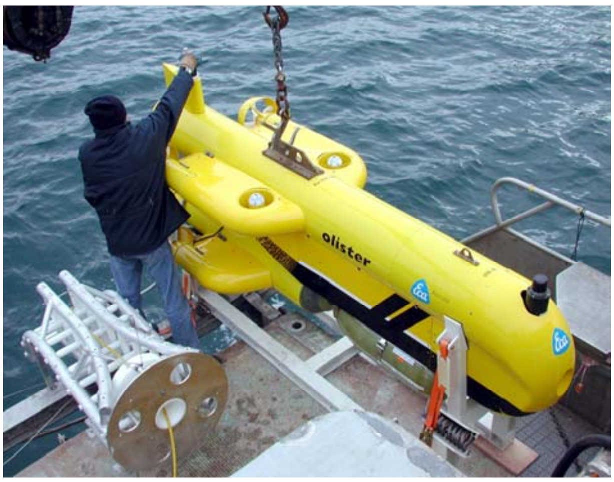
Tests are taking place to determine how deep the lidar is effective on various conditions. (NMRI)



Observational tower of 19m in height



ECA / OLISTER



ECA / OLISTER

The SOFIE Core Instrument

IFREMER

SOFIE: Spectroscopy using Optical Fibres In the marine Environment

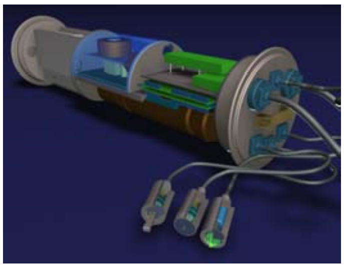
Description:

•Instrument Central

(spectrographe, sources lumineuses, detection et transmission de données)

•Optodes

Passive: Evanescence
Active: Fluorescence
Raman SERS



IFREMER

SOFIE: **S**pectroscopy using **O**ptical **F**ibres **I**n the marine **E**nvironment

(E.C. funded project)

Main Characteristics:

Mechanical:	Dimensions (L,Φ):	1.2m, 0.250m
	Weight: air/50kg	water/3kg
Electrical:	220V , 0.6A max	
	Connector: Jupiter	
Communication	real time: serial Standard RS485	

Maximum operational depth: 300m

IFREMER

NMRI

NAKHODKA-ERIKA technical lessons

CONCLUSION

To face a technical challenge due to a specific type of pollution:

highly innovative and dedicated techniques are needed

international cooperation is needed

to increase the chance to cope with

the most demanding situations