DENIM
EXECUTIVE SUMMARY

INTRODUCTION

The cleaning operations after the *Erika* spill have lasted for many months and in some specific cases almost two years. These later cases often correspond to coastal sites where sunken oil slicks have been found on the seafloor at depth of a few meters. It is of paramount importance to detect and map these oil patches so as to plan an adequate response such as a recovery operation.
The oil products transported at sea that have the potential, when accidentally spilled, to sink after weathering or mixing with sediment are quite numerous: asphalt, carbon black oil, bunker C, fuel oil n°5 and 6.
These sunken oil slicks will most probably affect seafloor areas that are situated near the surf zone or in river mouth where they can get mixed with sediment and then be trapped in specific places. When the local currents become stronger, during high tide or storm conditions, the shore line may be re-oiled in an unexpected way.
During the last twenty years there has been several spills involving heavy fuel oil in the world including North-America and Europe. In many of these accidents, part of the heavy fuel has sunk and produced a threat to the environment that has been difficult to evaluate because of the lack of means of detection and monitoring.

We had to <u>consider all available technologies that could help to identify and map the polluted seafloor area.</u>

First of all the <u>acoustical imaging systems,</u> that are commonly used for offshore research, are able <u>to quickly map the seafloor</u>. A number of such systems are commercially available but they have not been used in response to actual oil spills. For this reason a comprehensive acoustic experiment has been performed in Brest through the use of a former dry dock. Different types of heavy oil slicks were laid on top of an artificial sand floor in patches of two sizes and three thickness'. In this facility six sonar systems have been tested as for their response and ability to map oil patches according to their frequency, resolution and type: side scan sonar, multibeam/panoramic sonar, 3D real-time sonar camera. Thus 5 commercial systems and also one prototype front-looking sonar were tested. The results are rather positive when considering direct observation of thick slicks (2 to 20 cm) on a sand bottom.

In addition to acoustic systems, <u>indirect means</u> could be derived from other technologies through the <u>detection of dissolved fractions of the oil in the sea water</u>. This method implies sufficient concentration of the traced molecules like PAH which is decreasing during the weathering at sea of the oil spilled.
On an other hand the feasibility has to take into account the existing PAH in the local seawater so as to ensure that this method is relevant. The main findings and recommendations of the project team are given here under.

FINDINGS

Findings 1: High frequency sonar systems (200-500 kHz), commonly used at sea (side scan sonar, multibeam or front-looking sonar, 3D acoustic camera) enable to detect oil patches laying on a sand sediment floor because of the low reflectivity of the oil patches due to their high attenuation property. However the contrast depends on the altitude over the sea floor, the system type and the geometry of the beams.

Findings 2: The contrast that was obtained in comparison with the surrounding sand, for any sonar type and all three pollutant type (A/B/C), is in the order of 10-15 dB within the frequency range of 240-460 kHz for the three thickness (3/8/20 cm). Around 100 kHz the contrast is never more than 5 dB and logically varies with the thickness (the thinner the oil patch, the least the contrast).

Findings 3: The side scan sonar systems are working away from the vertical (30° to 80°) and in such conditions the oil-sand contrast is rather high (around 15 dB). As they should be operated at a constant altitude above the seafloor, these systems should provide good surveillance on wide swaths, although at nadir the resolution of their images is very poor. Front looking sonar and acoustic camera are able to map slicks in a more detailed way.

Findings 4: the main non acoustic techniques to trace the oil pollutant that could be relevant are of three types according to the physics: Lidar flurosensor, fluorimeter, mass spectrometer. In addition one also should consider bio-technologies and Raman sensors in the near future.

Findings 5: Lidar flurosensors have recently been developed but have not been used or experimented for the tracking of oil or chemical slicks. However because of differentiated spectrum response they have the ability to specifically detect oil in the underwater environment. The useful range of such a system is between 5 to 15 m.

Findings 6: Fluorimeters have the ability to measure the concentration of the oil dissolved fractions at their very location. The concentration measurement range seems to be between 10 nano-g/L and 10 micro-g/L.

Findings 7: Mass spectrometer field-use, when compared to other devices, appear to be more constrained. However recent developments have enable to use them underwater down to 200m.

Findings 8: Some recent mass spectrometer systems for laboratory may be used on board research vessels and their broad sensitivity make them a potential reference for all the underwater systems.

Findings 9: New optical sensors based on a concept of multi-probe instrumentation have been developed in the frame of the EC-funded project MISPEC. Three optical principles have been applied: refractometry, fluorescence and Raman scattering. The sensors, optodes, are linked to a core instrument which comprises a multiple channel spectrometer. The overall system has been designed to be operated *in situ* down to a depth of 300 m. The transducer is based on surface-enhanced Raman spectroscopy (SERS) to increase the sensitivity and improve the selectivity.

Findings 10: Bio-sensors may be sensitive and selective in the sea water, but although being potentially useful for tracking pollutants they have not been really developed for such a purpose.

CONCLUSIONS

The recent accidents in Europe (Erika, Ievoli Sun, Prestige,…) have certainly contributed to reinforce the need for underwater systems able to detect submerged pollutants, such as heavy oils, deposited on the sea-bottom or in the water column. It seems therefore of prime importance to test the techniques that are reviewed here and to adapt already available systems in order to improve the tracking of these pollution and to facilitate future work in case of an oil spill. Chemical spill response could also benefit from a better knowledge concerning some new tracking techniques and the related methods.

RECOMMENDATIONS

Recommendation 1: Side scan sonar systems could be deployed for mapping large areas so as to quickly assess where there could be oil pollution on the seafloor. Then in case of possible oil patches a more precise survey could be undertaken with the use of multibeam, front-looking sonar or 3D acoustic camera installed on board a vessel or an underwater vehicle equipped with a precise positioning system. The definitive confirmation could be obtained with sampling or more conveniently from close video shots by the use of an underwater vehicle.

Recommendation 2: Set a protocol to be used as a reference for the sampling of pollutant and the measurement of concentration for various pollutants being oil or chemical

Recommendation 3: Perform adequate testing, in tanks then in the sea, of the various non acoustic devices that have been selected in this study. It should allow to derive the performance and limits of each instrument as well as the constraints to operate them at sea on board a surface vessel or an underwater vehicle (ROV or AUV) and from these testing derive detailed recommendations as for the effective use of the various devices in real cases.

Recommendation 4: The surveillance needs that have been identified lead to recommend the use of an AUV to reliably and safely operate the detection equipment. Such AUV should be modular to easily accommodate different type of devices. It should be of reasonable size that could be operated from a coastal research vessel of medium size.

Recommendation 5: The organisation in charge of performing such a surveillance should be able to manage all interfacing and operational procedures through extensive testing in realistic sea environments.