SEA TRIALS ON CHEMICAL DISPERSION « DEPOL 04 » :

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ABSTRACT

In May 2004, Cedre organized with the French Navy and in collaboration with the French Customs, sea trials offshore Brittany.
These sea trials involved three controlled oil discharges which have been treated with two chemical dispersants using the Cessna POD spraying equipment from OSRL (Southampton UK) and a ship borne spraying equipment from the French Navy. Dispersants were respectively the products FINASOL OSR52 and GAMLEN OD 4000.
The slicks evolution was monitored with remote sensing techniques, sampled for analysis and measured in situ with spectrofluorometry.

The objectives of these sea trials were:
1. study of the natural weathering of the slicks,
2. assessment of the chemical dispersion of the slicks,
3. assessment of the operational possibilities of the Cessna POD spraying system.

Theses trials were also a good opportunity:
4. to run the annual *Bonnex* intercalibration exercise of the remote sensing means of the Bonn Agreement members,
5. to test new remote sensing devices developed by Actimar and NMRI,
6. to test roughly the Sweeping Arm, an oil recovery device purchased recently by the French Navy to equip its spill control vessels.

This paper presents these sea trials and their results considering mainly the chemical dispersion.
Despite the very calm meteorological conditions, the dispersant treatment gave positive results:
- although the first slick was not totally treated with dispersant, most of the oil has been dispersed,
- the comparison of the last two slicks evolution tends to show either a significant advantage of the aerial treatment over the ship borne one, or a higher efficiency of one dispersant over the other one.

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1. INTRODUCTION

In May 2004, with the logistical support of the French Navy and the French Customs, Cedre conducted sea trials, DEPOL 04, offshore the Atlantic coast of Brittany: this experiment consisted in simulating a real incident by a controlled release of 3 oils slicks. The slicks were monitored with aerial remote sensors and sampled for analysis, then treated with chemical dispersant; at the end of the experiment, residual oil was mechanically recovered.

These sea trials covered the following main objectives:

- study of the weathering of paraffinic and asphaltenic oils,
- assessment of the chemical dispersion of the slicks, when treated with an aerial application system, the Cessna-POD, and with a shipboard application system.

These sea trials gave the opportunity to carry out additional tasks:

- the BONNEX exercise, intercalibration of the aerial remote sensing equipment of the Bonn agreement members, (in this exercise, Sweden, Belgium, United Kingdom and France participated),
- the testing of new oil detection devices under development, DETECSUIV (ACTIMAR French company), LIDAR (NMRI, Japan).
- and finally, the Navy tested at sea its new recovery device, the sweeping arm which equips its supply vessels.

DEPOL 04 has been carried out with the additional co-operation of TOTAL S.A. which supplied the oil and the dispersant, OSRL which owns the Cessna POD dispersant application system, and SINTEF (Norway) and MUMM (Belgium) for scientific support.

2. GENERAL ORGANISATION

2-1 General programme

DEPOL 04 sea trials lasted over 3 days:

- on the first day: release of 10 m^3 of a paraffinic oil, slick A, which was let to weather for around 6 hours and was treated with aerial application of dispersant.

- on the second day: release of two 10 m^3 slicks of asphaltenic oil, slicks B and C, which were let to weather for 7 hours; the slicks were then treated with dispersant either by aerial application or by shipboard application.
- the third day was devoted to the recovery of the residual oil.

2-2. Analyses, measurements and data collection

Different data collections were performed during these sea trials:

1) oil sampling of the slicks was carried out with inflatable boats, in order to measure in the onboard laboratory the physical properties of the oil (viscosity, density, emulsification), [1][2]
2) spectrofluorometry measurements were conducted with inflatable boats in order to assess the dispersed oil content in the water column,
3) aerial imagery was carried out by the 6 remote sensing aircrafts, and 2 additional ones, flying over the slicks: visible, IR and UV, laser fluorometry sensors were used and sometimes combined together (*e.g.* combination of laser fluorometer with an IR sensor in the Actimar equipment).

As a general comment, it was quite difficult to carry out oil sampling on the slicks; the long distance between the slicks and the support vessel as well as the operational restrictions due to the take off and landing of the helicopter on the support vessel, led to limitations for bringing back on board as many samples as expected.
In addition to that, the spectrofluorometry measurements did not give all expected information on the dispersed oil concentration in the water column; the operators faced different problems such as pollution of the measuring cell of the equipment which led to false measurements, bogging down of the internal memory of the equipment which did not allow downloading the recorded data.
Hopefully, the 8 aircrafts which flew over the slicks collected a large amount of images which contributed to interpret the behaviour of the slicks and the dispersion processes: areas of the slick were assessed taking into account the thickness of the oil through its appearance.

3. DESCRIPTION OF THE TESTS

3-1. Meteorological sea conditions

During the 3 days, the meteorological conditions were quite calm especially on the second day (see table 1):

Table 1: meteorological conditions during sea trials DEPOL 04

	Wind (m/s)	Average (m/s)	Sea temperat.
05-25th- morning	0 to 1	0.5	15°C
05-25th- afternoon	1 to 3	1.7	
05-25th to 26th- night	3 to 2	2.6	
05-26th- morning	2 to 1	1.3	
05-26th- afternoon	1 to 0	0.3	
05-26th to 27th- night	0 to 2	0.5	
05-27th- morning	0	0	

3-2. “Slick A”

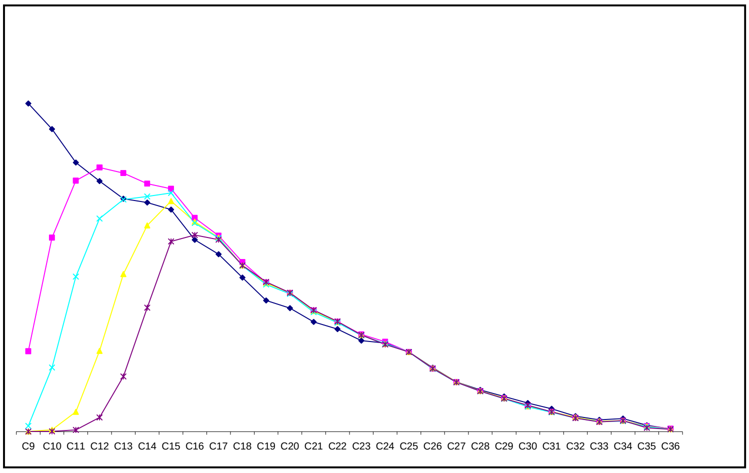
3-2-1. The oil

The oil, supplied by the TOTAL refinery of Normandy, was a mixture of fresh crude oils, especially North sea crude oils chosen in order to get significant proportion of paraffinic compounds; (Draugen [41%], Forties [33%], Saharan [13%], Statfjord [13%]). It was pre-weathered in Cedre by evaporating 11% of its volume and finally added with some topped Arabian light crude oil [<2%].
The properties and composition of this pre-weathered oil are given in table 2: the saturate fraction of the oil is majority. A representation of the GC pattern of the initial oil is given in picture 1and shows the evaporation process which affected the linear alkanes up to C16.

Table 2: Properties of the oil of slick A

Density		0.843 @ 14°C
Viscosity		7 mPa.s @14°C
Composition	Saturates	68.7%
	Aromatics	25.8%
	Resins	4.6%
	Asphaltenes	0.9%

Picture 1: n-Alkanes distribution of slick A oil, at the time of the release and 1, 4, 7 and 45 hours after (all the GC are normalised on C25)

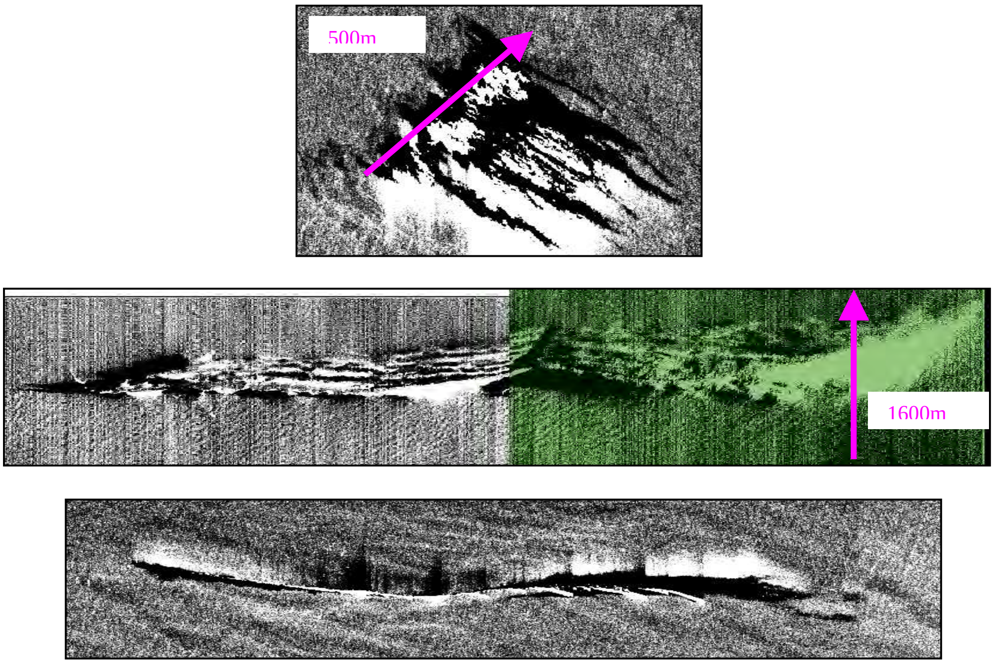


3-2-2. Description of the operation

On the 25th of May, at 10:00 in the morning, the 10 m^3 of oil were released crosswind for around 500 m. The sampling runs were carried out around 1 hour later, then 4.5 and 7.5 hours after the oil release (before and after the application of the dispersant on the slick).
The dispersant application was performed around 6 hours after the oil release (T6), by the airplane Cessna of OSRL, equipped with a POD dispersant application device and guided by

the UK spotting aircraft. According to the airplane crew, 5 spraying runs were performed, and 1 m^3 of Finasol OSR62 dispersant was applied on the slick.
By the end of the day, (8 hours after the oil release-T:8-) a complementary treatment was undertaken by the Navy vessel Lynx with Gamlen OD 4000 to get rid of the residual surface oil.
As some remaining oil was observed on sea surface, on the 27th of May (43 hours after the oil release), the recovery of the residual patches was conducted by the oil spill recovery vessel Alcyon equipped with a sweeping arm (1 m^3 of emulsion collected).
Picture 2 gives IR thermographies from the French Customs describing the evolution of the slick A, respectively after release, after dispersant application and one day later.

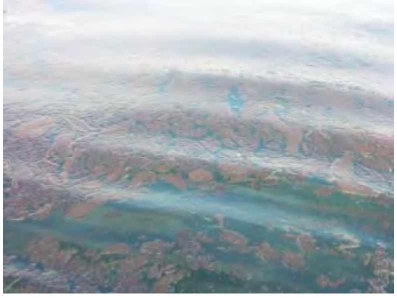
Picture 2: IR thermographies of slick A after release,
after dispersant treatment and one day later



3-2-3. Oil behaviour

The oil viscosity was close to 1000 mPa.s one hour after the release (at T= 1), to reach 3400 mPa.s before treatment (at T= 4.5).
The water content of the oil was measured and the stability of the emulsion assessed by measuring the proportion of water which settled naturally after different period of time [3].
The water content of the oil was found to be around 80 % one hour after the release (T= 1) but the emulsion stability was low (26% water settled after 30 min and 75% after 2 hours). 4,5 hours after the release (T= 4.5) the emulsion content was slightly lower, 72%, but its stability was much higher (5% water settled after 30 min, 20% after 2 hours and 29% after 24 hours).
Small lumps of emulsion (see picture 3) gathered to form the thick part of the slick were reported by observers, which can be interpreted as the crystallisation the paraffinic compounds).

Picture 3: Appearance of the emulsion before treatment



At the time of the treatment the slick was about 100 to 120 ha (3 x 0.4 Km).
After treatment (T= 7.5) the viscosity dropped down to 1000 mPa.s, but the emulsion water content remained relatively high, around 66%. However its stability decreased significantly: 40% water settled after 2 hours and 77% after 24 hours. Observers who sampled the slick reported a clear reduction of the number of emulsified lumps; the residual patches tended to break out when subjected to some agitation (*e.g.* a ship bow wave).
Two days after oil release, (T= 47), the remaining emulsion presented a water contain of 59%.

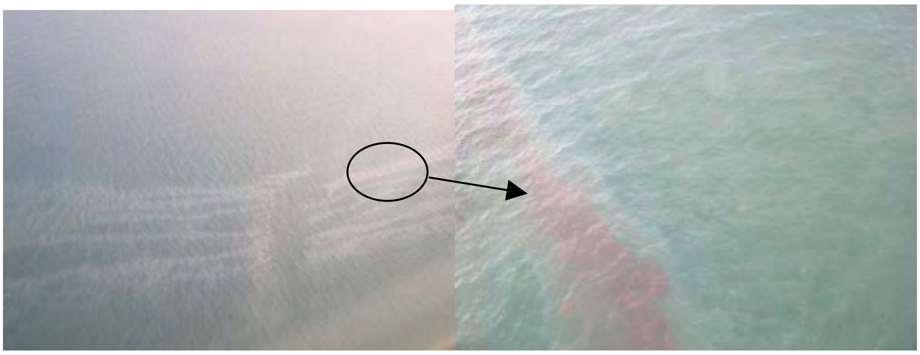
Pictures 4&5: Recovery of the remaining emulsion from slick A, with the sweeping arm, in a very calm sea, two days after release. Aspect of the emulsion

3-2-4 Dispersant application:
On aerial images the tracks of only 4 runs are clearly visible (representing from 1900 to 3040 m long and around 40 m width); the apparent treated surface can be assessed to 38 ha, which represents between 30 and 40% of the total surface of the slick (see picture 7).

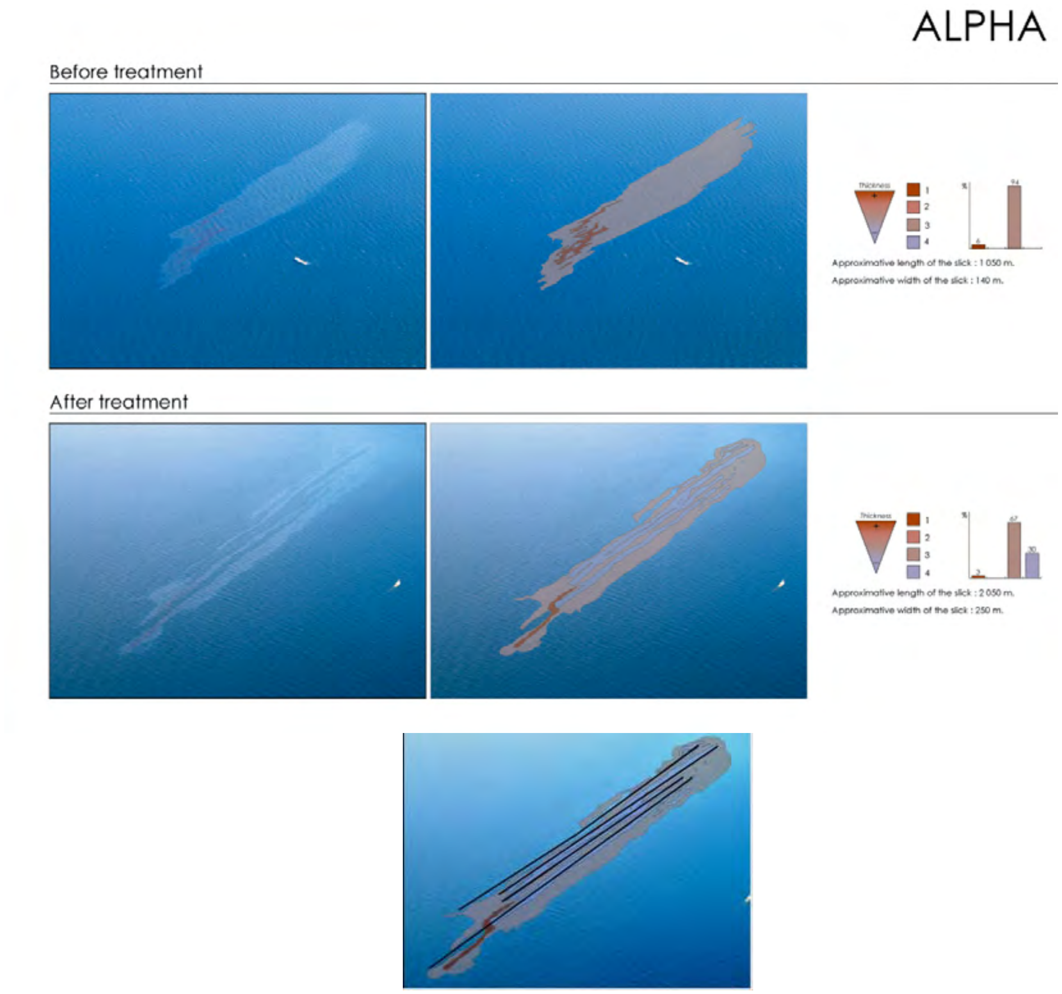
However, the treatment led to the clear reduction of the area of the thickest part of the slick (which dropped from 6 to 3% of the total surface of the slick). Picture 6 shows a stripe of remaining emulsion after the treatment.

In the area of the slick, the relative oil concentrations in the water column measured with Spectrofluorometry doubled after the dispersant application.

Picture 7: Appearance of the slick after treatment
with some untreated stripes of emulsified oil



Picture 6: Visible picture of slick A before and after application.
- on the left : aerial photographies,
- on the right : the original pictures have been processed in order to assess the relative areas covered by the different oil thickness (red emulsion to sheen) –see the histogram.
The 4 treatment runs are indicated on the bottom picture.



3-2-5. Discussion

Despite the dispersant treatment of this slick was carried out in the best possible conditions (good visibility, slick well targeted, assistance of the UK spotting aircraft for guiding, well trained crews), the slick was not totally treated (roughly half of the slick remained untreated as well as half of the thickest part – see picture 7). The remaining emulsion recovered 2 days after could probably be attributed to the emulsion left untreated.
These observations confirm that there are still possibilities for improving the operational procedures for dispersant application in order to apply the dispersant more steadily on the whole slick, thus avoiding untreated areas.

Surprisingly, the width of the treated tracks (30 – 40 m) is much larger than what could be expected from the spraying equipment Cessna-POD, (8 m according to the crew, possibly up to 10 – 15 m), which proves that the dispersant had some herding effect on the oil slick.

Despite the lack of natural agitation, the chemical dispersion with the Finasol OSR62 gave a positive result: it succeeded in reducing the amount of surface oil; the cubic metre of residual emulsion recovered after two days (1 m^3 which represented around 0.6 m3 of pure oil) should be compared to the 10 m^3 of oil initially released which would have become about 30 m^3 of emulsion.

3-3. Slicks B & C

3-3-1. The oil

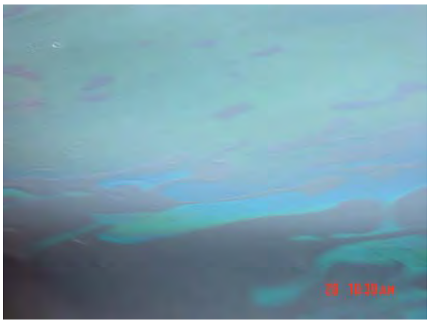
The oil used for slicks B and C was asphaltenic; it was a mixture of Heavy Fuel Oil (60%) and Light Cycle Oil (40%), supplied from TOTAL refinery of Normandy. These two products were mixed in Cedre facilities in order to get a homogeneous mixture with the following properties: density of 0.948 and 4.9 % of asphaltenes. Preparatory work carried out in laboratory showed that this oil could give at sea an emulsion up to 80% water with 5900 cSt viscosity; such characteristics would have been suitable to test the operational efficiency of dispersion.
However, despite the precautions which were taken for mixing these components, the batch of oil used for slick B was a bit heavier than the one used for slick C (oil viscosity was 800 cSt @15°C for slick B and 50 cSt @15°C for slick C).

3-3-2. Description of the operations

For each slick, 9 m^3 of oil were released early in the morning, crosswind, over around 600 m long. Slick B was marked out with a dye spot of rhodamine (red) and slick C released half an hour later was marked out with fluoresceine (green).
The surface oil was sampled between one hour and 3 hours after the release, then again from 5 to 7 hours after release.
Then the dispersant was applied by the Cessna-POD on slick B (between T= 7 and T= 8) and by the ship Lynx on slick C (between T= 7 and T= 8,5). After the dispersant application, ships were sent cruising at high speed on each slick to bring some mixing energy in order to enhance the dispersion process (Alcyon on slick B and Lynx on slick C).
After an additional sampling session (T = 8.5), and an aerial evaluation (T= 10), a complementary dispersant application was undertaken to treat the residual oil. As previously,

this complementary treatment was carried out by the Cessna POD on slick B and the ship Lynx on slick C; the dispersion application was followed with mixing provided by ships cruising in the slick.

Picture 8: Appearance of the oil of slick C two hours after release: the sea is very calm and there has been no formation of emulsion.



3-3-3. Oil behaviour

The weather was very calm and the sea quite flat (wind speed around 1 m/s dropping down to 0 during the afternoon).
Therefore, unexpectedly, no real emulsification (formation of water in oil emulsion) was observed; samples water contents were between 1 and 5 % for slick B and in the range of 0 – 3 % for slick C; see picture 8.

On both slicks the surface oil sampling became almost impossible due to the rapid spreading of the oil on a large area combined with the lack of emulsification which resulted in very low thicknesses; therefore for the following sampling sessions, it was too difficult for the dinghies to collect enough oil to get a significant sample.

3-3-4. Dispersant application

The objective of this trial was to compare the different application methods, (airborne and shipborne application) with mixing energy brought by ships cruising in the slicks to take into account the too calm sea conditions.

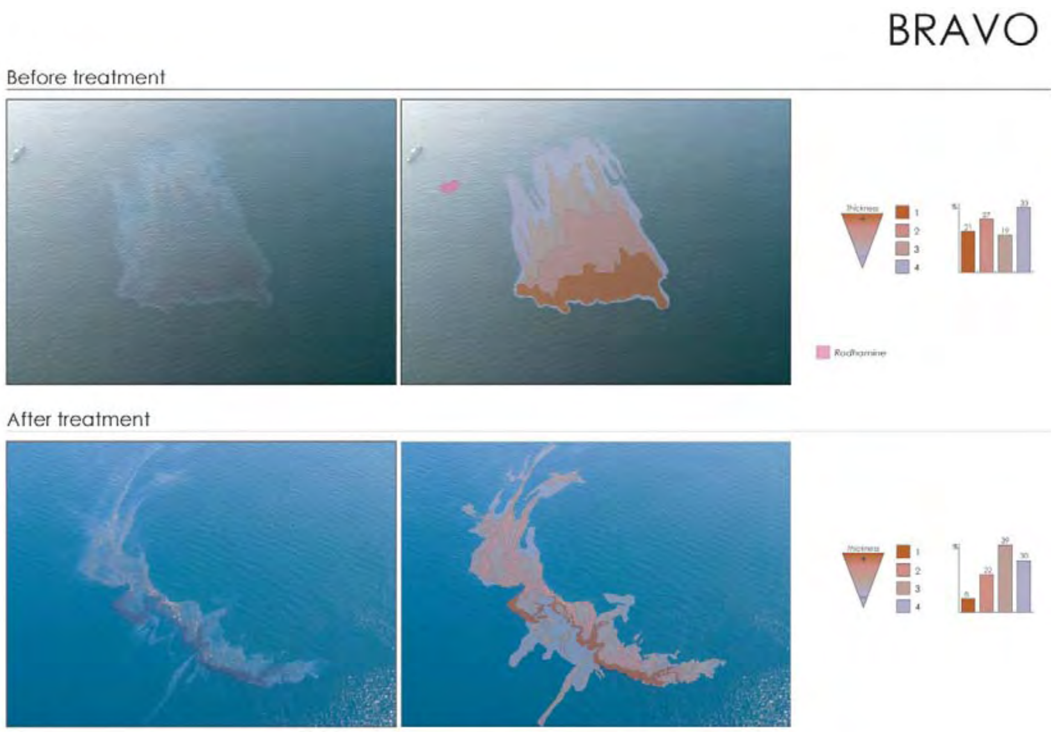
However, while the Cessna POD used Finasol OSR 62, the ship had to apply another dispersant, Gamlen OD 4000, due to an unexpected technical impossibility to feed the spraying pump with the proper dispersant, Finasol OSR62, stored in a special additional tank rigged on the deck. More, as the Gamlen OD 4000 was pumped straight from the ship tanks, the quantity of chemical applied was not known accurately.

Despite these difficulties, observations from the aerial images of the slicks gave some interesting information.

Slick B was treated by the Cessna POD during 35 minutes with 1 ton of Finasol OSR 62, followed by a mixing process provided by the ship Alcyon.
Picture 9 shows the slick B before and after the dispersant application; the relative areas of different colours (therefore different thicknesses) have been assessed.

It can be observed that the dispersion was partial and some thick parts of the slick remained on the sea surface. However, looking upwind these thick parts some orange colour can be seen which brings evidence that some dispersion occurred despite the very calm sea conditions.
More, the evolution of the relative areas of different thicknesses (see the histograms on the right) shows a relative reduction of the thickest parts for the benefit of the thinnest parts.

Picture 9: Aerial pictures visible spectrum, of slick B before and after application.
- on the left : aerial photographies,
- on the right : the original pictures have been processed in order to assess the relative areas covered by the different oil thicknesses (red emulsion to sheen) –see the histogram.

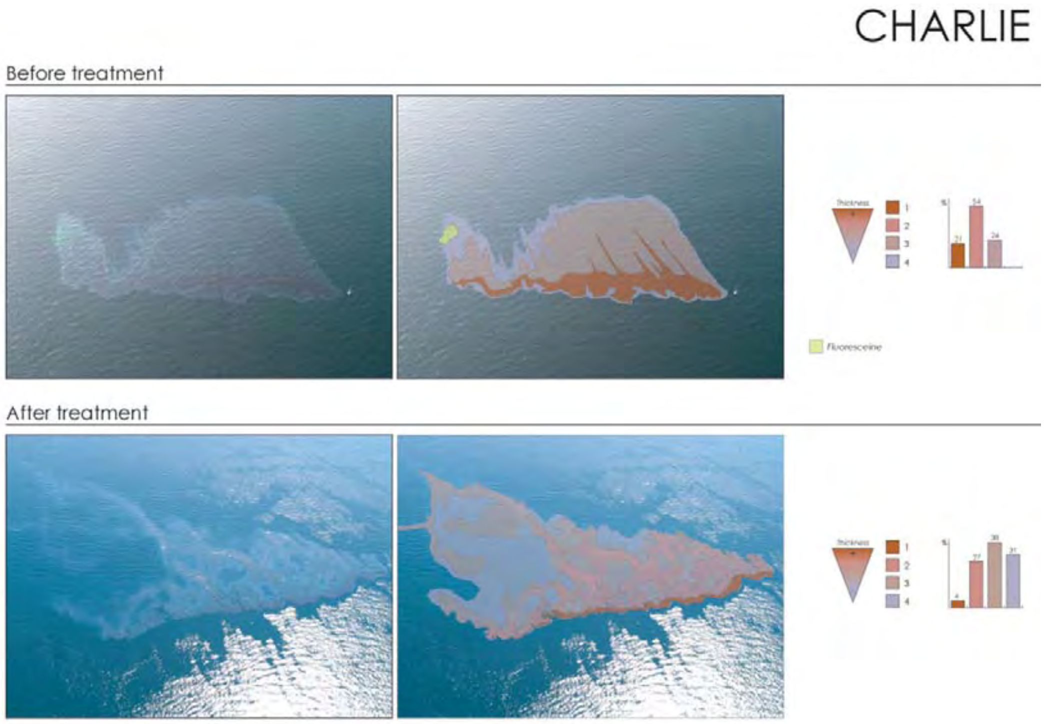


Slick C was treated by the ship Lynx for 1 hour and 10 minutes. The dispersant was applied neat with an adjustable flow rate spraying equipment of the French Navy; this equipment is composed of 3 spraying assemblies, which can be operated alone or simultaneously to get different flow rates (between 10 and 90 L / min).
According to the speed of the ship, the treatment rate can be adapted to the amount of oil to be treated (e.g. at 8 kt, from 20 to 150 l/ ha).
For the treatment, the Lynx cruised generally at 10 kt decreasing to 8 kt at the end to treat the thickest part of the slick.

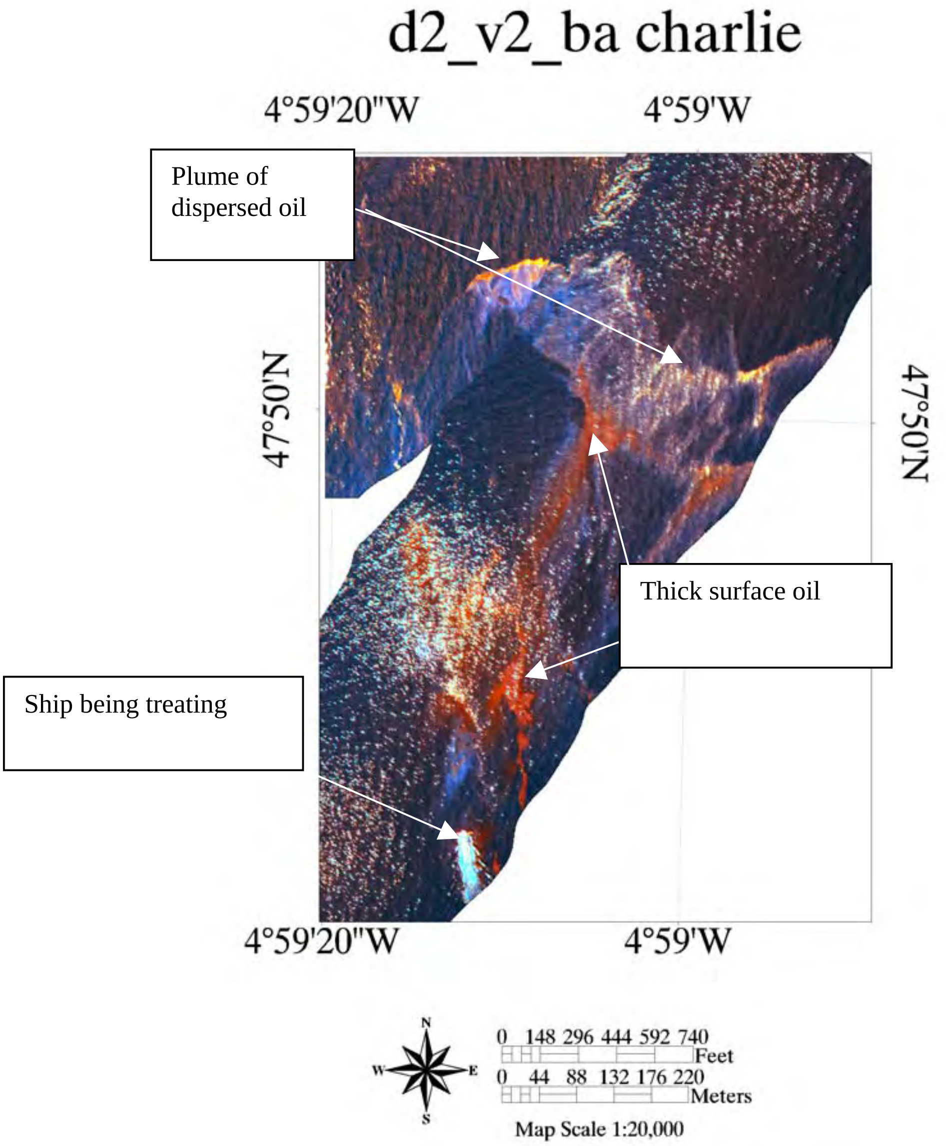
Picture 10 shows slick C before and after the dispersant application.
Similarly to slick B, a partial dispersion can be observed, with thick oil patches remaining on the sea surface but also a relative reduction of the thickest parts for the benefit of the thinnest ones.

Picture 11 which is an imagery from Actimar of slick C confirms that dispersion has been partial: some dispersed oil (yellow to pink plume), the track of remaining thick oil (red) and the ship being treating on the bottom of the picture can be seen.

Picture 10: Aerial pictures visible spectrum, of slick C before and after application.
- on the left : aerial photographies,
- on the right : the original pictures have been processed in order to assess the relative areas covered by the different oil thickness (red emulsion to sheen) – see the histogram

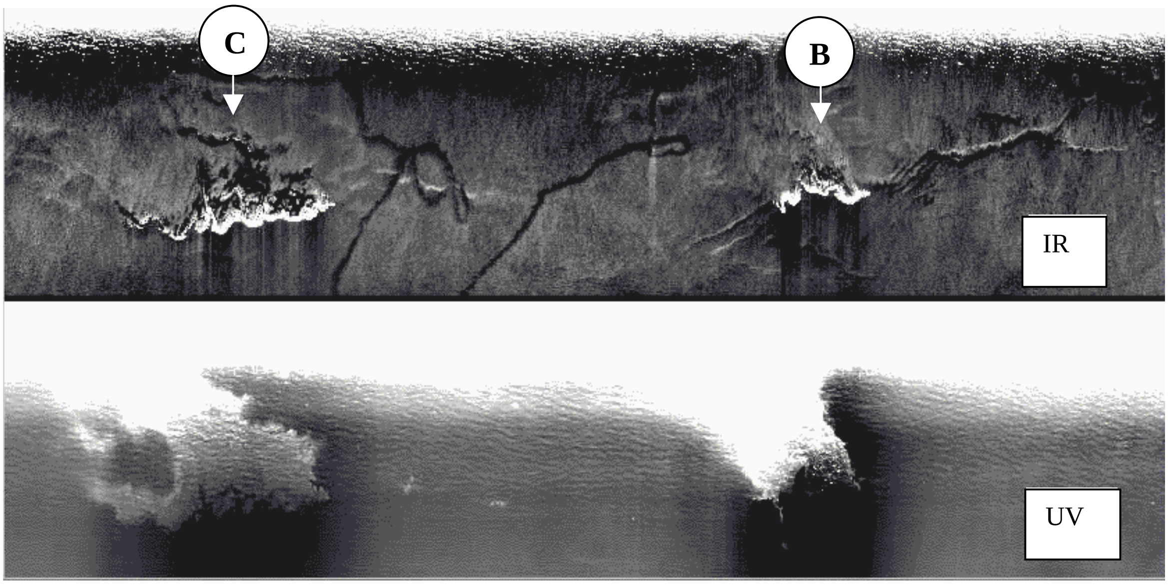


Picture 11: Aerial imagery of slick C during the treatment; we can see, surface oil, plume of dispersed oil and the ship treating (Actimar).



A comparison between the two slicks B and C after treatment can be done on the aerial imagery (IR / UV) taken by the French Customs – see picture 12; assessment from the IR picture shows a higher reduction of the thickest part for slick B than for slick C: slick B, thick area (white) 11 ha., medium thickness area (black) 8 ha. – slick C; thick area (white) 29 ha., medium thickness area (black) 55 ha. This observation is quite surprising as, with a very calm weather, the shipborne treatment which brings extra mixing energy with the ship bow wave, should have been more efficient; (such an observation had been done during Protecmar 6 sea trials in 1986 [4]: comparison of treatment in a very calm weather with a ship and an helicopter). Therefore, the difference observed between slick C and B can be attributed probably to the dispersant used, the Finasol OSR 62 used on slick B which seems to be more efficient than Gamlen OD 4000 used on slick C. This would reflect the laboratory efficiency tests carried out prior to the experiment with the IFP dilution test: the FINASOL OSR 62 gave a slightly better efficiency (E= 80) than the Gamlen OD 4000 (E= 74).

Picture 12:
Comparison of slicks B and C on IR and UV imageries



Another possible explanation for this difference could be the targeting of the slick : the Cessna POD has been continuously and directly guided by the spotting British aircraft during the treatment while the ship had to direct itself according to few smoke canasters launched by the Navy helicopter to mark out the thickest parts(see picture 13). In this respect, the slick B may have received a better treatment than slick C.

Traces of these slicks were detected in the following day: these traces of oil were spread out as very thin oil layer which tended to break out and self disperse when subjected to some agitation; these traces were no longer detectable on the third day. Despite the dispersion process has been obviously limited due to the absence of natural agitation, the dispersion of the slick occurred with time.

Picture 13: Treatment by the ship guided with smoke canasters and by the Cessna POD

4. GENERAL CONCLUSIONS

Depol 04 sea trials, organized in May 2004 offshore Brittany by Cedre, the French Navy and the French Customs, were designed to study the natural weathering of paraffinic and asphaltenic oils, to assess the efficiency of dispersant treatments. An aircraft Cessna POD spraying equipment from OSRL and a ship borne spraying equipment from the French Navy, were used to apply respectively Finasol OSR52 and Gamlen OD 4000 dispersants.
In addition to that, Depol 04 was a good opportunity to run the annual *Bonnex* intercalibration exercise of the remote sensing means of the Bonn Agreement members and to test new remote sensing devices developed by Actimar and NMRI.

The meteorological conditions during these sea trials remained very calm (sea state mainly between 2 and 0) which was not very suitable for the dispersion process due to the lack of natural mixing energy. However, on the first slick (paraffinic oil) a significant dispersion occurred and led to a large reduction of the residual surface oil: after 2 days, the weathered oil emulsion recovered at the sea surface represented only one cubic metre while 10 m^3 of pure oil had been originally released at sea.
Despite the guidance on the slick provided by the UK spotter aircraft, the dispersant treatment carried out by the Cessna POD system did not succeed in covering the whole area of the slick; particularly, some of the thickest areas have not been treated. This observation demonstrates the need to improve the procedures for guiding and for treating slicks in order to better target the areas to be treated.
The 2 last slicks (asphaltenic oils) were treated respectively by the Cessna POD with Finasol OSR 62 and by a ship borne adjustable spraying equipment for neat dispersants with Gamlen OD 4000. The aerial imagery of the treated slicks showed, few time after dispersant application, that some dispersion occurred in both slicks despite the very calm weather (sea state 0 to 1); however, although partial, the dispersion of the slick treated by the Cessna POD appeared to be better than the one of the slick treated by the ship. This observation indicates that the dispersant Finasol OSR 62 was more efficient than Gamlen OD 4000 and/or that the Cessna POD guided by the UK spotter aircraft targeted the slick better than the ship which was just guided by some smoke canasters launched by an helicopter on the thickest areas of the slick.

Both observations militate in favour of improving the operational procedures. During the two last decades dispersant formulations and spraying devices have been studied and improved, and probably, the procedures are now a major limiting factor in the dispersion technique.

Acknowledgments

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