RECENT ADVANCES IN DISPERSANT EFFECTIVENESS EVALUATION: EXPERIMENTAL AND FIELD ASPECTS

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ABSTRACT: *Although dispersants are used in different countries, it appeared from recent international meetings that more knowledge concerning dispersant effectiveness is still needed for a better response to oil spills. Large field trials which were conducted during the past two years raised some questions as to how dispersants work at sea. Even though the results obtained in different laboratory tests are generally in good accord, significant discrepancies of practical interest may be observed because of variations in the experimental conditions.*

With EEC support, an experimental program has been conducted by CEDRE and Institut Français du Pétrole (IFP), both with the already-described French middle scale field test and with different laboratory tests (U.K. and French standard tests and the recently developed dilution test). With the objective of correlating the results obtained in field tests and in laboratory tests, several parameters were investigated at sea with different dispersants: the type and viscosity of the oil, slick thickness, and oil to dispersant ratio. Based mainly on the results obtained in the laboratory with dilution tests, new aspects of dispersant behavior have been identified, relating to the nature of the oil and the energy input.

Despite the very large research efforts which have been conducted for ten years in the field of oil spill dispersants, a wide variety of viewpoints on their real efficiency still exists as became evident during the last international seminar organized by Esso Research Center, Great Britain, in November 1983. This seminar brought out the difficulties of obtaining representative results at sea to quantify the effectiveness of dispersant treatment of an oil slick and hence a disturbing degree of uncertainty in real field performance data.

It is now well recognized that the final efficiency of a chemical treatment is conditioned by several parameters: intrinsic effectiveness of the dispersant, the sea conditions, and the distribution of dispersant on the entire slick. The fact is that in all recent offshore trials only a fraction of the oil was primarily dispersed.[5,9,13] However, it is interesting to point out that during the French Protecmar 3 trials, a high percentage of oil was estimated to have been dispersed with an efficient dispersant.[2] Although this trial was done under calm sea conditions, the dilution process related to subsurface current was slow enough to let high hydrocarbon concentrations, up to 50 ppm at the 1 m depth, to be measured three hours after treatment. It must be mentioned, however, that such a performance could have resulted from an overdose of dispersant and has not been reproduced during further trials.[3]

Thus, it appears that research on chemical treatment effectiveness should still be performed and progress could be achieved both by product improvement and adjustment of operational techniques. Taking into account the high cost of offshore trials and the difficulties of quantitatively interpreting the data, laboratory tests remain a valuable way to assess the relative effectiveness of dispersants.

A lot of laboratory tests, differing widely in design and procedure, have been done throughout the world, but up to now attempts to correlate test data and effectiveness ranking really have not been successful.[14] It was claimed that laboratory results obtained in the U.K. by the Warren Spring Laboratory (WSL) revolving flask test showed a good correlation with actual sea tests,[10] but it has to be noticed that the latter was based only on visual observation.

On behalf of the European Economic Community an experimental program was conducted with two objectives:

- Developing a middle scale field method for evaluation of dispersant effectiveness, based on preliminary results[7]
- Correlating field data with European conventional laboratory tests in closed systems (U.K. and French standard tests based on the revolving flask procedure) and the dilution test in an open system recently developed by Institut Français du Pétrole (IFP) to measure both dispersants effectiveness and toxicity in similar conditions, implementing the dilution concept.[1,2]

Test materials

Six concentrated dispersants (A, B, C, D, E, and F) were selected to be representative of a wide range of effectiveness on the basis of known performances and previous laboratory tests. Five are commercially available or supposed to be in the near future (Finasol OSR 5, Dispolene 32 S, Corexit 9527, Shell DC, BP MA 1037), one is experimental.

The different types of oil used (Table 1) were selected to obtain dispersant efficiency data from a wide range of oil viscosities independent of test temperature (compare oil IIIa at 10° C with oil IIIb at 20°

Table 1. Physical properties of test oils

Oil and reference number		Density at 20° C	Viscosity (cp) At 10° C	Viscosity (cp) At 20° C
Topped Arabian light	I	0.900	85	50
Topped Forties-Brae	II	0.890	650[1]	200[1]
Medium-light fuel oil	IIIa	0.944	820	340
	IIIb	0.958	1,960	820
Medium-heavy fuel oil	IV	0.965	4,250	1,550
Heavy topped Arabian light	V	0.957		4,060
Heavy-light fuel oil	VI	0.993		4,400

1. See text

Table 2. French laboratory test—calculated efficiency (E) versus theoretical emulsified oil after 2 min and 6 min standing

	E = 5	E = 10	E = 15	E = 20	E = 25
Percent emulsified oil					
at t = 2 min	65	82	87	90	92
at t = 6 min	32	55	67	75	79

Table 3. Dispersant efficiency (percent) in the U.K. test; average values from 2 measurements, maximum variation from average is 5 percent in efficiency

	Oils				
Dispersant	I	II	III a	III b	IV
A	67	16	91	81	87
B	39	53	78	80	69
C	31	37	75	78	61
D	30	35	88	74	67
E	66	29	87	90	82
F	33	8	29	20	—

C, and oil IIIb at 10° C with oil IV at 20° C). Oils III, IV, and VI were obtained by mixing a heavy fuel oil with topped Arabian Light at different ratios.

Relative to other oils used, topped Forties has specific properties resulting from a high wax content: non-Newtonian behavior appearing in viscosity measurements (Rotovisco apparatus), and pour point very close to 10° C. The viscosity data give in Table 1 were determined by linear extrapolation at shear rate 1 s^{-1} of values obtained at different shear rates in the range 75–600 s^{-1}. The extrapolated value at 20° C has been corroborated by kinematic viscosity measurement at 25° C (erratic values were obtained at 20° C) to which a temperature correction factor was applied.

Dispersant effectiveness and fate of treated oil in laboratory tests

The conventional revolving flask tests. In the U.K. test[12] conducted at 10° C, the efficiency is calculated as the percentage of oil remaining emulsified after 2 min rotation of the 250 mL conical separatory funnel at 33 rpm, and 1 min standing. The French test procedure[11] is somewhat different: the flask, a 250 mL separatory funnel with a spherical upper part and a cylindrical lower part, is rotated for 30 min at 33 rpm, at 20° C. Three water samples are collected after 2 min, 4 min, and 6 min standing.

Assume that the percentage of emulsified oil (x) varies with the standing time (t) according to an exponential law:

$$x = ae^{-bt}$$

Where: $Lnx = Lna - bt$

The efficiency (E) is expressed as $-\frac{1}{b}$ and is therefore related to the emulsion stability. Obviously, the variation of E versus the percentage of emulsified oil is exponential (Table 2).

In the U.K. test, the oil concentration is about 18 g/L, concentrated dispersants being generally applied pure on the oil, whereas in the French test the oil concentration is about 3.6 g/L, concentrated dispersants being applied diluted in synthetic sea water (1 : 10 ratio). The results obtained in both tests with six concentrated dispersants, at a dispersant to oil ratio of 0.05, are summarized in Tables 3 and 4.

Dispersant rankings can be obtained at comparable oil viscosities, independent of test temperature: 50–85 cp, 820 cp, and 1,550–1,960 cp. They will be discussed later in correlation with field data.

However, some characteristic points emerge from Figures 1 and 2:

- Except for dispersant F which is rather poor in both tests and dispersant A which is only slightly better in the French test, relative efficiencies are of the same order of magnitude for the medium range of oil viscosity.
- Dispersants B, C, D, and E can be classified in two very distinct groups of efficiency for the lower range of oil viscosity in the U.K. test, but are rather similar in the French test for the same viscosity range.
- The effect of oil viscosity is quite different in the two tests: in the U.K. test, the variation of dispersant efficiency is similar to that already described,[8] with a maximum for five products corresponding to an oil viscosity in the range 1,000–2,000 cp. It has been assumed that the increased efficiency results from the oil density increasing with viscosity, making oil droplets more stable in suspension in water. However, it is unlikely that an oil density different of 0.06 between oil I and oil IIIb is the single explanation for the observed increase in dispersant efficiency on the basis of Stoke's law. On the contrary, it appears that the conditions of the French test procedure mitigate the effect of oil density so thoroughly as to make oil viscosity the main parameter.

Table 4. Dispersant efficiency in the French test (Dispersant: oil ratio = 0.05); average values from 2 measurements, maximum variation from average is 2 efficiency units

	Oils			
Dispersant	I	II	III a	IV
A	8.5	5.0	5.0	5.1
B	14.8	12.0	10.5	8.3
C	24.7	14.4	15.7	10.6
D	18.0	9.9	10.6	6.4
E	15.7	14.2	11.1	8.9
F	7.1	4.7	4.3	4.2

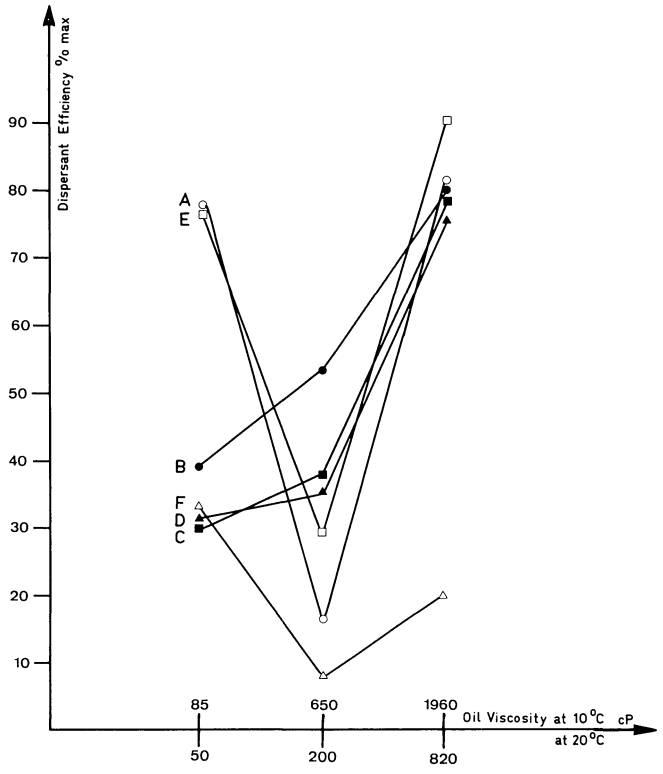

Figure 1. U.K. laboratory test—Dispersant efficiency versus oil viscosity at 10° C and 20° C

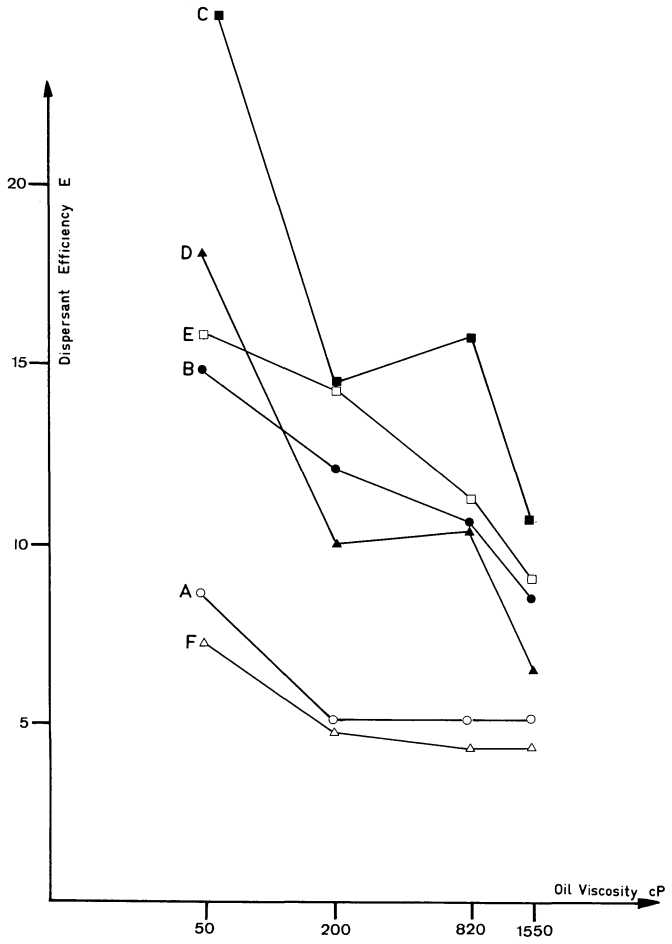

Figure 2. French laboratory test—Dispersant efficiency versus oil viscosity at 20° C

However, in most cases for both tests dispersant efficiency on oil II (topped Forties) appears abnormally low, especially in the U.K. test and with dispersant A. It is assumed that the reason for this could be related to the properties of oil (see above), dispersant A efficiency being more sensitive to wax content, particularly at a temperature very close to the pour point of oil.

The IFP dilution test. The most recent design of the test which has been previously described[1,2] is shown by Figure 3. Energy is supplied by a flat ring agitator periodically beating just under the water surface. A similar system was used in the so-called oscillating hoop test.[6] The ring (external diameter 145 mm, internal diameter 125 mm) is moved up and down with a 15 mm vertical path by an electromagnet controlled by an electronic timer. The frequency can be selected in the range 20–6.66 cycles per min, the ring remaining on the upper and lower positions during a half period.

The volume of synthetic sea water in the test vessel is 4 L (diameter 16.5 cm, height of water 19 cm). The test oil (4 g) is poured on the water surface inside a 10 cm diameter vertical ring and pure dispersant is evenly distributed on the oil with a syringe at the desired ratio. After dilution of oil droplets in the water column, the outflow is obtained by supplying water at a surface inlet, the vesssel being fitted at its bottom with an overflow pipe. In this study all data were obtained at 20° C with a dilution rate of 0.5 h^{-1}.

The concentration of completely and homogeneously emulsified oil follows the equation:

$$x = x_o e^{-Dt}$$

Where: x = the oil concentration at time t
x_o = the initial oil concentration
D = the dilution rate.

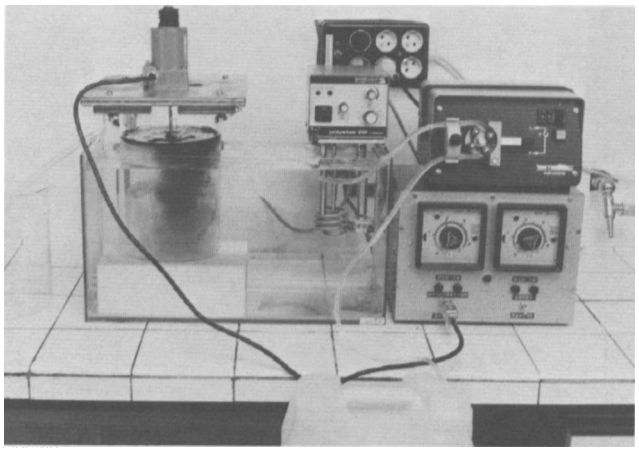

Figure 3. General design of IFP dilution test

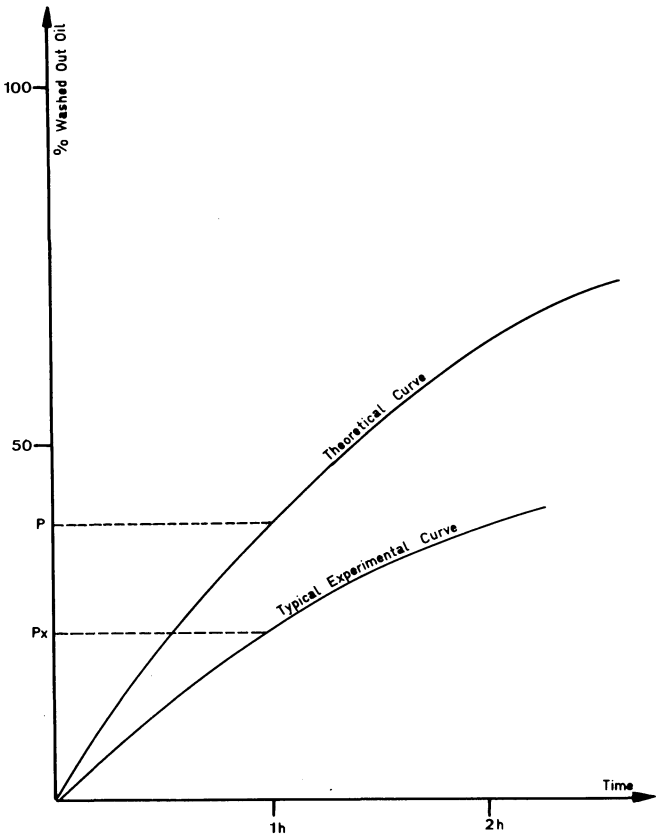

Figure 4. Dilution test—Cumulated percentage of washed-out oil versus time

The percentage of washed out oil at time t is:

$$P = 100\ (1 - \frac{x}{x_o}) = 100\ (1 - e^{-Dt})$$

The evolution of P versus t corresponds, in Figure 4, to the theoretical dilution curve, *i.e.*, 100 percent dispersant efficiency.

Experimentally, the cumulated percentage of washed out oil is determined by measuring oil concentration in the output water recovered during successive periods of time, for example 0–30 min, 30 min–1 h, 1 h–2 h. An example of an experimental curve is shown in Figure 4.

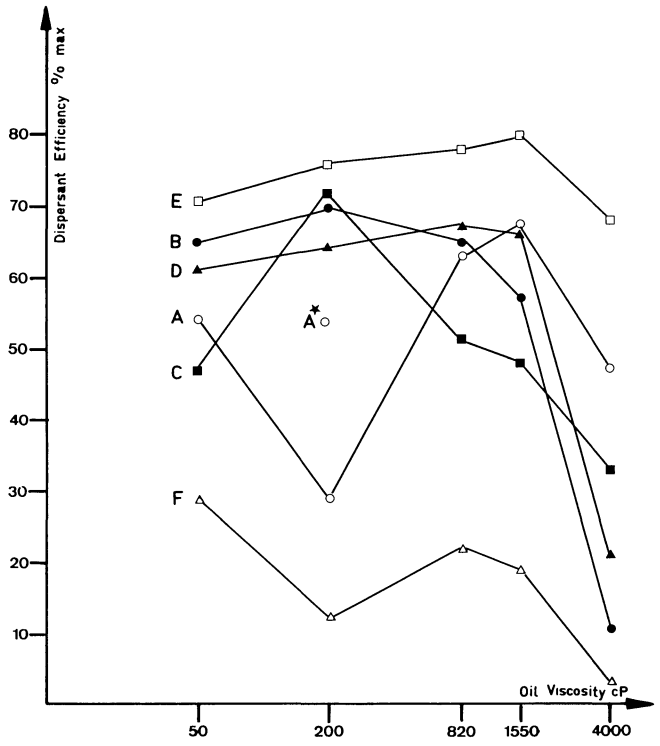

Figure 5. Dilution test—Dispersant efficiency versus oil viscosity at 20° C (beating frequency: 20 cycles per min)

In most cases, the experimental percentage of washed out oil relative to a dispersant x follows the equation:

$$Pa = \alpha P$$

The dispersant efficiency expressed in percent and defined as

$$E = 100\frac{Pa}{P} = 100\ \alpha$$

is constant versus time, as long as the above equation is followed. Consequently, dispersant efficiency could be determined after a short period of time. However, it seems more advisable to run the test for two hours: on the one hand possible irregularity early in the beginning of the test will be mitigated, on the other hand a variation of α versus time, the significance of which is discussed below, can be disclosed.

In the case of a poor dispersant, a fraction of the oil (F_1) remains on the water surface all the time. However, in most cases oil is completely mixed with the water during a short period of time (5 to 10 min), being more or less finely emulsified.

Even in the case of good dispersants a fraction of the oil (F_2) resurfaces more or less quickly. It appears that this fraction is never submitted to the dilution process and it is assumed that it is composed of the largest droplets which statistically escape from the most agitated part of the water volume and come to the water surface; even if they are transiently carried down to the bottom of the vessel, they are not drained off; when they come back to the surface either they are re-taken by the beating movement or remain definitely on the water surface when they have lost too much associated dispersant by solubilization.

The complementary oil fraction F_3 ($F_1 + F_2 + F_3 = 1$) which is permanently submitted to the dilution process is identical with the term α and is representative of the true efficiency of dispersants. A variation of α versus time would mean that re-coalescence from F_3 oil droplets occur.

Droplet size distribution in the output water (oil fraction F_3) has been determined with a Coulter Counter TA II particle size analyzer: as long as a correlation between dispersant efficiency and mean droplet diameter is not evident, it appears that in all cases the mean diameter is less than 60 μm.

These considerations can be compared with conclusions relative to other laboratory tests in closed systems (Labofina, Mackay, oscillating hoop) making the oil droplet size distribution the governing factor in dispersion.[4] Furthermore, they show that treatment effectiveness, in terms of dilution of oil droplets, is clearly determined by the early action of dispersant. The dilution test procedure, through a dynamic view of treated oil, accounts for real field treatment observations concerning the effectiveness of treatment: visual dispersant efficiency, and re-surfacing of oil.

The results obtained with the same materials as above, at beating frequencies 20 and 6.66 cycles per min, are give in Table 5; the efficiency has been determined after a 2 hour run.

Characteristic features appear from data obtained at the highest frequency (Figure 5):

- Variation of efficiency versus oil viscosity is similar for the five most effective dispersants: slight increase in the range 50–1,500 c. However, in the case of oil II (topped Forties) dispersant C appears to have an abnormally high efficiency compared to results obtained with other oils, even with the less viscous one. On the other hand, dispersant A is rather poor with this oil, as in flask tests; note again that this is probably related to the specific properties of topped Forties, dispersant A being effective with a fuel oil of similar viscosity (180 cp at 20° C) prepared as for other oils by mixing the heavy fuel oil with the topped Arabian light crude (see plot A★ in Figure 5).
- The effect of oil density appears more clearly with viscous oils (4,000–4,500 cp): dispersants are more effective on oil VI than on oil V although oil VI is slightly more viscous.

Data obtained with a lower beating frequency show that the decrease of dispersant efficiency at lower energy is generally more pronounced for oil IIIb than for oil I especially with dispersant C, dis-

Table 5. Dispersant efficiency (percent) in the IFP dilution test (dispersant: oil ratio=0.05)

Dispersant	Beating frequency in cycles per min	Oils					
		I	II	III b	IV	V	VI
A	20	54	29	62	67	47	70
	6.66	44	7	32	–	–	–
B	20	65	70	65	57	10	77
	6.66	49	53	25	–	–	–
C	20	47	72	51	48	33	60
	6.66	45	66	12	–	–	–
D	20	62	64	67	66	21	54
	6.66	19	38	13	–	–	–
E	20	71	78	78	80	68	81
	6.66	62	68	59	–	–	–
F	20	29	12	24	19	3	3
	6.66	15	–	8	–	–	–

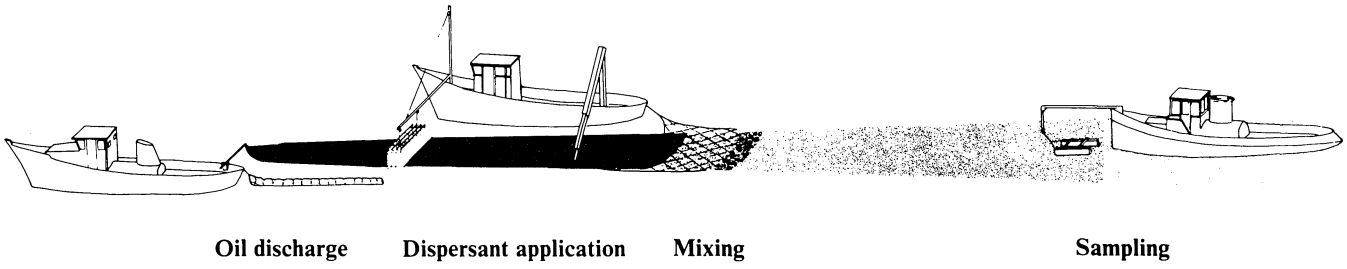

Figure 6. Medium scale field test—General procedure

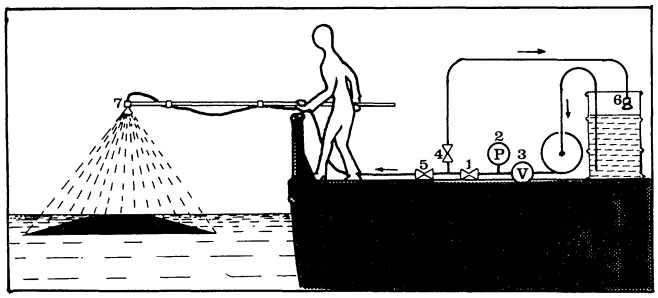

Figure 7. Field test—Oil discharge system

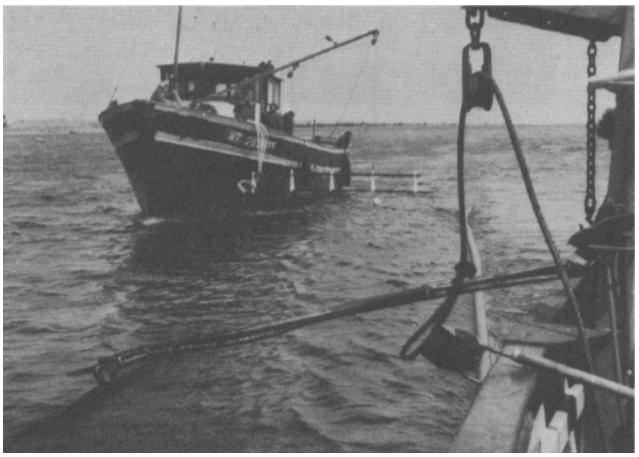

Figure 8. Field test—Discharge of oil and dispersant spraying boat

persant D being also sensitive to energy in the case of oil I. In the case of topped Forties, C and D efficiency is enhanced, A is quite ineffecitve. Dispersant E is on the whole the least sensitive to energy lowering.

Finally, the variable effect of energy on dispersion effectiveness can be tentatively related to the three steps of dispersion: diffusion of dispersant into an oil slick toward the oil/water interface, primary emulsification, and the dilution of small diameter oil droplets.

A high energy level obviously promotes the second step but can have conflicting effects on the first one, either improving the mixing of dispersant and oil or washing away the dispersant from the oil slick surface by the water if diffusion is not quick enough. With regard to this last point, the way of applying dispersant on oil is of major importance.

Considering the dilution step, it is noticeable that in many cases the dispersant efficiency determined in the dilution test is approximately constant with time within a 2 hour period: the decrease of the parameter α defined above is lower than 0.07. Measurement during a 6 hour period does not change the data significantly, which means that recoalescence of fine droplets (oil fraction F_3) is a minor process at constant energy.

However, the energy is decreased and when the downward current is not strong enough to drain the oil droplets off, they will resurface according to Stoke's law. After several hours at rest, oil will be reemulsified only to a small extent by additional energy. This observation shows the major role of dilution in low energy conditions.

The middle-scale field test

For the assessment of dispersant efficiency at sea, the middle scale field test elaborated by IFP and CEDRE has been used. The test procedure has been briefly described in a poster presentation at the last Oil Spill Conference.[7] Its objective was to compare the short term effect of various dispersants used in similar conditions for the treatment of small oil slicks. As shown on Figure 6 the test includes three steps:

1. Discharge of oil by a first boat heading into the wind at a constant speed
2. Application of dispersant and mixing by a second boat sailing on line
3. Evaluation of the dispersant efficiency by visual observations and subsurface sampling and analysis

Discharge of oil. Oil is pumped from drums and sprayed from the stern of the boat through a flat nozzle. A picture of the system is given in Figure 7.

The pumped oil can be discharged either through nozzle 6 back to the drum or through nozzle 7 set at the end of a pole held by the operator over the sea. The two nozzles are similar. The flow rate of oil can therefore be adjusted on board before spraying at sea.

The pump is a positive displacement one with a regulating device. Its performance is not affected by the viscosity of the oil. The nozzle is a very wide deflector type with a flat spray pattern. By varying the height and the orientation of the nozzle over the sea surface, the operator can adjust the spraying width.

Dispersant application and mixing. The dispersant spraying equipment is designed to work over a large range of flow rates, from 6 to 30 L/min of concentrate, according to the oil/dispersant ratio needed. It is composed of four spraying booms fed by a gear pump on which the rotation speed can be adjusted. Depending on the flow rate needed, one or several spraying booms can be used. The spraying booms are 5 m long, fixed near the bow as shown on Figure 8. The nozzles have a flat spray at an 80° C angle (Teejet spraying systems), and are set with diagram check valves.

Before spraying, the flow rate is adjusted while the dispersant is circulating back to the drum. The flow rate is controled by the volume totalizer. When the test starts, the return line is closed and the dispersant then is sent to the spraying booms.

For mixing, two systems have been used: a net of plastic chains towed at the stern of the boat, or a water jet hose with a straight stream at 20 m^3/h (Figure 9).

Sampling. Subsurface samples are collected from a small catamaran designed and built by IFP,[2] that is fixed to a jib boom at the bow of the sampling boat. The catamaran is equiped with three submerged pumps operating at about 0.4 m, 1 m, and 1.7 m below the water surface. The samples, which are continuously collected, are monitored by one line tubidimetry for the first two levels, and UV

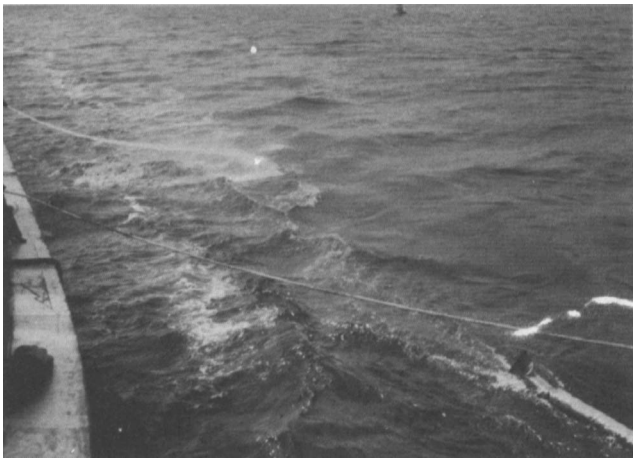

Figure 9. Field test—Mixing with a water jet

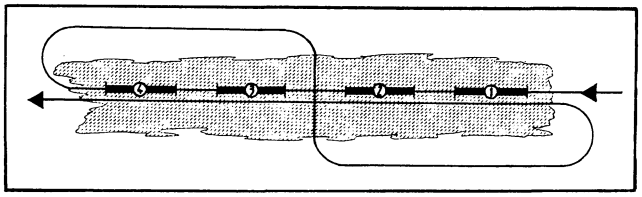

Figure 10. Field test—Sampling runs across the treated oil slick

fluorometry for the deepest one. The sampling flows are then recovered in bottles containing carbon tetrachloride for additional analysis by colorimetry. The analytic responses are registered and stored for later treatment with a small computer (Apple IIe).

Field operations. The sea tests were carried out in a wet dock at Marseille in June 1984. The dimensions of the dock (500 m × 2 km) are convenient for carrying out several tests per day without noticeable interactions. Each test was conducted in a separate area and the initial amount of oil in the water column was controlled with the analyzers.

The main parameters were: speed of the boats, 4 knots; flow rate of oil, 60 L/min; width of the slick, 5 m; mean thickness of the slick, 100 μm; and flow rate of dispersant, 12 L/min. For the light oils (I and II), the scheme of Figure 6 was applied, spraying the dispersant a few seconds after the oil discharge.

For the heavier oils (III and IV), the spreading rate of the oil was low and it was necessary to delay the spraying of dispersant in order to treat a well-formed slick. But the shape of the slick was not exactly a ribbon and the treatment was not so uniform as with light oils. As for most trials in a real environment, the meteorological parameters were also subject to small variations: the wind speed varied from 2 to 15 knots and the sea state from 0 to 2.

The high treatment ratio and the immediate mixing of the treated oil were chosen in order to reduce the influence of these variations. It was considered that all the slicks had been treated correctly. The sampling and analysis boat worked as shown in Figure 10. The first run was made 5 min after treatment with all the equipment working (sampling and analysis). Four samples were continuously collected over the whole length of the slick. For the second and third runs, 10 min and 15 min after treatment, only the analyzers were used.

Results. The assessment of oil dispersant efficiency in the middle scale field test was conducted in several different ways.

- Observations and pictures of the treated oil slicks—Dispersant rankings can be established by visual assessment on the basis of the categories proposed by the WSL:[8]

  Category 5—Very good. Virtually all oil dispersed in water column as fine droplets, appearance of a clear brown plume

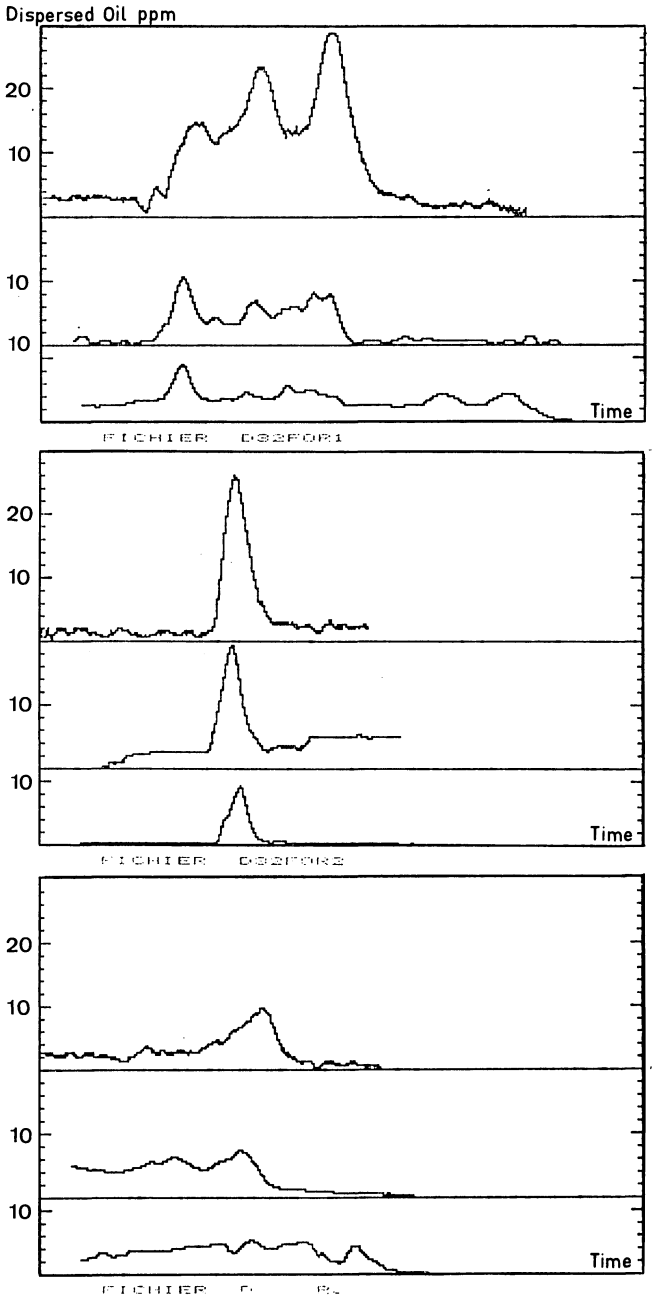

Figure 11. Field test—Typical continuous records of oil at the three sampling depths during the successive runs of the analytical boat

Category 4—Good. Majority of oil dispersed into water as fine droplets, brown to dark brown plume

Category 3—Fair. Dark cloud of droplets accompanied by a slick of undispersed oil

Category 2—Bad. A small proportion of the oil dispersed into the water column, mainly as coarse droplets, appearance of a black cloud

Category 1—Very bad. A thick slick formed with no oil noticeably dispersed

- Computer analysis of continuous determination of the oil content in the sea water pumped to the surface from three depths—The on-line records of the analyzers give interesting information regarding the shape of the dispersed oil plume and its evolution with time (Figure 11). However, they hardly supply comparative data from

Table 6. Conditions and performance of various dispersants in the field test

Oil	Dispersant	Oil volume (liters)	Dispersant volume (liters)	D/oil ratio	Visual assessment	Average oil concentration at the 1 m depth (ppm)
I	B	60	10	0.17	5	9.6
(50 cp)	C	60	10	0.17	4	4.5
	D	50	12.5	0.20	4	6.0
II	B	40	10	0.25	5	10.0
(200 cp)	C	50	11	0.22	5	25.0
	D	25	5	0.20	3	6.0
III	A	48	10	0.21	5	16.4
(820 cp)	B	36	9	0.25	4	11.2
	C	40	6	0.15	3	8.0
	D	48	10.5	0.22	3	12.0
	E	48	10	0.21	5	16.5
	F	40	11.5	0.28	2	6.0
IV	B	40	10	0.25	3	14.0
(1,550 cp)	C	40	11	0.27	3	3.0

one test to the other, due to the influence of the nature of the oil and the droplet size on the analytical response.

- Direct IR measurements of the hydrocarbons recovered in the collected water samples—The most significant data are obtained from the direct infrared method applied to the samples collected from the intermediate depth, between 5 and 8 min after treatment. The upper sampling level is excessively sensitive to surface agitation and includes a fraction of oil ready to resurface instead of being completely dispersed. At the lower sampling level, the oil concentration range is limited and the differences in efficiency of the dispersants cannot be distinguished.

All the oil/dispersant systems tested in the laboratory could not be examined at sea. Table 6 gives the conditions and the results of the middle scale field test for a number of different oils and concentrated dispersants from the average dispersed oil concentration at the intermediate level as measured by the direct IR method.

The results of the field tests are presented in Figure 11 for dispersed oil concentration versus oil viscosity as they are for the laboratory tests, keeping in mind that oil concentration is only a figure of effectiveness. The experimental plots for dispersants B and D are characterized by a slow increase in efficiency with increasing viscosity up to 1,500 cp, and by the absence of a clear breakpoint with oil II. The trend for dispersant C is completely different because of its high efficiency with the paraffinic oil II.

Discussion

Comparison of the results at sea with those obtained in the laboratory, for the oils and dispersants involved in every test, suggests the following conclusions.

- The French standard test does not account for variations in dispersant efficiency with increasing oil viscosity as observed in the field test. However, the ranking of the three dispersants tested at sea with the mid-viscous oil II is in good agreement with the laboratory results
- The U.K. standard test, on the other hand, highly enhances the direct relation between dispersion efficiency and oil viscosity. However, except for *F*, the dispersants can hardly be distinguished from each other with the viscous oils. Moreover, due to the low temperature of this test, the high paraffin content of oil II leads to a negative effect on efficiency of most dispersants, and the high activity at sea of dispersant C is not demonstrated
- Correlations between the middle scale field test and the dilution tests in the laboratory depend on the energy introduced in the experimental system. At the higher energy level (beating frequency 20 cycles per min; see Figure 5) most dispersants, except for A and C, exhibit a slowly increasing (D, E) or nearly constant (B, F) efficiency with increasing viscosity in the range 50–1,500 cp. Dispersant C shows a positive effect and dispersant A a negative one with the high paraffinic oil II. These results are in relatively good agreement with those obtained at sea, when mixing is applied to the treated oil slick (Figure 12).

Furthermore, when considering each oil separately, the ranking of the involved dispersants is the same for a given viscosity in both the dilution test and the field test.

The results obtained at the lower energy level show that these conditions should be more representative of the field test when no mixing is supplied, but the results at sea have to be completed in this way.

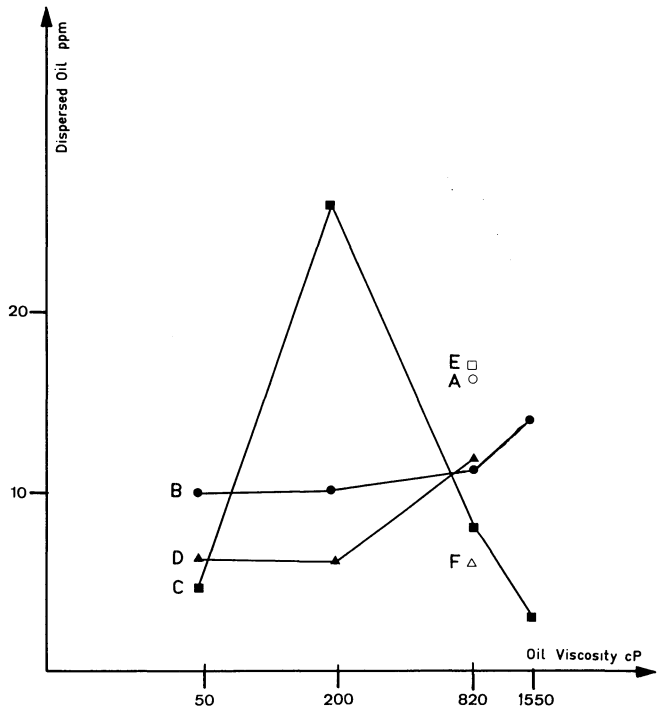

Figure 12. Field test—Dispersed oil concentrations at the 1 m depth versus oil viscosity

Conclusions

Because dispersant offshore trials are costly and lead to variable results in effectiveness assessment, a middle scale field test was operated in order to obtain a realistic dispersant ranking which should allow the selection of the most representative laboratory conditions from among three different procedures, in closed or open systems: the French standard test, the U.K. standard test, and the new dilution test developed by IFP.

The procedure of the middle scale field test for use in both open and sheltered waters is described. The method consists of successively discharging and treating oil under standard conditions with two boats sailing in line. Evaluation of relative dispersant efficiency was based on the hydrocarbon content of water samples collected, after given times, from various depths. it was shown, however, that the method could be simplified by measuring the oil content only at the 1 m depth.

The results obtained simultaneously at sea and for the three laboratory tests with a number of oils and six concentrated dispersants are:

- The trend of the U.K. standard test is similar to that observed at sea, but with more viscous oils, the dispersants can hardly be distinguished.
- The French standard test does not account exactly for the variation in dispersant efficiency with oil viscosity.
- The results in the dilution test are in relatively good agreement with those obtained at sea when mixing is applied to the treated oil slick; the ranking of the dispersant for a given oil viscosity is the same as in the field test.

The results of the study suggest that the dilution test should be the most representative of the fate of treated oil according to dynamic sea conditions which are of a major importance for oil dispersion.

Acknowledgments

This study was carreid out with funding from the European Economic Community (D G XI) and the Ministère de l'Environnement. The authors would like to acknowledge the constructive assistance of Port Autonome de Marseille and Service Maritime des Bouches-du-Rhône.

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