UK 2003 oil spill dispersant sea trials:
Overview of work done and results achieved

Alun Lewis, Oil Spill Consultant, UK

1. INTRODUCTION

The two questions most often asked about the use of oil spill dispersants are:

(i) Will the dispersant 'work'?
(*Will spraying dispersant cause the spilled oil to be rapidly dispersed under the prevailing conditions?*)

(ii) If the dispersant does 'work', will dispersing the oil do more harm than good?
(*Will exposure to the temporarily increased dispersed oil concentration in the water column cause more harm to marine organisms than the benefit achieved by removing the spilled oil from the sea surface and preventing it from drifting ashore and doing damage to habitats and species that might be there?*)

This paper concerns the first question because the second is irrelevant if the answer to the first is a definitive "No". Spraying dispersant onto a spill of oil that will not be dispersed is a waste of time and money. If the dispersant does not 'work' there will be no risk of harm from the dispersed oil, but there will also be no potential benefit.

The answer to the first question would ideally be "Yes" or "No", but most things are rarely as simple as that; there are often degrees of success (and failure). It is reasonable to assume that a dispersant will 'work well' on some oils and 'work not so well' on other oils. The way of determining this appears almost trivial; the most obvious way is to lay down two identical oil slicks at sea, spray only one with dispersant and then observe and measure what happens. If the one that was sprayed with dispersant disperses and the one that was not treated with dispersant does not disperse, then the dispersant has 'worked'. This is exactly what oil spill response researchers have been doing for the last 35 years or so. So why is the subject of dispersant effectiveness still the subject of continued debate, discussion and disagreement?

The main problem is that it is not currently possible to use measurements to construct an accurate 'mass balance' (the amount of oil that has been dispersed, or of the amount of oil that has not been dispersed and is still on the sea surface) at any time during an experiment at sea, or at a real oil spill response.

It is possible to get very good indications of successful dispersion by using UVF fluorometry to measure the localised increase in dispersed oil in water concentrations at various points under the dispersant-treated slick, and it is possible to monitor the change in the behaviour of the oil remaining on the surface in the slicks by remote sensing from aircraft, but it is not possible to say with accuracy that a certain percentage of the total oil spilled has been dispersed (the 'mass balance') at a particular time.

The desirability of measuring an accurate ‘mass balance’ sometimes seems to be nothing more than a technical squabble between specialists, and the proposed solutions always seem to require substantial financial investment in more work and more complicated (and expensive) equipment, but there is a basic point that needs to be addressed; if “dispersant effectiveness” at sea (i.e. measuring an accurate ‘mass balance’) cannot be unambiguously determined, what is the justification for using dispersants as an oil spill response technique?

This is not to say that dispersants do, or do not, ‘work’; it is our inability to measure how well (or not) that dispersants ‘work’ that is the real issue.

It is very easy to measure “dispersant effectiveness” as percentage effectiveness in a wide variety of laboratory tests, but that only moves the argument along one ‘notch’; the challenge then is to relate a percentage effectiveness value obtained in a particular laboratory test to the ‘mass balance’ at sea - which still needs to be assessed or measured. The technical impasse seems almost insurmountable; what is required is something that currently cannot be done.

1.2 Purpose of the UK 2003 oil spill dispersant sea trials

The background to the UK 2003 sea trials was to try and use something that could be easily be done at sea - visual observation of the effects of using dispersants - and then relate these observations to measurements made in laboratory and in wave tank tests with controlled variables under controlled conditions.

The visual observations were not intended to be a substitute for a technical means of determining an accurate ‘mass balance’ - it is obviously impossible to tell how much oil has been dispersed by just looking at it - but until such a technique is available, visual observation is most obvious means.

The visual observations are an easily obtained link between what happens at sea and what happens in the laboratory and in the test tanks. In addition, in the absence of any better method, visual observation is often the method that is currently used ‘in the field’ at real incidents to assess whether the dispersant is working, or not.

The second element of the UK 2003 sea trials was to use a matrix approach to avoid the problem of a set of results that only applied to one very specific set materials and conditions. Residual marine fuels oils of different viscosity, different dispersant brands and different dispersant treatment rates were used. The British summer weather provided a range of prevailing sea conditions.

2. THE UK 2003 OIL SPILL DISPERSANT SEA TRIALS

The small-scale sea trials were conducted at a location approximately 10 nautical miles to the south of the Isle of Wight at the end of June 2003 (Lewis, 2004 and Colcomb et al., 2005).

The test oils used were Intermediate Fuel Oils; IFO-120, IFO-180 and IFO-380 grade fuel oils. IFOs are graded by their viscosity at 50ºC; IFO-180 has a maximum viscosity of 180 cSt (centistokes) at 50ºC and IFO-380 has a maximum viscosity of 380 cSt at 50ºC. The IFO 180 oil has a viscosity of approximately 2,000 cP at 15ºC (the sea temperature at the time of the sea trials) and the IFO 380 had a viscosity of 7,000 to 8,000 cP at 15ºC. Three oil spill dispersants, all of which have been approved by Defra (Department for Environment, Food and Rural Affairs) for use in UK waters in recent years, were used in this work. Three nominal treatment rates were used; nominal DORs (Dispersant to Oil Ratios) of 1:25, 1:50 and 1:100. A DOR of 1:25 is the typically recommended dispersant treatment rate, but some laboratory studies had indicated that dispersants could still be effective when used at the lower treatment rates.

2.1 Procedure

The test oils were pumped from the deck of *Wilcarry* and laid down onto the sea as a 20-metre long strip or ‘carpet’ through a Manta Ray™ skimmer head as the barge sailed directly into the wind at approximately 2 knots. Each test slick contained 20 litres oil. Dispersant was sprayed at the required nominal treatment rate onto the oil layer from the modified Boatspray™ system shortly after it was deposited on the sea. The average actual DOR achieved was calculated after the tests using evidence from video and still cameras. A team of observers in a small vessel then observed the dispersant-treated test slick as waves passed through it and made their visual observations.

2.2 Visual observations made during dispersant use

It is not possible to quantify the amount of oil that has been dispersed by visual observation. However, it is possible to use visual cues to assess whether or not the dispersion process appears to be proceeding. The most visible signs of dispersion of oil occur in the crests of waves as they pass through the dispersant-treated oil slick. Dispersed oil is evident as a brown or black colouration that causes the crest to appear opaque. The plume of dispersing oil droplets can often be seen as a light-brown ‘cloud’ trailing in the wake of the cresting wave, below the surface in the upper layers of the water column. If dispersion of oil is not occurring, the crest remains ‘bright’ and transparent and the individual ‘blobs’ of oil can be seen as the slick is temporarily broken up by the wave, prior to the oil resurfacing and reforming the slick.

Visual observation of the effects of dispersants on oil can be ambiguous. Dispersant that washes off the oil and into the water produces a temporary, white cloud in the water. Addition of dispersant causes many spilled oils to spread out rapidly and be ‘herded’ into strands and patches.

Most importantly, the visual observation of an initial dispersion does not necessarily indicate that the dispersion is permanent; the larger droplets of oil may resurface shortly after the intense turbulence of the cresting wave has passed.

A team of seven observers, all of whom had previous experience of observing dispersant use in experiments and at real oil spills, were based on the MCA *Osprey* and filled in their observations on a standardised reporting form, specifying the degree of observed dispersion, and other effects, on a four-point scale. The form is shown as Table 1. The test runs were coded and randomised so that the precise combination of oil, dispersant and treatment rate was unknown to the observers. The observers did not discuss their individual observations and the completed forms were collected after each test.

Rank	**Standard Phrase**	**Description**	**2 mins**	**5 mins**	**10 mins**
1	**No obvious dispersion**	Dispersant being washed off the black oil as white, watery solution leaving oil on surface. Quantity of oil on sea surface not altered by dispersant			
2	**Slow or partial dispersion**	Some surface activity (oil appearance altered). Spreading out of oil. Larger droplets of oil (1 mm in diameter or greater) seen rapidly rising back to sea surface, but overall quantity appears to be similar to that before dispersant spraying			
3	**Moderately rapid dispersion**	Quantity of oil visibly less than before spraying. Oil in some areas being dispersed to leave only sheen on sea surface, but in other areas still some oil present.			
4	**Very rapid and total dispersion**	Oil rapidly disappearing from surface. Light brown plume of dispersed oil visible in water under the oil and drifting away from it			

Table 1. Visual observation ranking form

2.3 Results from UK 2003 oil spill dispersant sea trials

The results are shown in Tables 2 and 3. These results have been discussed in more detail in other papers (Lewis, 2004, Colcomb et al., 2005, S L Ross, 2005b). The main trends are:

- The lower viscosity oil (IFO 180) was apparently dispersed to a high degree by some dispersants, but the higher viscosity oil (IFO 380) was only apparently dispersed to a much more limited degree by some dispersants.

- Higher wind speeds (11 to 14 knots, Beaufort Force 4) appeared to cause a higher degree of apparent dispersion than lower wind speeds (7 to 10 knots, Beaufort Force 3) for a particular oil / dispersant / treatment rate combination. This is unsurprising as the frequency of cresting waves ('white horses') increases over this wind speed range.

- Dispersant C appeared to be the most effective dispersant on the IFO 180 oil, but none of the dispersants appeared to be very effective with the IFO 380 oil.

The primary sources contain much more detail and these should be consulted for more information.

IFO 180 Tests						
Test	Dispersant and nominal treatment rate used	Actual applied DOR (Min.) Average (Max.)	Average observation ranking (after dispersant added)			Wind speed (knots)
			2 min	5 min	10 min	
10	Dispersant C at 1:25	(1:41) 1: 29 (1:20)	**4**	**4**	**4**	12
11	Dispersant C at 1:50	(1:111) 1: 79 (1:55)	**3.2**	**2.7**	**2.3**	12
10A	Dispersant C at 1:25	(1:41) 1: 29 (1:20)	**3**	**3.2**	**3**	7
10F	Dispersant C at 1:25	(1:41) 1: 29 (1:20)	**3**	**3**	**3**	8
12	Dispersant C at 1:100	(1:180) 1: 128 (1:90)	**2.3**	**2.2**	**1.8**	11
14F	Dispersant A at 1:25	(1:41) 1: 29 (1:20)	**2.2**	**2.8**	**2.5**	10
17F	Dispersant B at 1:25	(1:41) 1: 29 (1:20)	**2**	**2**	**2**	8
17	Dispersant B at 1:25	(1:41) 1: 29 (1:20)	**1.7**	**2**	**1.8**	9
14	Dispersant A at 1:25	(1:41) 1: 29 (1:20)	**1.5**	**1.8**	**1.4**	10
15	Dispersant B at 1:50	(1:111) 1: 79 (1:55)	**1**	**1**	**1**	8

Table 2. Visual observation results on IFO 180 oil

IFO 380 Tests						
Test	Dispersant and nominal treatment rate used	Actual applied DOR (Min.) Average (Max.)	Average observation ranking (after dispersant added)			Wind speed (knots)
24F	Dispersant C at 1:25	(1:58) 1:41 (1: 29)	**3**	**2**	**2**	14
18FA	Dispersant B at 1:25	(1:58) 1:41 (1: 29)	**2.7**	**1.2**	**1.2**	13
18F	Dispersant B at 1:25	(1:58) 1:41 (1: 29)	**2.5**	**2.2**	**2**	12
18	Dispersant B at 1:25	(1:58) 1:41 (1: 29)	**2**	**2**	**2.3**	7.5
18A	Dispersant B at 1:25	(1:58) 1:41 (1: 29)	**2**	**2**	**2**	7.5
25	Dispersant C at 1:50	(1:158) 1:111 (1: 79)	**1.7**	**1.7**	**1.7**	8
23F	Dispersant A at 1:25	(1:58) 1:41 (1: 29)	**1.7**	**1.2**	**1.2**	11
23	Dispersant A at 1:25	(1:58) 1:41 (1: 29)	**1.6**	**1.6**	**1.5**	9
19	Dispersant B at 1:50	(1:158) 1:111 (1: 79)	**1.4**	**1.6**	**1.4**	8
24A	Dispersant C at 1:25	(1:58) 1:41 (1: 29)	**1.1**	**1.2**	**1.2**	8
24	Dispersant C at 1:25	(1:58) 1:41 (1: 29)	**1**	**1**	**1**	8.5

Table 3. Visual observation results on IFO 380 oil

3. COMPARISON OF VISUAL OBSERVATION RANKING RESULTS MADE AT SEA WITH LABORATORY TEST RESULTS

Since it is currently impossible to measure an accurate 'mass balance' of the amount of oil dispersed at sea, it is obviously impossible to produce a correlation between the visual ranking and the percentage of oil dispersed at sea for the different test oil / dispersant / treatment rate / wind speed combinations tested. However, the visual rankings and results obtained in different laboratory test methods and wave tank studies conducted in a series of collaborative projects can be compared. Tests were conducted on the same test oils, the same dispersants and the same treatment rates using:

- Swirling Flask Test (SFT) (EPA standard, Environment Canada standard method).
- Baffled Flask Test (BFT) (developed by EPA to replace the SFT).
- Exxon Dispersant Effectiveness Test (EXDET).
- Warren Spring Laboratory Test (WSL Test) (UK standard method).

Details of these methods and a comprehensive explanation of the results obtained using them are contained in the appropriate references (Clark et al., 2005, Colcomb et al., 2005, Lewis, 2004, Trudel et al., 2005) and only selected highlights of several trends are presented in this paper.

Table 4 contains the results of testing with dispersant C at nominal treatment rates of 1:25, 1:50 and 1:100. As might be reasonably expected, dispersant C appeared to be less effective at sea with reduced treatment rate; it appeared to be very effective at sea (within the constraints of the observation method and time of observation) and was ranked at 2 minutes as 4 - "Very rapid and total dispersion" at a DOR of 1:25, but only 2.3 - **"**Slow or partial dispersion" at a DOR of 1:100. The SFT method produced a low percentage effectiveness value of 7% with a DOR of 1:25, while both the BFT and the WSL methods produced high percentage values. However, the WSL method also produced relatively high values with the low treatment rate at a DOR of 1:100.

IFO 180 test oil and Dispersant	Treatment rate (nominal DOR)	Sea trial (11 - 12 kt wind) 2 min Ranking	SFT method (%)	EXDET method (%)	BFT method (%)	WSL Test method (%)
C	1:25	4	7	44	77	95
C	1:50	3.2	-	31	72	86
C	1:100	2.3	-	-	-	66

Table 4. Effect of treatment rate of dispersant C on results with IFO180 oil

Table 5 contains the laboratory test results obtained with the different dispersant brands and IFO 380 oil, and compares these with the visual observations made after 2 minutes during the tests at sea at the higher wind speeds of 11 to 14 knots. The visual observations indicated that less dispersion was occurring with all three dispersants, but there was an observable difference. As with the IFO-180 oil, the SFT method produced a very low value, while the BFT and WSL methods produced relatively high percentage values and the EXDET method produced intermediate results.

IFO 380 test oil and Dispersant	Treatment rate (nominal DOR)	Sea trial (11 - 14 kt wind) 2 min Ranking	SFT method (%)	EXDET method (%)	BFT method (%)	WSL Test method (%)
A	1:25	1.7	-	6	-	26
B	1:25	2.5 / 2.7	-	6	57	63
C	1:25	3	5	32	65	51

Table 5. Effect of dispersant brand with results obtained with IFO 380 oil

The information contained in Table 6 shows that there was visibly less apparent dispersion (intermediate between **"**No obvious dispersion" and "Slow or partial dispersion") in tests conducted at sea at lower wind speeds of 8 to 9 knots and at lower treatment rates. The WSL and BFT methods produced relatively high percentage values for dispersion, with lower values obtained by the EXDET method.

IFO 380 test oil and Dispersant	Treatment rate (nominal DOR)	Sea trial (8 - 9 kt wind) 2 min Ranking	SFT method (%)	EXDET method (%)	BFT method (%)	WSL Test method (%)
A	1:25	1.6	-	6	-	26
B	1:50	1.4	-	4	41	52
C	1:50	1.7	-	21	-	48

Table 6. Effect of dispersant brand with results obtained with IFO 380 oil

The WSL and BFT methods produced high dispersant effectiveness percentage values with oil / dispersant / treatment rate combinations that produced little visible dispersion at sea. While the SFT method produced very low dispersant effectiveness percentage values with combinations that produced apparently high levels of dispersion at sea.

4. COMPARISON OF VISUAL OBSERVATION RANKING RESULTS MADE AT SEA WITH WAVE TANK TEST RESULTS

It is not possible to carry out a ranking of the visual signs of dispersion in laboratory tests in the same way that had been conducted at sea because the mixing processes in the various laboratory tests are different from thosewhich occur at sea. However, it is possible to carry out the same visual observation ranking in wave tank tests and also determine an accurate ‘mass balance’ of dispersed and non-dispersed oil. The same oil / dispersant / treatment rate combinations that had been tested at sea were tested in:

- The S L Ross wave tank in Ottawa, Canada (Belore et al., 2005).
- OHMSETT (Oil and Hazardous Materials Simulated Environmental Test Tank) in New Jersey, USA (S L Ross, 2000a, 2000b and 2005).

Wave tank tests can be conducted at different mixing energy levels achieved by operating the wave generator at different frequencies and displacements. These different mixing energy levels may, to some limited extent, equate to different sea states caused by different wind speeds.

Table 7 contains the results from testing dispersant C with IFO-180 oil in the SLR wave tank and OHMSETT at two different wave generator frequencies; 30 cycles per minute and 33 cycles per minute. The visual observation rankings made at sea are those obtained in the higher wind speed range (and are the same as in Table 3). The visual observation rankings in the SLR tank and at OHMSETT at 33 cpm are similar, but somewhat higher, to the rankings obtained at sea. The rankings obtained at OHMSETT at 30 cpm are much lower than those obtained at sea.

IFO 180 test oil and Dispersant	Treatment rate (nominal DOR)	Sea trial (11 - 12 kt wind) 2 min Ranking	SLR Tank % (Ranking)	OHMSETT tank	
				30 cpm % (Ranking)	33 cpm % (Ranking)
C	1:25	4	97 (4)	36 (1.0)	90 (4)
C	1:50	3.2	50 (3)	21 (1.2)	84 (4)
C	1:100	2.3	39 (3)	-	-

Table 7. Effect of treatment rate of dispersant C on results with IFO180 oil

The mixing energy regime in the SLR tank and the OHMSETT tank at 33 cpm caused similar visible effects as were observed at sea with wind speeds of 11 to 12 knots. The percentage effectiveness values obtained in the SLR tank and at OHMSETT at 33 cpm (measured by recovering non-dispersed oil) indicate that a visual ranking of 4 relates to 80% or more of the oil being dispersed and a visual ranking of 3 relates to 40 to 50% of the oil being dispersed.

Table 8 contains the visual observation rankings made at sea are those obtained in tests made in the lower wind speed range of 8 to 9 knots. The ranking results obtained in the SLR tank and at OHMSETT at 33 cpm are slightly higher than those observed at sea, particularly for dispersant C, but similar for dispersant A. The dispersant effectiveness values obtained in the SLR tank and OHMSETT at 33 cpm indicate that a visual ranking of 2 indicates that approximately 20% of the oil has been dispersed, but a visual ranking of 1 was also observed when 36% of oil had been dispersed.

IFO 180 test oil and Dispersant	Treatment rate (nominal DOR)	Sea trial (8 - 9 kt wind) 2 min Ranking	SLR Tank % (Ranking)	OHMSETT tank	
				30 cpm % (Ranking)	33 cpm % (Ranking)
A	1:25	1.5 / 2.2	23 (2)	24 (1)	17 (2.2)
B	1:25	1.7 / 2	82 (3)	-	-
C	1:25	3 / 3	97 (4)	36 (1)	90 (4)

Table 8. Effect of dispersant brand with results with IFO180 oil

Table 8 contains the results of testing the three dispersants with the higher viscosity IFO 380 oil at sea in two wind speed ranges, and in the SLR tank and at OHMSETT at 30 cpm and at 33 cpm. The visual rankings obtained in the SLR tank and at OHMSETT at 33 cpm are higher than those observed at sea with the higher wind speed tests, but visual rankings made at OHMSETT at 30 cpm are lower than the observations made at sea with the lower wind speed tests.

The dispersant effectiveness percentages appear to broadly correlate with the visual observation rankings; low percentages of oil dispersed (1% to 20%) were observed to be visual ranks of 1 to 2, higher percentages of oil dispersed (53% to 84%) were associated with higher visual ranks of 3 and 3.5.

IFO 380 test oil and Dispersant	Treatment rate (nominal DOR)	Sea trial (7.5 - 9 kt wind) 2 min Ranking	Sea trial (11 - 14 kt wind) 2 min Ranking	SLR Tank % (Ranking)	OHMSETT tank	
					30 cpm % (Ranking)	33 cpm % (Ranking)
A	1:25	1.6	1.2	1 (1)	-	16 (2)
B	1:25	2 / 2	1.2 / 2.2	15 (1)	20 (1.1)	53 (3.5)
C	1:25	1 / 1.2	2	53 (3)	13 (1.3)	84 (3)

Table 8. Effect of dispersant brand with results with IFO 380 oil

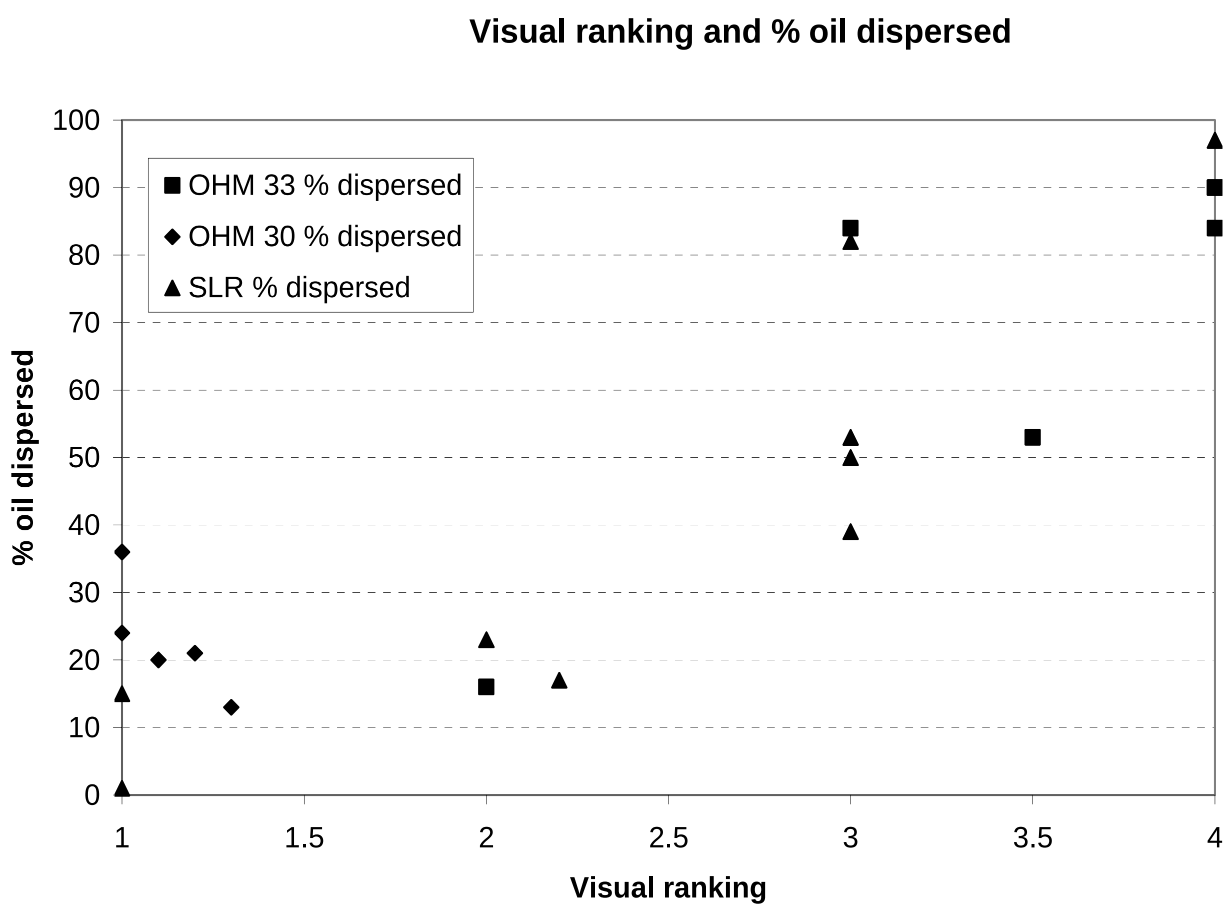

Figure 1. Visual rankings plotted against percentage of oil dispersed in tank tests

5. CONCLUSIONS

The work described in this paper has been reported in much greater detail in the papers included in the References. These primary sources should be consulted for details of procedure and more detailed conclusions. However, from the work and results reported in this paper, several broad conclusions may be drawn:

1. A simple four-point visual observation ranking scale, although somewhat subjective and prone to various errors, can be used to assess whether dispersion of oil is taking place at sea and can be used to estimate the percentage of oil that will be dispersed. The scatter is large and the correlation is far from perfect (Figure 1 shows all the results presented in this paper), but a visual ranking of 4 (“Very rapid and total dispersion”) is associated with the dispersion of 80% of more of the oil, in tank tests where a ‘mass balance’ can be determined.

2. The results presented in this paper indicate that this broad correlation will be similar for dispersion of oil at sea; if the dispersant-treated oil looks as though it is dispersing, it most probably is dispersing and will probably disperse to a large degree. Conversely, if the application of dispersant does not appear to cause any degree of visible dispersion in a short time, the probability is that the oil will not subsequently disperse. The situation will probably be different for emulsified oils where emulsion-breaking is known to take time, but emulsified oils were not tested in this work.

3. The various laboratory methods available to test dispersant / oil / treatment rate combinations give a very wide range of dispersant effectiveness values because they use different levels of mixing. The SFT method produces much lower results, and the BFT method produces much higher results, than those apparently observed at sea in wind speeds ranging from 7.5 to 14 knots, and measured in tank tests operated under conditions to produce similar observations to those made at sea. The WSL method also produces higher than those apparently observed at sea in this wind speed range. The EXDET method produces the nearest equivalence, but seems to produce a ‘compressed scale’ that underestimates dispersion to produce low percentage results. It is possible that the WSL method produces results that are indicative of dispersant performance at higher winds speeds in excess of 20 knots, and that the BFT method produces results that are indicative of dispersant performance at even higher wind speeds, but this hypothesis has not been tested in this work.

4. Properly designed tank tests can produce a reasonable - although not perfect - simulation of the major processes that cause dispersion of oil at sea. In the absence of a technology that permits accurate quantification of dispersed oil in water concentrations simultaneously at all points underneath a dispersing oil slick at sea, tank tests are the most useful tool for studies of dispersants, providing more information than can be gained from laboratory tests.

6. ACKNOWLEGEMENTS

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