

# **Use Of Dispersants In Oil Spill Response To Minimize Environmental Damage To Birds And Aquatic Organisms**

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## **Abstract**

**Use of any oil spill response technique is a policy decision, which is the responsibility of the appropriate authority. This yield in particular for the use of dispersants. This paper provides information to support decision making on the use of dispersants. It gives information on the risks of oil slicks for birds and of dispersed oil for the aquatic organisms. The approach is based on criteria related to the dimension of an oil slick, the type of waterway and the water depth at the spill site. The dimensions of an oil slick, and in particular the layer thickness can be estimated from aerial observations and can further be determined with the help of an appearance/colour code table. This paper results in practical guidelines when the use of dispersants from environmental point of view is acceptable, conditional or not recommended.**

**It can be concluded that the dispersion of oil into the water column is not likely to result in acute toxic effects on aquatic organisms in deep, well-mixed waters. In other types of water the potential for effects of dispersed oil on aquatic organisms can be considerable. At sea, in coastal waters and large rivers, treatment with dispersants of small to medium spills (up to 200 m<sup>3</sup>) leads to a reduction in risk for birds while the dispersion of oil into the water column is not likely to result in acute toxic effects on aquatic organisms.**

**On inland waterways (canals, port area, rivers), the application of dispersants will lead to a net environmental benefit only in case of very small spillages (litres).**

## **Introduction**

One of the response methods to deal with oil spillages is the use of dispersants (Baker 2000 and IMO 1995) Chemical dispersants enhance the natural dispersion of oil into the water column and eventually the biodegradation of a proportion of the oil. The quantity or proportion of dispersed oil ultimately biodegraded - and the ecological benefit that this actually may bring - is quite a 'live topic' at the moment. Biodegradation of harmless oil components may be of little benefit if the more harmful and toxic oil components persist long enough to do damage.

Effective dispersion of oil reduces the risk of exposure of birds to the oil slick. The concentrations of oil components in the water column increase however, which may cause effect on aquatic organisms.

Many considerations of trade-off of potential benefits and risks of dispersant use have been made with reference to open-sea conditions. Dispersant non-use zones (or zones of dispersant use with caution) have been defined only as minimum water depths or proximity to the coast.

There is a wide variety in types of surface water systems ranging from open seas, coastal waters, estuaries, lakes and rivers to narrow and shallow canals and trenches at which oil spills can happen. This diversity in hydrological circumstances, and also in ecological sensitivity, makes it quite impossible to define one single procedure to decide upon the use of chemical dispersants to treat an oil spill. Moreover, application of dispersants without paying attention to the dilution capacity of the receiving water is likely to result in an under- or over-estimation of the risk of exposure to concentrations of oil/dispersant mixtures that surpass no-effect levels. Therefore, attention has to be paid to mixing processes in the different surface waters.

Use of any oil spill response technique is a policy decision, which is the responsibility of the appropriate authority. In general, the minimization of environmental damage is best served by preventing spillage of oil or the mechanical recovery of spilled oil. When these options are not feasible, the use of dispersants can be considered to minimize the effect of surface slicks of oil on birds or to reduce the amount of oil washing ashore. The effects of the oil on aquatic organisms should be considered prior to the application of this technique, as oil is dispersed into the water column following the use of dispersants. This paper provides information to support decision making on the use of dispersants by providing information on the risks of oil slicks for birds and of dispersed oil for aquatic organisms.

Aerial surveillance of oil spills is a common detection technique for larger water systems and can possibly be combined with spraying of dispersants. During aerial surveillance the dimension of total area polluted, the coverage percentage of oil in this area, and the percentages of each individual colour/appearance can be assessed. This information on an oil spill can be used when deciding on the response technique to be used.

In most countries the use of dispersants to combat oil is strictly regulated. A policy decision on the use of dispersants should be based on the limited information on the amount and distribution, together with information from the spill site such as type of water system, water depth, weather conditions and ecological sensitivity. Such a decision should also take into account effects of dispersion on the effectiveness of other response method, e.g.: If oil, treated with dispersants but not yet actually dispersed, washes ashore, the use of dispersants will reduce the stickiness of the oil, which may make clean up less difficult. If the oil has been dispersed it will not be washed ashore, being present as oil droplets dispersed in the water column. Water containing dispersed oil droplets may be carried by currents into shallow water areas where the oil droplets might come into contact with intertidal sediments. Being dispersant-treated, the oil droplets will be less likely to stick to sediments than if they were naturally dispersed. Dispersants are only effective when applied properly and at an oil viscosity lower than 2000 - 5000 cST (Koops and van der Veen 2002)

There are other references that claim a higher viscosity limit for dispersants. There has been some confusion because the viscosity value referred to is sometimes the viscosity of emulsified oil. In the early stages of emulsification the process can be reversed by the application of dispersant - dispersants are emulsion-breakers. Application of dispersants

can lead to a positive net environmental benefit: if saving birds by the use of dispersants leads to an acceptable risk for the aquatic organisms in the water column. The effects on birds can sometimes be reduced with other response methods, (e.g. mechanical recovery) which does not transfer the oil into the water column

Relevant for the decision on the response technique to be used is also the number of birds on scene, the sensitivity and economic value of aquatic life

### Effects Of Oil On The Water Surface

The effects of an oil spill at the water surface are mainly determined by the exposure of birds to the oil layer and the oil that washes ashore. The threshold layer thickness at which birds will be affected is approximately 25 ml/m<sup>2</sup>, (Scholten *et al.*, 1996). This corresponds to a layer thickness of 25 micron. Any oil layer thickness in excess of 25 micron will be harmful for birds that contact the slick.

In aerial surveillance the following appearances/colours, of known layer thickness, can be discriminated [Fig I.] (Bonn Agreement Oil Appearance Code):

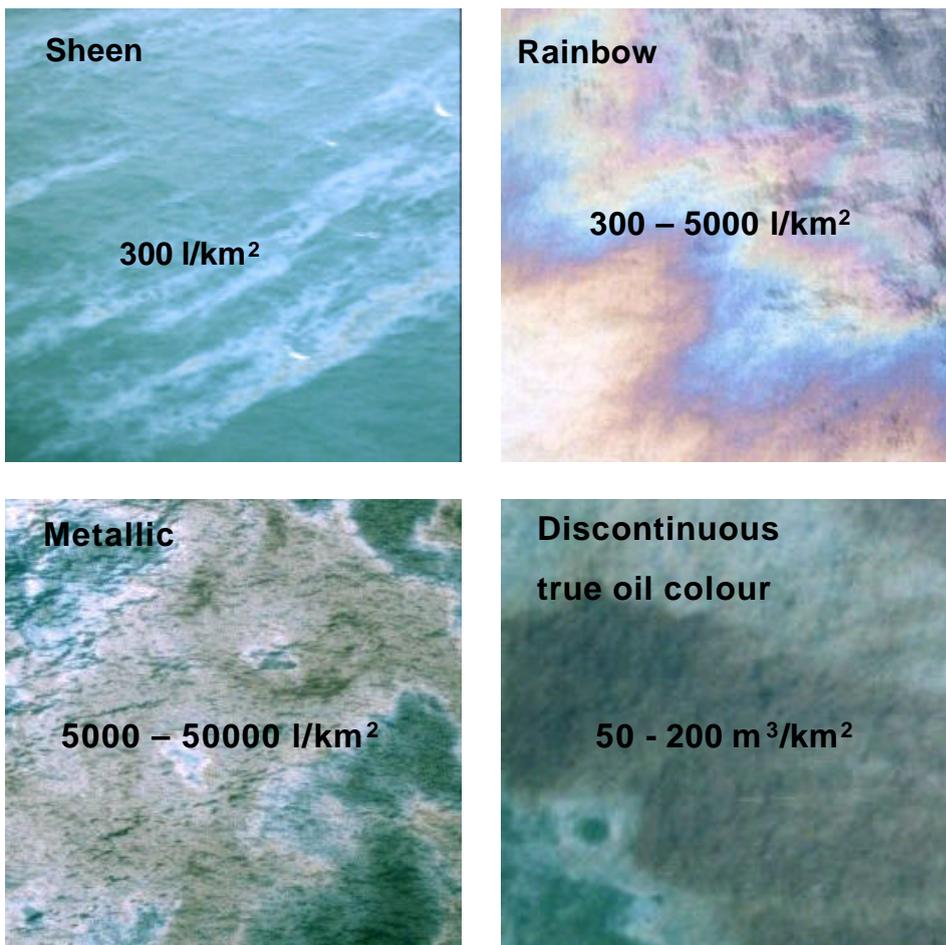


Figure I Appearances/colours to distinguish different layer thickness

- “Sheen” (< 0.03 micron)
- “Rainbow (0.03 –5 micron)”
- “Metallic” (5 – 50 micron),
- “Discontinuous true oil colour” (50 – 200 micron), and

“Homogeneous true oil colour” represents a layer thickness in excess of 200 micron  
The surface layer toxic threshold for birds of 25 micron is classified as “metallic”, ranging from 5 to 50 micron (Koops, 2001).

In case the oil layers are thinner, the use of dispersants is not considered since this will not reduce the effects to birds and may only increase the effects to marine water column organisms. It should be noted that the number and species of birds that are likely to be present in the spill area is important information to evaluate the net environmental benefit.

### Effects Of Dispersed Oil In The Water Column

Enhancing the natural dispersion of oil into the water column will reduce the effects of oil on the water surface. A drawback, however, is the increase of oil concentrations in the water column resulting in increasing effects to marine organism in the water column and in and on the aquatic sediment. This negative effect is due to enhancing the (natural) dispersion of the oil into the water column, which results in increased oil concentrations in the water column. The effects of organisms exposed in the water to the dispersed oil/dispersant could be lethal depending on the exposure time, and the type of organism and on the composition and concentration of the oil.

In Table 1 some Lethal Effect Concentrations are given for different groups of organisms, exposure times and organisms as well as the No Effect Level concentrations. The data on which the relation between effect concentration and time are based were derived from the database “Medusa’s Head” of TNO MEP Den Helder. This database contains toxicity data from toxicity experiments of which result are published or direct from test laboratories.

**Table 1 Lethal concentration values (50% and 5 % ) for different exposure times and organisms as well as the Predicted No Effect Level concentrations.**

Organism	96h-LC <sub>50</sub> (mg/l)	4h-LC <sub>50</sub> (mg/l)	4h-LC <sub>5</sub> (mg/l)	PNEC (mg/l)
Fish	4.2	99	23.4	0.0450
Zooplankton	3.2	76	10.7	0.0100
Molluscs	3.8	91	15.6	0.0015
Shrimps	3.0	71	10.1	0.0026

Dispersed oil will dilute as a function of time and will at some point reach a concentration below the Predicted No Effect Concentration (PNEC). The dilution rate depends on the turbulence in the water (mixing), the volume of the receiving water, and spill size. The impact on marine organisms in the water column depends on the oil concentration, the exposure time, and the number of organisms exposed.

## Effect Threshold Values

When considering the application of dispersants, it is important to predict the potential risk to the aquatic environment. Toxicity threshold values should be derived that can be used to protect to the aquatic environment. The level of protection desired is a policy decision.

An oil/dispersant concentration in the water may have the potential to cause lethal effects. The higher the exposure concentration, the shorter time it takes before lethal effects appear (see Table 1). In an actual spill situation the concentration in the water is not constant and will also decrease as a function of the time due to dilution in the water. Dispersing fresh low viscous oil is an instantaneous process that may cause acute effects in case the oil/dispersant concentration exceeds a certain level for a certain exposure time. When dispersants have to break an emulsion before they disperse the liberated oil, dispersion could be quite slow.

At low dispersed oil/dispersant concentrations, only very limited effects of the use of dispersants can be expected.

In this paper the level of severity of effects are classified as follows:

- (1) Effects are likely to be negligible,
- (2) Limited effects are likely.
- (3) Effects are likely to be severe

Two toxicity threshold effect concentrations have been selected to distinguish between the different responses. It was chosen to set the thresholds at conservative levels

The first toxicity threshold boundary was defined as a concentration beneath which only effects are likely to be negligible. A lethal concentration of 5% (LC<sub>5</sub>) of the most sensitive organism is an often-used toxicity threshold value.

Assuming that very limited effects in the water column are acceptable (emergency situation and saving birds and shoreline), the LC<sub>5</sub> 4 hours rather than the LC<sub>5</sub> 96 hours should be used. Since mainly very short-term effects are relevant, an exposure time of 4 hours seems best applicable. From Table 1 it appears that the lowest “4 hours-LC<sub>5</sub>” is 10 mg/l, taking into account sufficient spreading in sensitive species and trophic levels. However, to take account of uncertainties in effect levels and the limited number of species considered, a safety factor of 10 is applied to derive at a value of 1 mg/l.

The second threshold should indicate concentrations above which “effects are likely to be severe” to occur. It is proposed to apply the lowest “4 hours LC<sub>5</sub>” with no safety factor. Between the first and the second threshold level limited effects are considered likely to occur.

The approach using the lowest “4h-LC<sub>5</sub>” and a safety factor of 10, results in:

- a **first toxicity threshold concentration of 1mg/l** and using the lowest “4h-LC<sub>5</sub>”, and no safety factor a **second toxicity threshold concentration of 10 mg/l**

These threshold values (See

Table II) will be used in the following approach.

**Table II**      **Used threshold values to distinguish three levels of severity**

<b>Level of severity</b>	<b>Threshold values (mg/l)</b>
Effects are likely to be negligible	<1
Limited effects are likely	>1 <10
Effects are likely to be severe	>10

For comparison, on the basis of ‘chronic’ No Observed Effect Concentrations (NOEC’s) for 26 species a Maximum Tolerable Risk level (MTR) of 0.079 mg oil/l has been calculated (Scholten *et al.*, 1993). This level assumes that 95% of the species are protected at continuous exposure concentrations.

This paper focuses on large water systems and relatively small spills in which dilution is an important process. It does not take into account partitioning to sediment, or chronic effects of oil components and should therefore not be used for small water systems and relatively big spills. This paper does not address the eco-toxicological properties of dispersants, which should be considered by regulators.

## **Predicted Environmental Concentration In The Water Column**

Knowledge of water mixing characteristics will result in a better understanding of the risks to aquatic ecosystems as a result of chemically dispersing oil into the water column. The theoretical concentration of a particular spill scenario, assuming that all oil has been chemically dispersed into the water, can be calculated (PEC = Predicted Environmental Concentration) and compared with the two toxicity effect threshold concentrations previously discussed.

Dilution of the oil droplets in large lakes, estuaries and seawater is predominantly dictated by mixing energy/ turbulence from wind and tide currents. The oil concentration depends primarily on the layer thickness of the slick to be dispersed, and on the mixing capacity (dilution rate) of the water body in which the oil will be dispersed. Dispersion is a physical and not a chemical process.

Due to the turbulence of the receiving water, the oil droplets will dilute in all directions and will at some point reach levels where effects are likely to be negligible. Hence, knowledge about the range and degree of mixing in relation to local hydrology is of importance for the establishment of criteria and standards that can be used for the risk assessment of oil dispersion.

The dispersed oil/dispersant concentration depends primarily on the average oil layer thickness at the water surface, and on the depth of the water underneath. Oil slick thickness varies over an enormous range within a slick from sheen less than a micron thick at the tail of the slick to several millimetres thick in patches if the oil is emulsified. This is a problem for dispersant use as it inevitably means that localised areas are over-treated and thicker areas are under-treated.

Secondly, the horizontal spread of the dispersed oil in the water determines the dilution and by that the concentration as a function of time. As a consequence, the initial concentration will be high, but the number of exposed organisms is limited, while later on there will be an enormous increase of exposed organisms due to the increased volume of water containing the diluted oil/dispersant droplets, but only at a much lower exposure concentration.

Application of dispersants sometimes leads to an almost instantaneous cloud/plume of dispersed oil that will drift away with the current. It is assumed here, that organisms are exposed continuously to the cloud/plume, and that the concentration decreases in time as a result of dilution. This is a conservative assumption, since only planktonic organisms (algae, zooplankton) are transported with the water current; benthic, organisms, are fixed at one place and will only be exposed for the duration the polluted water volume will pass; for mobile organisms like fish, the exposure time is rather unpredictable, but will be shorter than 'continuous'.

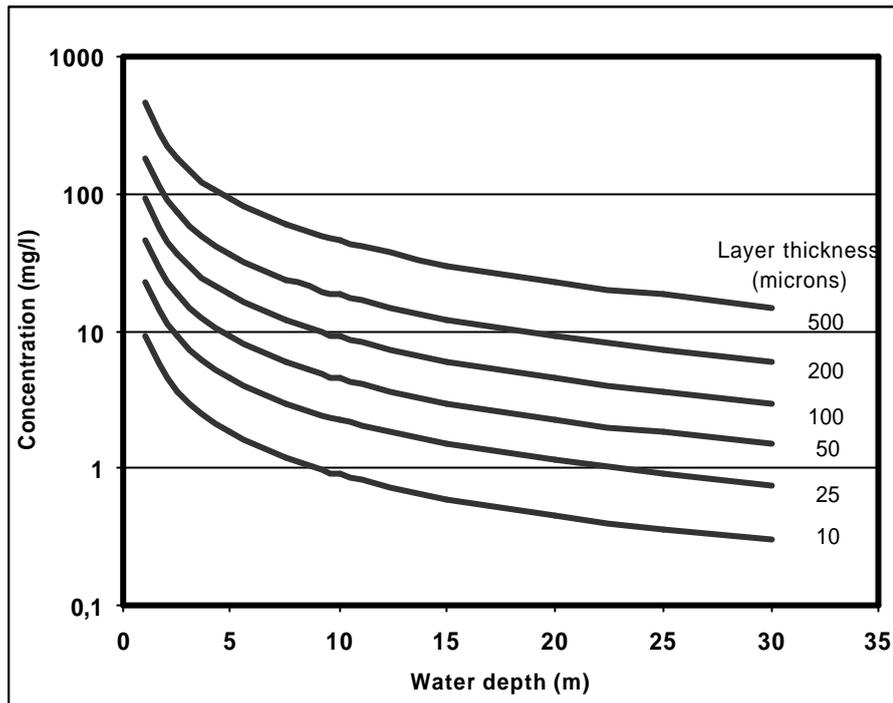
The Predicted Environmental Concentration (PEC) is assessed 4 hours after applying the dispersant. This concentration is compared with the toxicity threshold values for water column organisms at an exposure time of 4 hours.

The use of dispersants will be considered only in waters with a high mixing energy. It is therefore assumed that the oil in this time period will dilute into the whole water body underneath the slick resulting in a homogeneous concentration equal to the amount of oil per  $m^2$  of oil layer (kg) divided by the volume of water ( $m^3$ ) to the bottom underneath (water depth). In case the water column is stratified, the mixing depth (and not the water depth) should be considered.

Dilution of the dispersed oil to the bottom (vertical diffusion) is rather fast (Reed, 2001) and determines the initial concentration in the initial exposure period. The lateral (or horizontal) diffusion causes the concentration decrease over the next exposure period. The lateral diffusion can vary considerably depending on the spill site.

The PEC in the water column is determined by the initial dilution over the water column (from water surface to water bottom or mixing depth) followed by a horizontal dilution factor depending on specific hydrological conditions of the receiving water body. As a conservative approach, the dilution factor is taken over a relative short period of time (4 hours) resulting in a relative high concentration.

The initial oil concentrations in the water column underneath an oil slick can be calculated. by dividing the weight of oil per  $m^2$  (oil density times layer thickness (m) times  $1 m^2$  by the water depth (m)) shows results of some calculations for several oil layers with varying thickness.



**Figure II** The concentration of oil (PEC) assuming homogeneous dilution over the whole (mixed) water column and assuming no lateral diffusion occurs.

Figure II shows that increasing water depth and decreasing layer thickness results in lower concentrations of oil after the use of dispersants.

The concentrations shown in Figure II assume an initial homogeneous dilution over the whole (mixing) water column. The time required to reach this vertical diffusion depends on the water depth and the vertical diffusion coefficient, as formulated by Bowden in the following way:

$$t_v = 0.25 \frac{H^2}{K_v}$$

In which:

$t_v$  = time for vertical diffusion to bottom

$H$  = water depth

$K_v$  = vertical diffusion coefficient (strong mixing 0.01 m<sup>2</sup>/s to calm mixing 0.0001 m<sup>2</sup>/s)

This results in a time period of 25 to 2500 seconds per meter water depth for strong mixing waters and calm waters, respectively. The concentration will further decrease as a result of lateral diffusion.

## Dilution Factor Due To Lateral Diffusion

The vertical dilution is determined by the water depth and has been described in previous section. The dilution also depends on specific conditions of the spill site (turbulence, currents etc.).

It is assumed that the vertical dilution to the bottom is taken over by the horizontal dilution,. In other words, the oil is initially spread over the water column, i.e. from water surface to bottom, and then diluted further by horizontal diffusion. As a consequence, the differences in dilution per spill site are mainly determined by water depth and horizontal diffusion.

The final dilution factor is defined here as the ratio between the volume (Q) of water in which the oil droplets will dilute on short notice ( $Q_{4 \text{ hours}}$ ) after the application of dispersants and the assumed initial volume of water from surface (Length times Width times Depth) to bottom underneath the spill ( $Q_{\text{init}}$ ):

$$\text{Dilution}_{-}\text{factor} = \frac{Q_{2-4\text{hours}}}{Q_{\text{init}}} = \frac{L_t * W_t * D_t}{L_i * W_i * D_i}$$

In most waters the initial depth at time i ( $D_{i=4 \text{ hours}}$ ) is equal to the final depth at time t ( $D_t$ ). This makes the dilution factor independent of the water depth and as a function of the increase in area ratio. The dilution factor resulting from lateral diffusion is very sensitive to the initial spill size (and thus  $Q_{\text{init}}$ ), and boundaries such as banks in an inland waterway or enclosed water volumes. Boundaries will limit the lateral dilution and thus limit the  $Q_{4 \text{ hours}}$ . The plume width increase (L) caused by the mixing in the horizontal direction depends on a diffusion velocity (V), the current velocity (U) and the transport distance (X) of the dispersed plume of oil droplets by current from the site where dispersants have been applied:

$$L = 2\sqrt{3} * \frac{V}{U} * X . \quad (1)$$

Typical values for the current velocity (U) are 0.1 to 2 m/s and for the lateral diffusion velocity (V) 0.004 to 0.016 m/s. (Reed 2001). As  $X = U * t$  and assuming a time period of 4 hours (14400 sec) X will be 1440 m and 28800 m for current velocities of 0.1 and 2 m/s, respectively. For these values of U, V and X the width increase (L) is given in

Table III based on Formula 1

**Table III** Plume width increase (L) after 4 hours as a function of current velocity (U) and diffusion velocity (V)

Lateral diffusion velocity: V (m/s)	Plume width increase L (m)	
	U=0,1; X=1440	U=2; X=28800
<b>0.004</b>	200	-
<b>0.016</b>	800	-
<b>0.004</b>	-	200
<b>0.016</b>	-	800

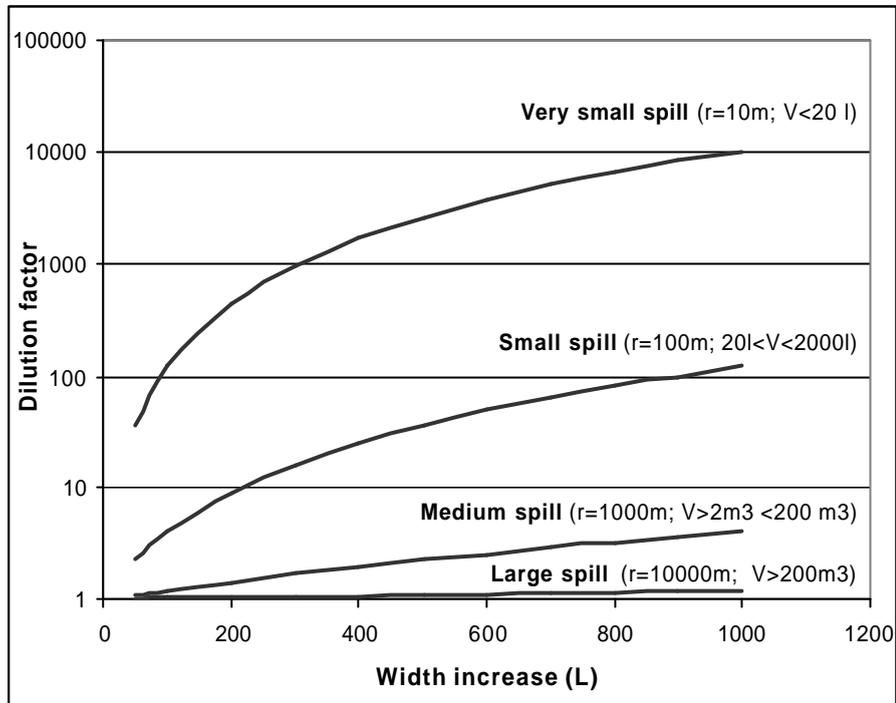
In terms of dilution factor, the original size of the spill plume also has to be taken into account as the width mentioned in

Table III is the *increase* in width, and not the total width. The original spill size therefore plays an important role in determining the final dilution factor. Assuming a plume due to dispersion, which is initially circular with a radius  $r$  (m), this radius of the dispersed oil plume will increase with the width increases mentioned in

Table III

Figure III shows the calculated dilution factor as a function of the plume width increase (see

Table III) and the initial radius (r) of the plume directly after applying dispersants.



**Figure III** Horizontal dilution factors as a function of initial plume size (radius)

Table IV gives some horizontal dilution factors for different typical water systems and spill sizes. These values are estimated with the help of Figure III.

In strong mixing waters,  $L = 800$  (see

Table III) is used to represent high diffusion velocities, and for calm waters  $L = 200$  is used to represent low diffusion velocities. In the case of high diffusion velocities, where  $L=800$ , dilution factors are assumed of 10000, 100, 10, 1 for very small spill up to large spills, respectively. For  $L = 200$  this results in 1000, 10, 1, 1 for very small spills up to large spills, respectively. The dilution factor is 1 in case the water body has no or very limited mixing capacity (still water no current, no wind etc.) or is limited by boundaries such as banks.

Rivers can be considered as fully turbulent while in trench-like waters, like polders waters and tributaries, only limited turbulence is likely to occur from time to time. Owing to the low flow in canals of this type, dilution could be hindered and only occurs slowly. On the other hand most dispersants do not work well in freshwater. Some dispersants hardly work at all in freshwater, although they can be formulated to do so. Dispersant use in rivers therefore is limited.

**Table IV Horizontal dilution factors for different types of water and spill sizes**

Type of water	Dilution factors			
	Very small spills (1 – 20 l) $r=10$	Small spills (20 – 2000 l) $r=100$	Medium spills (2 – 200 m <sup>3</sup> ) $r=1000$	Large spills (>200 m <sup>3</sup> ) $r=10.000$
Open sea (tidal currents and wind)	10000	100	10	1
Lakes/ large open waters (limited current and wind)	1000	10	1	1
Large rivers (high flow and wind)	10000	100	10	1

In the open sea, it is expected that the horizontal dilution factor for small spillages will already exceed a factor 10000 within a short period of time, due to tidal and wind-induced currents. In large open inland waters (lakes, canals, etc.) a horizontal dilution factor of 1000 is more likely over a period of 4 hours, while higher dilution factors may only be expected in the inland surface water group of “large rivers”.

The horizontal dilution factors presented in Table IV should be considered as approximations based on general characteristics of such water systems (lateral diffusion velocity 0.016 m/s) and categorized spill sizes. It should be realized that in surface waters several other horizontal dilution factors might also contribute to the actual dilution.

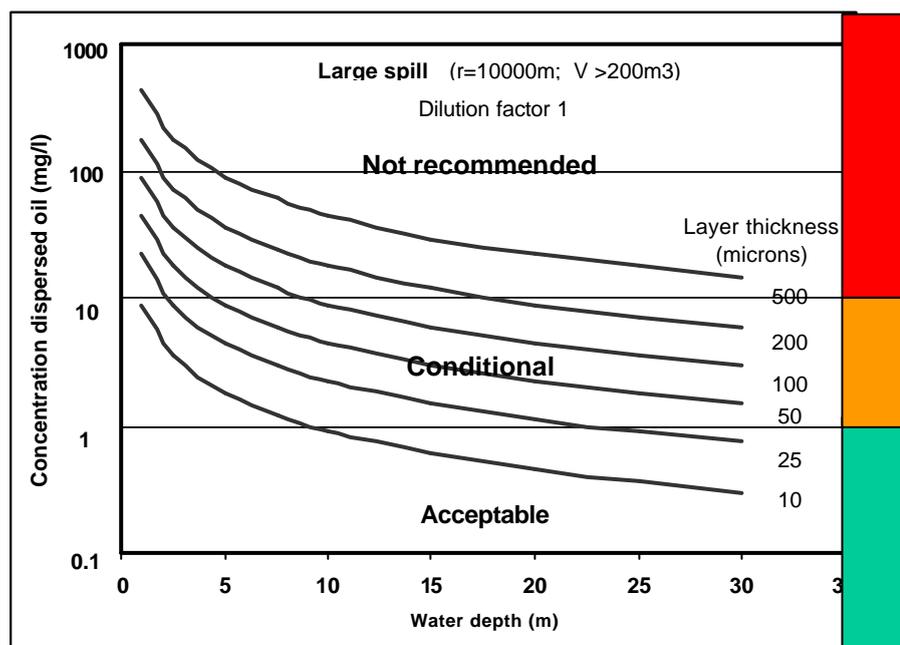
Figure V to Figure V show the Predicted Environmental Concentrations (PEC - dispersed oil in water column) for different dilution factors as given in Table . If the water depth is known one can determine, with the help of these Figures, whether the use of dispersants is acceptable from an environmental point of view, or not. The zone is the area in which the transition of the relevant layer thickness (to be determined with the help of the appearance/colour code) with the water depth at the spill site

In Figure V to Figure V the horizontal dilution factor is increased each time by a factor 10 and also the effect on threshold concentrations are coloured to distinguish three zones:

- Green zone: **Use of dispersants is, from the environmental point of view, acceptable:**  
This is the case when the PEC in the water column is below the 1 mg/l threshold value (Effects are likely to be negligible.)
- Orange zone: **Dispersant use is, from the environmental point of view, conditional:**  
This is the case when the PEC in the water column is between the 1 mg/l threshold concentration and the 10 mg/l threshold concentration (Limited effects are likely (Decision-making should be based on protection of sensitive wildlife bird concentrations, floating fish eggs etc)and other resources due to floating oil on the water surface.
- Red zone: **Dispersant use is, from the environmental point of view, not recommended:** At all concentrations higher than zone 1 and 2 (above the 10 mg/l threshold concentration)

It is clear that the decision on whether or not dispersants should be used strongly depends on; the size of the spill, the water depth and the thickness of the oil layer.

Three oil spills (a large, medium and small spill) are simulated, indicating a recommendation on the use of dispersants, depending on the layer thickness of the oil slick, the concentration of dispersed oil and the water depth. Based on these results, it can be concluded that large spills (>200 m<sup>3</sup>) normally with a layer thickness of 100 – 200 µm (0.1 – 0.2 mm) should not be treated with dispersants unless the water depth is more than 20 meters. Medium spills could be treated with dispersants in case the water depth is more than 5 meters, assuming a layer thickness of less than 200 micron (0.2 mm). Small spills (< 2,000 litres) could be treated with dispersants regardless of the water depth.



**Figure V Predicted Environmental Concentrations for large chemically dispersed spills (dilution factor 1)**

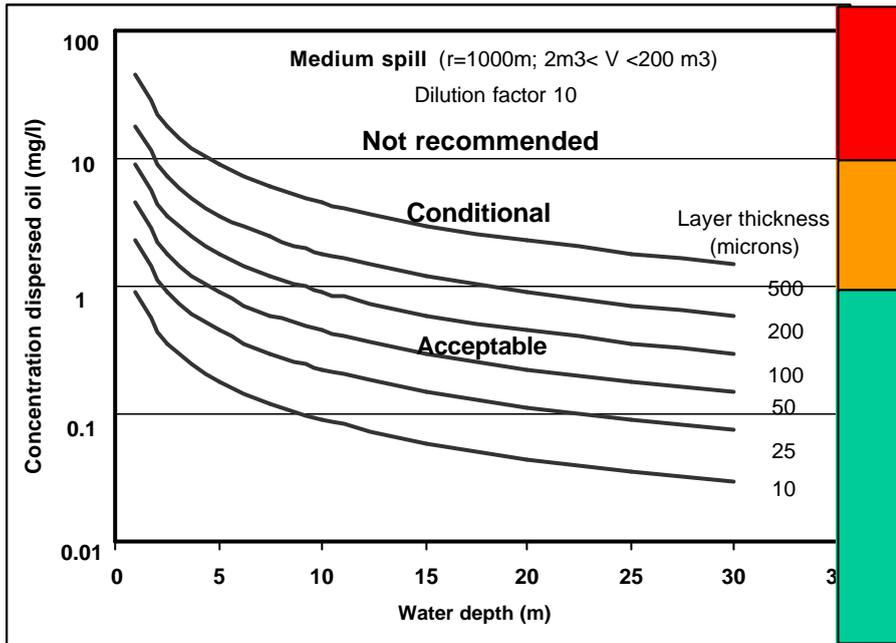


Figure VI Predicted Environmental Concentrations for medium chemically dispersed spills (dilution factor 10)

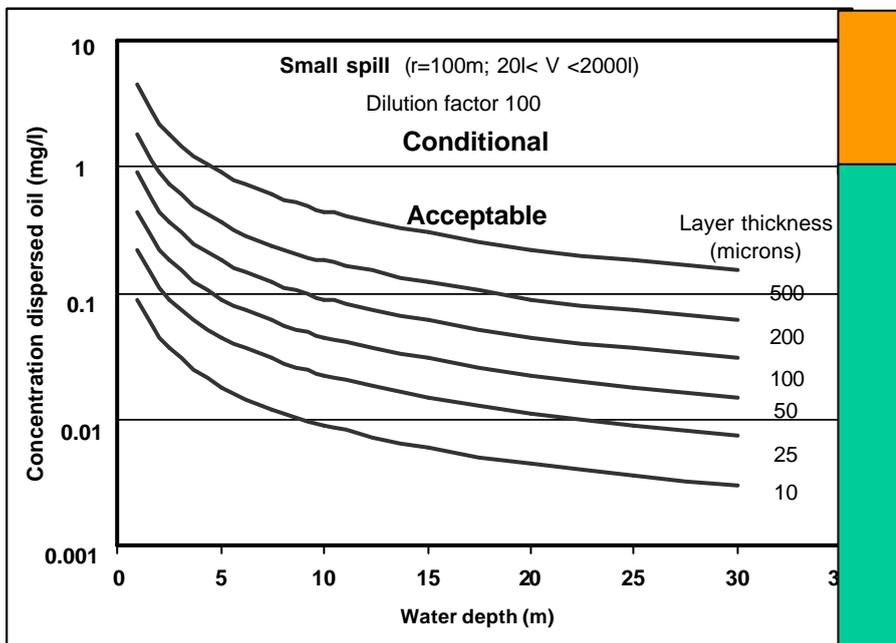


Figure VII Predicted Environmental Concentrations for small chemically dispersed spills (dilution factor 100)

## Discussion & Conclusions

The use of dispersants is one of the options to reduce the effects of floating oil. Alternative response methods should always be considered. The use of dispersants enhances natural dispersion and therefore also the biodegradation rate. The oil is not removed by dispersants, but it is converted into a changed physical form (droplets) in a different compartment of the environment, viz. the water column. Since the oil-water surface area is increased by the formation of tiny droplets, dissolution and biodegradation rates are enhanced. Response methods that remove the oil out of the marine environment should have priority, since no increased effects in the water column will occur. The use of the dispersion method should be selected only if environmental benefits are likely to occur.

The spraying of dispersants from an aircraft is a fast response method compared to the other response methods that need a vessel to apply. If time is important, this could enhance the possibilities if success of using dispersants.

Dispersants should, from environmental point of view, not be used for very thin layers (“sheen” and “rainbow”) of oil, since these are unlikely to cause severe effects on birds. An oil layer thickness of 25 micron for the effect threshold on birds has been used in this paper. The net environmental benefit of using dispersants in such cases may even be negative.

It should be stressed that the assumptions used in this paper depend on the efficiency of the dispersants to be used. Less effective dispersants will reduce the amount of oil entering the water column, but will also not be able to effectively reduce the risk of oil at the water surface. The effectiveness and efficiency of the use of dispersants always needs to be evaluated on scene, in order to allow for changes in the response strategy. In the decision making support system that is presented here, it is assumed that the oil is technically dispersible and will disperse completely after treatment.

The lack of accurate and reliable data with respect to hydrological parameters and the great variety of circumstances makes it difficult to derive simple estimates of dilution factors in all type of surface waters. Therefore, the dilution factors given in Table should be considered as an indication rather than an accurate estimate. On the other hand, the dilution factor is not the most important factor for predicting the environmental concentration. The spill dimension (surface area polluted before application of the dispersants) plays even a more important role. It has to be kept in mind that the estimated dilution factors have been derived from data that were partly obtained by calculations from a mathematical model that, so far, has not yet been validated. To ensure good decision-making with regard to dispersant use, it will be necessary to continuously enhance the reliability of the information behind the decision support system.

The way of calculating the oil concentration (PEC - Predicted Environmental Concentration) after applying dispersants, and the selected dilution factors, are considered conservative, since additional natural processes will also enhance dispersion. The wind drift, for instance, will bring the floating slick above clean water with a speed of 3% of the wind. The enhanced natural dispersion process is not instantaneous but takes some time, and this helps further to dilute the oil over a larger volume of water, resulting in a lower PEC. For inland waterways the use of dispersants could only be considered in case of very small spillages and special fresh water dispersants would need to be used.

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