# Inclusion of an Oil Database into a Forecasting System.

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**Abstract**

Within the framework of its own public service mission, Météo-France provides assistance to the authorities in charge of marine pollution response, either on a national scale (Plan POLMAR-Mer) or in an international background (i.e. helping the Spanish Authorities during the Prestige oil spill). Specially influenced by the latest accidents (Erika 1999 and Ievoli Sun 2000) the existing forecasting system of marine pollution is being updated and an Oil Database implemented.

Including an Oil Weathering Model and the Oil Database into the drift forecasts, the forecasting system will provide more exhaustive information for the contingency planning and risk assessment. Actually, weathering is critical for non-conservative pollutants, such as high-density fuel oils spilled during the Erika and the Prestige's events, but it is even more important for light crudes that can turn into very viscous pollutants. The simulation divides the behaviour and fate of oil issue in two parts: the processes of mass transfer (such as evaporation or vertical dispersion) and the processes that introduce significant changes in the physical-chemical properties (emulsification for instance). The transport model was coupled to the oil weathering model by introducing the evolutions of the rheological properties of the pollutant (i.e. viscosity). Some experiments are also regularly carried out at CEDRE, in order to calibrate the formulations used in the forecasting system and to constitute an oil database (maximum water contents, distillation curves, etc…).

## 1 Introduction

Following the ERIKA spill that polluted the French coasts in year 2000, it was decided to improve the Météo-France forecasting model on two aspects: the drifting model was made more accurate (Daniel et al., 2003) and the weathering processes were taken into account through an additional model implemented in the software. To achieve the second objective, an original strategy was adopted: the modelling part was built in connection with experimental data obtained on oils of various origins and provided by TotalFinaElf. This process presented the advantage of dealing with real cases of experimental releases but it revealed also to be more complex. As a matter of fact, the accuracy of the weathering tests in the flume had first to be investigated: the oils behaves differently at the pilot scale, and the kinetics as well as some maximum values (especially viscosity) have to calibrated with field experiments.

On the other hand, this combination of theoretical and experimental considerations enable to adjust the model on specific aspects such as the viscosity threshold set up for natural dispersion. In addition, it seemed possible to go further by constituting a database not only with complete weathering experiments, but on the basis of a limited set of experimental data obtained in the laboratory.

In order two give a general view of the difficulties that had to be faced with, the experimental work will be described, with a focus on the calibration and the reliability of the tests. Concerning the modelling part, a peculiar interest will be awarded to the vertical dispersion issue.

## 2 Experimental Data on Oil Weathering

### 2.1 Objectives

The experimental weathering studies allow to achieve two complementary objectives. In one hand, the results obtained constitute a reliable basis to implement an emergency response plan: the different properties and potential evolutions enable to predict the most appropriate technique according to the environmental conditions and the weathering stage of the spilled oil.

On the other hand, in addition to this initial objective, the various oils tested constitute a database that is regularly enriched by new products. This set of data represent an interesting way to validate the oil weathering model that is developed by Météo France as it provides simultaneously the evolution of various parameters (density, viscosity, water content, evaporation rate, flash point, ...). Moreover, this database tends to be somewhere representative of the great variability of oils (crude and refined oils, light and heavy products, asphaltenic and paraffinic oils).

### 2.2 Methodology

The methodology applied to study the behaviour and evolutions of spilled oil has been described previously for both flume test experiments (Guyomarch and Merlin, 2000) and weathering in open pools (Guyomarch *et al*, 2002).

For a restricted number of oils, the pilot scale tests mentioned could be completed by field trials, with a minimum oil volume of 8 $m^3$.

These studies were also favourably completed by specific tests dedicated to assess the potential efficiency of various fighting techniques such as dispersion, oleophilic recovery, and, based on detailed chemical analyses, the potential for bioremediation operations. These determinations are especially required when dealing with emergency response plans.

### 2.3 Tested oils

Until now, about 20 oils have been weathered in the flume – or *Polludrome* – according to a systematic methodology (except the dispersibility test that has been replaced for the IFP protocol) and for similar environmental conditions : same agitation level and two temperatures, 10 and 20°C (only a few experiment have been conducted at the average temperature of the oil field). Some examples of tested oils are presented table 1.

Table 1 Examples of oils tested in the flume (1999-2002)

| Name | Origin | Type | Main characteristic |
|---|---|---|---|
| ABK (Abu Al Bukhoosh) | United Arab Emirates | Light crude | Asphaltenic |
| ALWYN | North Sea | Light crude | Low asphaltenes content |
| HIDRA | Argentina | Light crude | Asphaltenic |
| CUSIANA | Colombia | Light crude | Asphaltenic |
| Condensates | Indonesia | Refined | Volatile, no emulsification |
| DALIA | Angola | Medium Crude | |
| ROSA | Angola | Medium Crude | |
| N'KOSSSA | Congo | Light crude | Paraffinic |
| KITINA | Congo | Heavy crude | Paraffinic |
| DJENO mixture | Congo | Heavy crude | Paraffinic |
| BAL (Arabian Light) | Saoudi Arabia | Light crude | Asphaltenic |
| AL KHALIJ | Qatar | Medium crude | Asphaltenic |
| BEKAPAI | Indonesia | Light crude | Paraffinic |
| HANDIL | Indonesia | Light crude | Paraffinic |
| ERIKA, PRESTIGE HFO | - | Refined | Asphaltenic, very viscous |

## 2.4 Results of preliminary calibrations

### *2.4.1 Asphaltenic crudes*

The combination of the pilot scale device, completed with field trials, allowed to assess the evolutions of many crudes based on the flume test data. In this way, some corrective factors have been introduced to extrapolate experimental evolutions to various environmental conditions. Particularly, the effect of increasing wind speeds was investigated on the kinetics of various parameters (Guyomarch *et al*, 2002). Some additional work has also been initiated on the viscosities that revealed to be higher in field experiments. Preliminary comparisons seem to demonstrate a reverse relationship between the differences of viscosities (between flume and field) and the asphaltenes content.

In addition, a relationship was established between the asphaltene content (determined at the end of the experiment taking into account the evaporation rate) and the maximum of viscosity obtained after a one-week weathering period in the flume (Figure 1). The two curves meet at one point in the range 2-3 % of asphaltenes. This is in agreement with previous results that demonstrated viscosities higher at 20°C in comparison with tests conducted at 10°C. The explanation of this inversion could be the prevalence of the evaporation process for oils characterised by asphaltenes content close to the limit of emulsification, generally admitted at 3% (when considering soft asphaltenes).

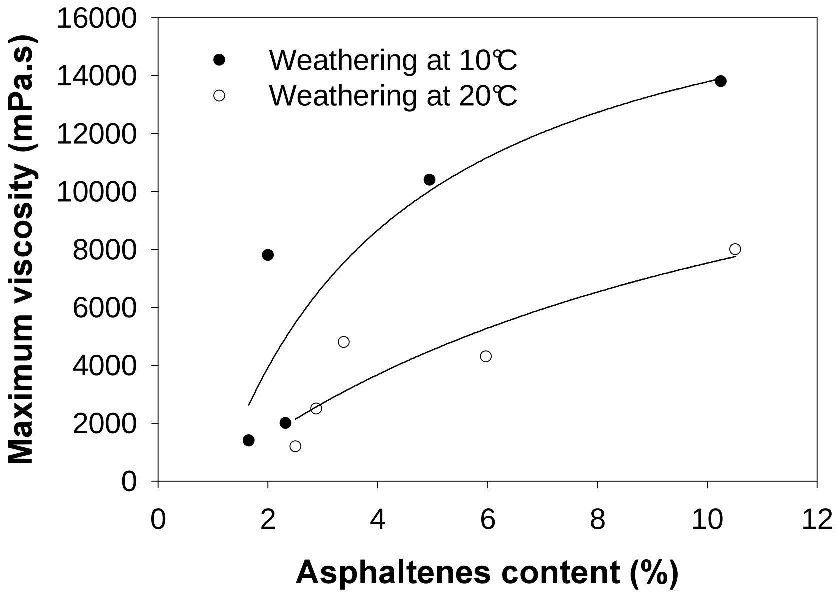


Figure 1 Maximum of viscosity versus asphaltenes content

*2.4.2 Paraffinic oils*

The case of the paraffinic oils proved to be more complicated. The weathering experiments conducted in the flume are affected by the important mixing energy generated in the area close to the wave beater. Even decreased to a low level, it is sufficient to provoke the natural dispersion of the product, in disfavour of the emulsification process. This phenomenon was illustrated in the tests by a progressive decrease of the water content after it had reached a maximum value.

On the other hand, the weathering performed in the open pools allowed to obtained coherent results, but the number of experiments that could be conducted were limited due to the logistical difficulties of these tests. However, even in these favourable conditions, the variability of the results proved to be high (figure 2).

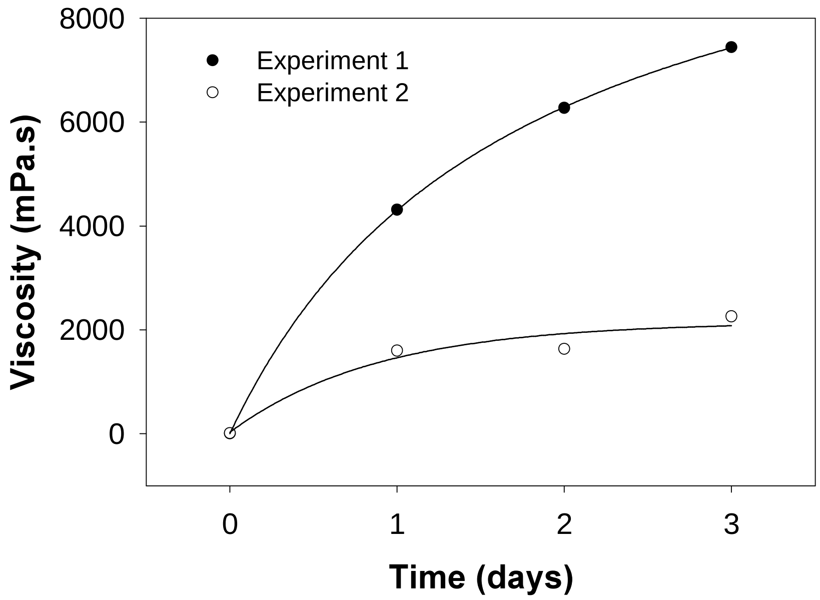


Figure 2 Variability of the evolutions observed for a paraffinic oil

## 3 Updates of the Forecasting System

The French national weather service is in charge of supplying all the information related to a pollution event, such as meteorological and drift pollutant forecasts. Included in this forecasting system, the MOTHY model was developed to simulate the transport of floating pollutants in the marine environment in three dimensions. It was defined as an integrated system that includes hydrodynamic coastal ocean modelling and real time atmospheric forcing with a global atmospheric model.

The transport processes already considered in the model are the horizontal advection due to ambient currents (wind and tide forcing), the turbulent diffusion by ocean turbulence and the buoyancy of oil droplets submerged within the water column. Other mechanical and physical-chemical processes are being introduced in the model in order to improve the accuracy of the results. These updates are validated with recent spill events, like the Prestige or the Erika accident or another ones that took place in the Mediterranean sea.

Some processes are well known like evaporation and emulsification (Sebastiao and Soares, 1995); hence, their simulation depends basically on available data. Other processes, due to their complexity (mixture of mechanical and physic-chemical), could be simulated at different levels of accuracy, taking into account more or less information. The process of vertical dispersion within the water column is an example of this latter one. Part of the oil slick is transformed in oil droplets (oil-in-water emulsion) and will drift and be degraded in a quite different way. In fact, this vertical dispersion should be considered as the key process in the oil spill modelling, which acts as a linkage between other processes like spreading or shear diffusion.

All of these processes have to be included into the existing forecasting system, without lose of its operativity.

### 3.1 Updates in the transport model

As a Lagrangian model, MOTHY models the oil slick as a distribution of independent droplets that move in response to currents, turbulence and buoyancy. The hydrodynamics are obtained by a coupling between a 2DH barotropic model and a 1DV eddy viscosity model (Daniel, 1996).

The 2DH model is forcing by tide and by winds and sea level pressure forecasts from a global atmospheric model. This depth-integrated barotropic model solves the non-linear shallow-water equations on a 1 or 5' grid mesh.

The 1DV eddy viscosity model is constrained by depth-integrated current from the 2DH model, by surface wind and bottom frictional stress. This approach allows a rotation of current direction with depth.

In recent work, the effects of the general circulation and the associated large-scale currents have been studied. This effect was investigated in the Western part of Mediterranean Sea where such currents are significant (Daniel et al., 2003). Due to the lack of operational oceanography system in the zone, two different methods were tested to represent these currents in the MOTHY system: introducing currents derived from climatology or produced by operational oceanography prototypes such as the MERCATOR system (Madec, 1998). Two actual pollution events - *Haven* 1991, *Lyria* 1993 - were simulated; the inclusion of this general circulation leads to improve the results of the oil drift.

### 3.2 Weathering model

The weathering of hydrocarbons is a set of physical and chemical processes that modifies the properties of the initial released pollutant We are interested in simulating those processes that suppose variation of mass (evaporation, emulsification and vertical dispersion) and especially the way these processes modify the physical-chemical properties - the *rheology* - of the non-conservative pollutant. Then, the main question is how this rheology interacts with the drift and spreading processes.

In an operational forecasting system we should find an agreement between accuracy of the simulation and the available data needed as input to this system during a crisis event. In fact, some processes such as evaporation and emulsification evolve very quickly, within hours or days. Then, it could be more important to know the threshold values of these processes (related basically to oil composition) rather than to assess the kinetics of the rheology evolution (related to a changing environment).

The linkage between the transport model and the oil weathering model (OWM) was achieved through a mass transfer between surface slick, atmosphere and water column, and through the evolution of the oil density and viscosity (Comerma et al., 2002).

#### *3.2.1 Mechanical spreading*

In the Lagrangian model, the mechanical or natural buoyant spreading was simulated by the horizontal turbulent diffusion on the water surface. The model includes some methods to calculate the extension of the oil slick, considering the area related to the oil droplets distribution on the water surface.

The evolution of this area could be compared with other analytic expressions, for instance the well-known Fay's equations where the area increases as a function of time and volume (eq. (1)).

$$A_{II}(t) \sim \left( \frac{V^{2/3} \cdot t^{1/2}}{\nu^{1/6}} \right) \Leftrightarrow \mathbf{t} \geq 1 \cdot day \qquad (1)$$

where $A$ is the area of slick ($m^2$),
$V$ ($m^3$) initial volume of oil spill,
$t$ elapsed time,
$\nu$ Kinematic viscosity of seawater ($m^2/s$).

Others authors have introduced additional parameters to this simple expression, suggesting the inclusion of other parameter such as oil viscosity (Reed et al., 1999).

The Fay's oil slick spreading (Fay, 1969) was described in a one radial-dimension. Hence, we have to include the vertical dispersion by means of the shear diffusion developed, inter alter, by Elliot et al (1986). In fact, during an oil spill in open sea, the observed oil patches are stretched by the wind due to the three-dimensional spreading, diffusion and drift; there is a formation of a tail under the main slick. This tail is mainly responsible for the pollution within the water column, especially when the pollutant comes ashore: the lower density of the continental water (estuarine and river flows) leads to the precipitation (and sedimentation) of this dispersed oil.

The former 1DV model allowed to reproduce the vertical variation of the horizontal currents: this constituted an accurate way to simulate the current transport generated by the wind in a near-3D approach.

### *3.2.1 Evaporation*

We have introduced a first order kinetics law to simulate the fraction of oil evaporated:

$$\frac{dF}{dt} = \frac{K_e \cdot A}{V_0} \cdot \exp\left[ 6{,}3 - 10{,}3 \cdot \left( \frac{C_1 + C_2 \cdot F}{T} \right) \right] \qquad (2)$$

where:

F: evaporated fraction
$K_e$ : coefficient of mass transfer
A : surface oil slick ($m^2$)
$V_0$ : oil spilled volume ($m^3$)
$C_1$, $C_2$ : distillation constants
T : temperature (K°)

and considering that $K_e = 2{,}5 \cdot 10^{-3} \cdot U^{0{,}78}$ , where U is the wind speed (m/s).

The distillation constants are obtained form distillation curves of each hydrocarbon. Thus, there is a linear relation between the evaporated fraction and the boiling temperature ( $T_b = C_1 + C_2 \cdot F$). If the oil distillation data is available (or the same type of oil was tested in laboratory) $C_1$ and $C_2$ values can be obtained. If not, we can use the general expressions of these coefficients related to the API density (NOAA, 1994).

*3.2.2 Emulsification*

In the weathering model, we incorporate a simple first-order rate law for mousse formation, proposed by Mackay et al. and commonly accepted:

$$\frac{dY}{dt} = -KU^2 \cdot \left(1 - \frac{Y}{Y_f}\right) \qquad (3)$$

At present, there are some interesting updates of this simplest equation, taking into account, for example the initial oil composition. In recent work, Fingas and Fieldhouse (2001), suggested a classification of emulsion by its components (asphaltenes, aromatics) and final rheological properties (viscosity and final water content). Thus, the formation of water-in-oil emulsions seems better understood; its modelling is mainly related to the oil composition.

In this way, four clearly states of water-in-oil emulsions have been defined. These are established by their stability over time, appearance (viscous, fluid, colour) and by rheological measurements. The states are:

- Stable water-in-oil emulsions (brown solid materials, 80% water content)
- Mesostable water-in-oil emulsions (brown/black viscous liquids)
- Entrained water (black liquids, separated oil and water one week formation)
- Unstable water-in-oil (less than 10% water content after one week formation)

As we can deduce from preliminary results from oil tested in the *Polludrome*, the emulsion of some paraffinic products are inevitable unstable. These products could increase their water content until 70-80% but after two or three days of continuous mixing, the emulsion breaks and some 10-20% of water is released. One example will be presented next chapter.

Hence, this instability of the emulsion has to be reproduced in the formulas: the water content could decrease after some elapsed time. The simplest option could be to reduce the limit of water content in the mixture (Yf) to the final stable value.

*3.2.3 Evolution of oil viscosity and density*

Due to weathering processes, some rheological variables of pollutant change dramatically. In the model, the evolution of viscosity and density of oil are considered.

As different authors noticed, density increase as a function of temperature, evaporated fraction and water content as follows:

$$\rho = Y \cdot \rho_W + (1 - Y) \cdot \rho_0 \cdot (1 - C_T \cdot (T - T_0)) \cdot (1 + C_F \cdot F) \qquad (4)$$

where:

$\rho$ : density of pollutant (kg/m$^3$)
$\rho_w$ : density of seawater (kg/m$^3$)
$\rho_o$ : density of initial oil at $T_0$ (kg/m$^3$)
$T_0$ : oil temperature reference (K°)
T : temperature (K°)
$C_T$, $C_F$ : adjusting parameters
Y : water content

These parameters must be adjusted with experiments in laboratory and depend basically on oil compounds properties. For the moment, the values of 0,0008 y 0,16 are adopted for the parameter $C_T$ and $C_F$, respectively.

The increase in density has to be introduced in the transport model, affecting the behaviour of buoyancy of oil droplets in the water column.

The increase in viscosity as a function of water content of the emulsion *(Y*), the environmental temperature (*T*) and evaporation (*F*) is reported as:

$$\nu_f = \nu_0 \cdot \exp\left(\frac{C_3 \cdot Y}{1 - C_4 \cdot Y}\right) \cdot \exp\left[C_5 \cdot \left(\frac{1}{T} - \frac{1}{T_0}\right)\right] \cdot \exp(C_6 \cdot F) \qquad (5)$$

where:

$\nu_0$ : viscosity of initial oil at $T_0$ (kg/m$^3$)

$C_3$, $C_4$ , $C_5$, $C_6$ : adjusting parameters

The values of 2.5 and 0.654 for the parameters $C_3$ and $C_4$ are commonly accepted (Mackay et al., 1980). Parameters $C_5$ and $C_6$ could be evaluated in the laboratory. Different crude oils and other hydrocarbon products have been tested in the Cedre flume test. During the test, the measurements of the evolution of the oil viscosity could be drawn against the previous formula, taking different empirical values for $C_5$ and $C_6$.

The parameter $C_5$ could be obtained by comparing values of the viscosity of two non-weathered oils at different temperatures. Hence, we obtain a couple of values of viscosities ($\nu_1$ , $\nu_2$) and temperature ($T_1$ , $T_2$ ), where $C_5$ is the slope of the line (eq. 6).

$$\frac{\Delta \log(\nu)}{\Delta T} = \frac{[\log(\nu_2) - \log(\nu_1)]}{[T_2 - T_1]} = C_5 \qquad (6)$$

From the available tested oils, there is an important variation of $C_5$ coefficient between different products as we can observe in next Figure 3; Here, $C_5$ is ranged between 0.018 and 0.4.

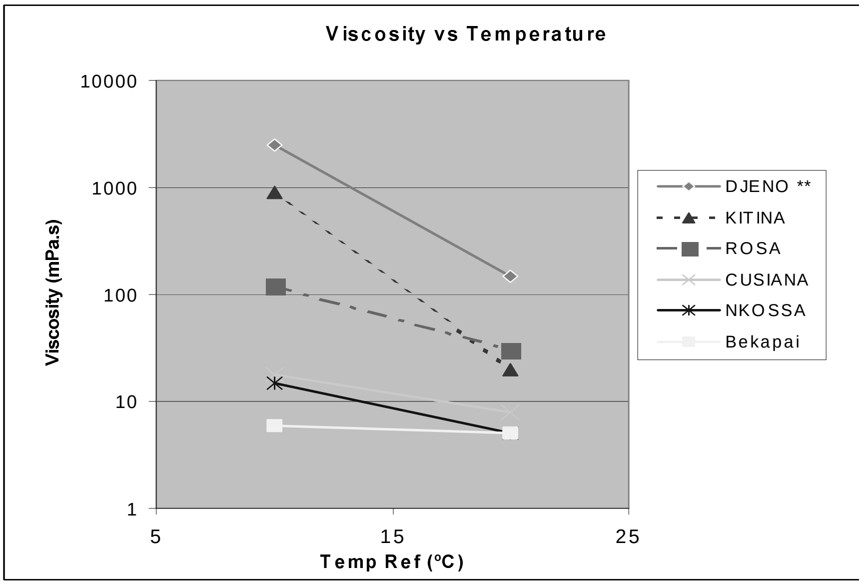


Figure 3. Viscosity of different non-weathered Oils as a function of temperature.

As we can deduce from preliminary results of the oil database, when the ratio composition of (Asphalts / Resins) is high, the product is more sensible to temperature (Table 2).

Table 2. Values of C5 for different non-weathered oils

| Product | Relation Asphaltenes/Resin | Coefficient C5 |
|---|---|---|
| Alwyn | 0.03 | -0.034 |
| Bekapai | 0.15 | -0.018 |
| Dalia | 0.28 | -0.069 |
| Al Khalij | 0.52 | -0.073 |
| Kitina | 9.33 | -0.381 |

When coefficient $C_5$ has been determined we can estimate $C_6$. The value of $C_6$ could be fixed by adjusting the calculated viscosity (eq. 5) to the measured viscosity during the flume test (temperature assumed constant). For those products that have been tested in the flume the C6 coefficient is ranged between 2.0 (Dalia) and 8.3 (Al Khalij).

## 3.3 Modelling the Vertical Dispersion

*3.3.1 Principles of natural dispersion*

Due to mixing processes as breaking waves, the initial oil slick floating over the sea surface is transformed in little oil droplets, causing the entrainment of pollutant in the water column. It's the so-called oil-in-water formation process.

This vertical process depends on the mixing energy (wave height) and the oil's properties (i.e. density and viscosity). Owning some studies in laboratory by Delvigne (1993), it is just needed three parameters in order to characterise this process of natural dispersion:

- Number *N(d)* of dispersed droplets with size *d*
- An empirical constant, $C_0$ oil entrainment rate (depending on oil)
- The initial intrusion depth, $Z_m$

The most remarkable result of these experiments was the fact that exists a simple relationship between the number of particles *N(d)* and its diameter (*d*), obtaining a similar relative droplet size distribution independently of experiments conditions. This leads to a relation between the volume of dispersed oil Q(d) within the mixing layer as a function of a threshold diameter (d). That is:

$$Q(d_i) \propto Const \cdot d_i^{1,7} \quad (7)$$

With this formula, the evolution of entrained oil will be computed as a function of sea state and the "maximum" droplet size definitively dispersed.

In the modelling Lagrangian approach, the volume of an initial oil spill is reproduced as a group of particles, which distribution of size follows some specific law. Each particle (or group of particles with same diameter) simulates a proportion of the initial volume, function of its size. This leads to the necessity of evaluate each time step the spatial distribution of Lagrangian droplets. Some authors emphasise the relevance of using a distribution of droplets constant by size or constant by volume (Varlamov et al. 1999) and furthermore the range choice of this droplets distribution (i.e. minimum and maximum size, Tkalick et al. 2002) and the number of particles used in the simulation.

In order to reduce the computational time, another simplest approach is suggested: the volume of dispersed oil could be evaluated by means of eq (7), evaluating each time step which diameter represents the fraction of particles permanently dispersed. This "critical" diameter will depend on sea state (ocean turbulence) and the weathering of oil (density).

### *3.3.2 Estimation of the critical diameter*

The oil droplets dispersed into the water column are driven by ocean's turbulence but also by buoyancy. The buoyancy force depends on the density and size of the oil droplets, so that larger (more buoyant) droplets tend to remain in the surface layer whereas the smaller droplets tend to mix downwards because the turbulence.

In this way, in the numerical model, for each time step and for each particle, these two strengths (buoyancy and vertical dispersion) are balanced in order to define the vertical movement. In this situation, the critical diameter ($d_{crit}$) is numerically defined as the "maximum diameter of droplet's oil that stays 95% of time within the water column".

Until now, a linear size distribution of oil droplets, typically ranged to 50 until 500 μm, was used in the model MOTHY. Now, a new distribution is tested. Five diameters were chosen, maintaining the 50-500 μm range. The number of each group of diameters has been deduced from relation (eq 7), fixing the number of biggest droplet (Table 3).

Table 3. Number of droplets for each diameter group

| Diameter ($d$, μm) | 500.0 | 281.2 | 158.1 | 88.9 | 50.0 |
|---|---|---|---|---|---|
| Number of droplets $N(d)$ | 1 | 4 | 14 | 53 | 200 |

Next figure 4 represents the percentage of oil droplets dispersed within the water column for each size during the five simulated days. As it is shown, $d_{crit}$ was closed to the lower diameter, 50 μm.

During the simulation, the weathering module was activated: the oil density increased each time step. That's why the percentage of particles in the water column increased with time.

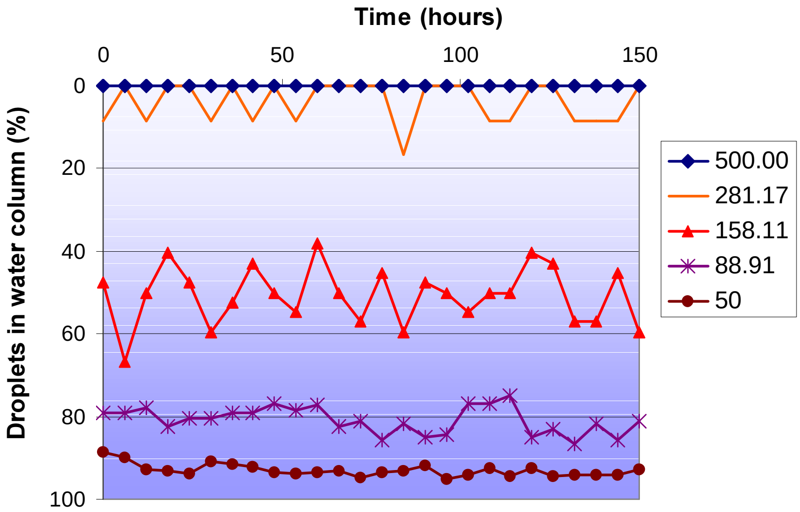


Figure 4. Buoyancy and vertical diffusion

### *3.3.3 Oil droplets distribution*

In order to reproduce as well the slick drift and the tail of the oil spill, we have to consider in the simulation a wide range of droplets size. In fact, droplets little than $d_{crit}$ will always remain in the water column (0-50 μm). Hence is not necessary to represent a large number of smaller particles; they will represent the fraction of polluted water under the main slick.

In the other hand, bigger droplets (>800 μm) have to be included in order to represent the mass exchange between the mixing layer and the surface slick. Within these first meters near the surface, the effect of wind and wave remains important; droplets and patches near the surface are drifted faster, elongating the initial 3D shape of oil from wind direction.

When the oil reaches the threshold value of dispersibility (viscosity near 3000 cSt.), the vertical dispersion processes is stopped in the oil weathering model. Then, the volume of dispersed oil will still constant.

## 4 Discussion

### 4.1 Calibration and Preliminary results

We will summarise the results obtained from one tested product in the Polludrome, a Rosa Medium Crude oil from Angola. This crude was weathered during one week, maintaining wind (5 m/s) and mixing energy constant. Two tests were done at two different temperatures, 10º and 20ºC (constant during experiment).

This crude oil reached different values of maximum evaporation and emulsification depending on the test temperature (Table 4).

Table 4. Weathering Threshold values for Rosa Crude

| Maximum | 10ºC | 20ºC |
|---|---|---|
| Emulsification (Yf) | 73.0 | 62.0 |
| Evaporation | 13.7 | 30.0 |

In next Figure 5 we show the evolution of the measured oil viscosity and the calculated one from eq (5). During the first days, there is a good agreement between measurement and formula; in this way, one can obtain a mean value 2.5 for C6. However, due to the “des-emulsification” the viscosity decreases and the formula doesn’t fit so well.

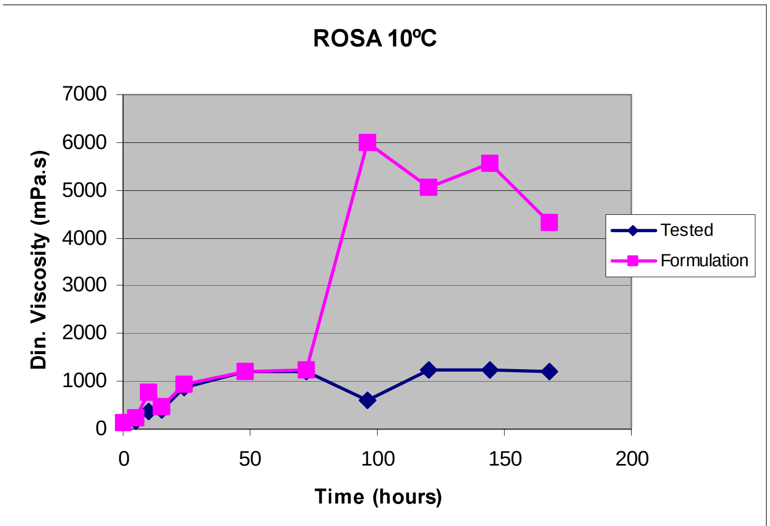


Figure 5. Comparison of measured and calculated oil viscosity.

In next Figure 6 we compare the evolution in water intake as a function of test temperature. At 20ºC, the emulsification increase quickly until 75%, leading to a unstable emulsion.

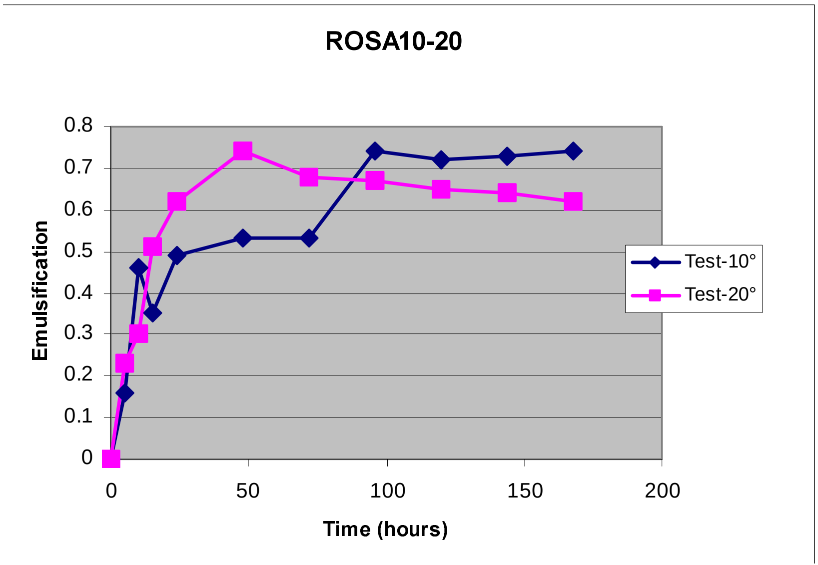


Figure 6. Comparison of oil emulsification at 10 and 20ºC.

As we can deduce from these preliminary results, it's necessary to determine more accurately the other factor that determine the evolution of the rheology. In this sense, the photo-oxidation seems to play an important role to stabilise the emulsion.

### 4.2 Additional laboratory tests

The C5 and C6 parameters presented in the modelling part (section 3.2) could be determined according to laboratory and flume tests. Besides the initial objectives of the flume test experiments, it is planned to add a series of artificial weatherings (mainly evaporation and emulsification) performed in the laboratory according to procedures previously largely described (distillations, water incorporation by the energy provided by the rotation of separating funnels).

In addition to these work focused on data acquisition, the laboratory work can bring elements on the vertical dispersion of oil in the water column. Preliminary and qualitative observations have lead to a limit set at 3000 cSt: this limit need to be confirmed by full studies dedicated to this topic. This threshold value will determine the ending in the simulation of the natural vertical dispersion.

## 5 The Prestige accident

On the 19th of November 2002, the tanker PRESTIGE containing 77,000 tons of heavy fuel oil sunk at 130 miles off Galician coasts. The ship broke in two parts and caused an oil spill of more than 30,000 tons of Heavy Fuel Oil that polluted an extensive coastal area of some thousands of kilometres. At that time, several questions were raised, among which a very important one: how and where will it drift?

When the oil came ashore, the subject of concern was to identify the origin of the oil patches observed on beaches, even those which were not expected to get polluted considering the forecasting of the drifting. All these determinations were a key element in the validation of the predictions, especially for a black tide that impacts the shoreline on thousands of kilometres.

This recent Prestige oil spill event can be compared to the Erika spill near the Brittany coast (December 1999). Unfortunately, in a very short time, this Atlantic coastal zone has suffered two pollution events, two identical oil spills. In fact:

- the spilled oil was near the same: a very viscous fuel-oil, not allowed in the UE but transported in its waters
- the two tankers were very old and a single hull type
- after an unusual random walk, the vessel sinks, releasing the main part of its cargo (near 30.000 m3 for the Erika and 40.000 m3 for the Prestige). This leads to a black tide, polluting an extensive coastal area of some thousands of kilometres.

The complete characterization of the oil was performed by several laboratories (Le Cedre in France, CSIC Institute in Spain) and showed that the cargo of the Prestige was very close to the Erika one, in term of chemical composition but also as concerns its physical characteristics (mainly viscosity and density).

### 5.1 A Marine Pollution event

In the maritime corridors, we can found a very heavy traffic of tankers and others cargos. In these zones, like the Galician or Brittany coasts, the probability of an incident (collisions, accidental and operational spills, etc.) is very high.

During an oil spill event is essential to characterise the oil beached on the coast in order to find out if this pollutant comes really from the sunken vessel or it comes from an illegal operational release of oil. In the recent Prestige spill, unfortunately, some samples obtained from different beaches and oiled birds didn’t come from the Prestige tanker.

In the very short term after the spill, during the first week, the authorities in charge of response doesn’t need a very accurate approach of the oil drift forecast. Usually all the efforts are focused to the coordination between responders and decision-makers rather than to the recompilation of spill data. In this short period of time, the forecasting system has to be robust, efficient, in spite of the lack of input data. Afterwards, the resolution of the forecasting system could be improved by means of assimilation of data (aerial surveillance, oil composition, etc.).

## 6 Conclusions

An experimental work has been described. Some oils have been tested in laboratory in order to assess the weathering processes. This oil database was used as input and calibration of an oil weathering module included in the forecasting system.
As well responders and modellers have to know the threshold values of some processes like evaporation, emulsification or vertical dispersion. The formulas of the evolution of rheology have been validated and calibrated with the available data but further experimental work will be done on the assessment of the chemical-kinetics.
It’s important to note that the updates of the existing forecasting system have to be done without lose of its operativity.

The Prestige spill represents a unique opportunity to test this updates: during the crisis, the main concern was the knowledge of the composition of the pollutant. Nowadays, there is an overflow of information related with the accident, as well slicks drifts and weathering of the pollutant. Further analysis will be done in order to test the forecasting system.

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