A NUMERICAL METHOD FOR THE CALCULATION OF AN OIL SPILL SPREADING

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ABSTRACT
A revision to mathematical and numerical to use in order to determine the trajectory and growth of a spill of petroleum in water was done. A numerical model was compared with some field data (11,12) and mathematical models. This comparison allowed us to determine the technical viability of using the numerical model for the prediction of the spill and evaluating the grade of adjustment of the studied models.

INTRODUCTION
The prediction of a spill of petroleum is mainly composed of two parts: 1) the trajectory of the slick of petroleum, and 2) the evaluation of the characteristics of the slick (spreading). Both the trajectory and spreading are associated with the hydrodynamics of water. Additionally, the spreading is regulated also by the physical and chemical characteristics of the petroleum and water.

Some authors have considered a spreading of the slick as an independent phenomenon of the hydrodynamics of the water, this simplification is used as base for the modeling of the behavior of spills of petroleum (2,3,4,15). This method does not always supply good output. This circumstance motivated the elaboration of this work, which compares the outputs of the correlations generally used with the numerical model and experimental data (11, 12).

THEORY
The theory of modeling of oil spills could be divided in two parts: the first, associated to the spreading that is used to determine the size of the slick (area and thickness average). It is supposed that in this case the form of the slick is a circle and does not consider the hydrodynamics effect.

The second part associated to the numerical methods employed to predict the size and trajectory of the oil spill by the computational fluid dynamics.

Spreading
The spreading is the key for the estimate of the evaporation, the dispersion, the environmental impacts and in general for all the physical, chemical and biological processes (17). However, these equations in order to represent the spreading (2,3,4,13,15), do not reflect several of the observations, such as: 1) the growing of the skill, with heterogeneous thickness; 2) the reduction of the spreading for the change of the viscosity; 3) the breakup of the skill in small patches; 4) the dependence of the spreading of the conditions of discharge; and 5) the effects of the hydrodynamic in the size final (1).

In general, the models that explain the spreading of the petroleum in water were based on the same work (Fay's expression) (3), in order to modify it or validate a new function without achieving important advances. The Fay's correlations follows having validity to explain the spreading, due to the theoretical and experimental support. Next, the models of spreading employed in this work are described.

Model of Blokker
The model (2), expound the following mathematical formulation, where the radius of the slick is proportional to the
initial volume of the spill and the properties of the petroleum, therefore:
\[
R_{o} = \left[ R_{0}^{3} + \left( \frac{3KtV_{o}\rho_{o}}{\pi\rho_{w}} \right) (\rho_{w} - \rho_{o}) \right]^{\frac{1}{3}} \quad (1)
\]
where \( K \), is a constant of Blokker equal to 216 cm³/gr-s, \( \rho_{o} \) and \( \rho_{w} \) are densities of oil and water, respectively, in gr/cm³, \( t \) is time in s, \( R_{0} \) is the initial radius of slick in cm, \( R_{o} \) is the radius in cm and \( V_{o} \) is the initial volume in cm³.

**Model of Fay**

For Fay the slick of petroleum passes for three stages, in which each force of spreading is balanced with a force retardant (4). These stages or regimes of flow are the following:
- Regime of gravity- inertia: called inertial stage.
- Regime of gravity- viscosity: called viscous stage.
- Regime of superficial tension- viscosity: called superficial tension stage.

The forces of gravity and superficial tension are balanced by the inertial forces in the interior of the slick and by the friction forces on the boundary. The inertial force diminish with the time due to mass loss and thickness of oil while the friction forces increase due to the emulsification. In this way, the superficial and potential energy diminish with the speed of spreading is associated with a process of production of energy and each force retardant with a process of dissipation of energy.

A petroleum slick generally passes by these three regimes, however, when spilled volume is small, the viscous or superficial tension regime could be dominant (8).

In order to determine the growth of the slick in each of the stages, coefficients of spreading should be used, according to tables 1 and 2.

**Table 1. Laws of spreading**

<table>
<thead>
<tr>
<th>Regime</th>
<th>One - dimensional</th>
<th>Two - dimensional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inertial</td>
<td>( L = K_i (\Delta g A t^2)^{1/3} )</td>
<td>( R = K_{i0} (\Delta g V t^2)^{1/6} )</td>
</tr>
<tr>
<td>Viscous</td>
<td>( L = K_{v0} (\Delta g A t^{1/2} / \mu^{1/2})^{1/3} )</td>
<td>( R = K_{v0} (\Delta g V t^{1/2} / \mu^{1/2})^{1/6} )</td>
</tr>
<tr>
<td>Surface Tension</td>
<td>( L = K_s (\sigma^2 t^2 / \mu^2)^{1/3} )</td>
<td>( R = K_{s0} (\sigma^2 t^2 / \mu^2)^{1/6} )</td>
</tr>
</tbody>
</table>

where \( g \) is the acceleration of gravity in m/s², \( A \) is the volume of oil per unit of longitude, \( \mu \) is the cinematic viscosity, in m²/s, \( \sigma \) is the spreading coefficient or superficial tension, in dyn/cm, \( \rho \) is the density of water in kg/m³ and \( V \) is the initial volume of petroleum in m³.

**Table 2. Spreading coefficient**

<table>
<thead>
<tr>
<th>Regime</th>
<th>One - dimensional</th>
<th>Two - dimensional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inertial</td>
<td>1.5</td>
<td>1.14</td>
</tr>
<tr>
<td>Viscous</td>
<td>1.5</td>
<td>1.45</td>
</tr>
<tr>
<td>Superficial tension</td>
<td>1.3</td>
<td>2.30</td>
</tr>
</tbody>
</table>

The final thickness of the slick is the mono-nuclear layer that no upper to \( 10^{-2} \) or \( 10^{-3} \) cm, due to the fact that the last fractions are evaporated and the spreading coefficients become zero, to increase the superficial tension between the petroleum and the water (8).

In simple form the final area of a spill could be valued by means of the following equation (4):
\[
A = 10^{-5} V^{0.75} \quad (3)
\]
where \( V \) is the initial volume of the slick in m³.

The limits for the regimes of spreading respond to the following conditions (8):
- For the gravitational regime, the thickness \( h \) should be equal to:
\[
h = \left( \frac{\sigma}{\rho g \Delta} \right)^{\frac{1}{2}} \quad (4)
\]
- For viscous regime, the thickness \( h \) should be equal the following:
\[
h \geq (\sigma t)^{\frac{1}{2}} \quad (5)
\]

**Model of Mackay**

The spreading is governed mainly by the balance between the gravitational and of viscosity forces (15), and it could be calculated by means of the following equation:
\[
\frac{dA}{dt} = K_{A} \left( \frac{V}{A} \right)^{3/2} \quad (6)
\]

where \( A \) is the area of oil slick in m², \( t \) is the time in s, \( V \) is the initial volume in m³ and \( K_{A} \) is a constant equal to 150 in s⁻¹ (15).

Some comparisons with field data show that upon employing the constant volume, the final area is over-estimated in two orders of magnitude. Therefore, it should use the constant volume only during the first days of simulation. In order to estimate the final area of the spill, it should use 50% of the initial volume (18).

**Numerical Model Proposal**

The equations of conservation that describe the flow could be represented through the following general equation (16,21):
\[
\frac{\partial}{\partial t} (\rho \phi) + \nabla \cdot (\rho \vec{v} \phi) = \nabla \cdot (\Gamma_\phi \nabla \phi) + S_\phi \quad (7)
\]
where \( t \) is the time, \( \phi \) is any dependent variable, \( \vec{v} \) is the velocity vector, \( \rho \) is the density, \( \Gamma_\phi \) is the transport coefficient of the dependent variable, and \( S \) represents the source terms per unit of volume.

The dependent variables considered as well as their associated transport coefficients result in the continuity, the momentum, the conservation and the turbulence equations (see table 3). In this table, the symbols \( \vec{u} \) and \( \vec{v} \) are the speed components in the directions x and y respectively; \( C_p \) is the concentration of the petroleum in kilograms per unit of volume; \( k \) is the turbulent kinetic energy, and \( \varepsilon \) the dissipation rate of the kinetic energy; \( \mu_l \) is the laminar dynamic viscosity, \( \mu_t \) the turbulent dynamic viscosity and the sum of the laminar and turbulent viscosities are defined as the effective dynamic viscosity\( \mu_e \), \( \rho_0 \) is the product of the density of the continuous
medium and the diffusivity of the petroleum in water in m/s²; \( \sigma_k \) and \( \sigma_\varepsilon \) are the empirical diffusion coefficients employed in the turbulence model.

**Table 3. Coefficients of transport for each variable**

<table>
<thead>
<tr>
<th>Equation</th>
<th>( \phi )</th>
<th>( \Gamma_\phi )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuity</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Momentum</td>
<td>( U, v )</td>
<td>( \mu_\varepsilon )</td>
</tr>
<tr>
<td>Conservation of petroleum</td>
<td>( C_p )</td>
<td>( \rho \alpha )</td>
</tr>
<tr>
<td>Kinetic turbulent Energy</td>
<td>( K )</td>
<td>( (\mu_i + \mu_t) / \sigma_k )</td>
</tr>
<tr>
<td>Dissipation speed</td>
<td>( \varepsilon )</td>
<td>( (\mu_i + \mu_t) / \sigma_\varepsilon )</td>
</tr>
</tbody>
</table>

**Advection**

The advection of a slick of petroleum on the water is due to the wind, the current and the wave's movement (1). The current could be modeled based on statistical data or by means of hydrodynamic models, in which the new versions consider the advection in real time (17).

The model to represent the advection is expressed as the sum of the effects of the speed of the tides, \( V_T \), the current, \( V_C \), the wind and the surf, \( V_{LS} \) (18,24), thus:

\[
V = V_T + V_C + V_{LS} + C_{10} U_{10} \tag{8}
\]

where \( U_{10} \) is the velocity vector at 10 meters above sea level per experimental factor, \( C_{10} \).

Both \( V_T \) and \( V_C \) are obtained from field data and \( V_{LS} \) is important when the slick is in the surf region (1).

**Diffusivity Coefficient**

For the calculation of the diffusion coefficient, the following expression (20) was employed. It was obtained based on the spreading theory (3,4,8), thus:

\[
\alpha = \frac{1}{2} \left[ g \frac{\Delta \rho}{\rho_o} V \right] \tag{9}
\]

between the first hour and the first week,

\[
\alpha = \frac{1}{2} \left[ g \frac{\Delta \rho}{\rho_o} V^2 \right] \tag{10}
\]

where \( \alpha \) is a diffusivity coefficient in m²/s, \( g \) is the gravity force in m/s², \( \Delta \rho = \rho_o - \rho_p \) is the difference between the oil and water densities in kg/m³, \( V \) is the initial volume in m³, \( V \) is the kinematic viscosity of petroleum in m²/s, and \( t \) is the time in s.

The diffusive coefficients (20) have been validated (4); by means of the comparison with numerous experimental data and theoretical work, starting from the equations of Navier-Stokes (8).

Some authors propose the use of diffusive coefficients (24); which are used in some work (1).

**Model of turbulence**

The \( k-\varepsilon \) turbulence model (7) was used. In that model the kinetic turbulent energy \( k \) and their dissipation rate \( \varepsilon \) determined the speed scale and lend of the turbulent movement respectively. The source terms for the conservation equations of \( k \) and \( \varepsilon \) are:

\[
S_k = (P_k - \rho \varepsilon) \tag{11}
\]

\[
S_\varepsilon = (C_{1k} P_k - C_{2k} \rho \varepsilon) \frac{\varepsilon}{k} \tag{12}
\]

where \( P_k \) is the production speed of \( k \). The turbulence viscosity is calculated by the local values obtained for \( k \) and \( \varepsilon \), thus:

\[
\mu_\varepsilon = C_\mu \rho \left( \frac{k^2}{\varepsilon} \right) \tag{13}
\]

The turbulence constants are in table 4 (10):

**Table 4. Constants for model \( k-\varepsilon \)**

<table>
<thead>
<tr>
<th>( C_\mu )</th>
<th>( \sigma_k )</th>
<th>( \sigma_\varepsilon )</th>
<th>( C_{1E} )</th>
<th>( C_{2E} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.09</td>
<td>1.0</td>
<td>1.314</td>
<td>1.44</td>
<td>1.92</td>
</tr>
</tbody>
</table>

**Boundary conditions**

For this case, the boundary conditions both for the bottom as well as for the free surface were defined.

- **Solid Surfaces**

  The condition of border for the solid surface, are due to the effect of friction, which have been included in the equations of quantity of movement, like a wind stress. This stress (19), employs the functions of a typical wall for flows with friction, and it basically consist to determined the boundary conditions in an external point of viscous surface, where the Logarithmic Law is valid and the turbulence could be considered in local equilibrium.

  For this point, to a distance \( \delta \) of the solid surface, the resulting speed to this surface is determined to:

\[
U_{res} = \frac{1}{k} \ln \left( \frac{E y^+}{} \right) \tag{14}
\]

where \( \kappa \) is the Von Karman constant equal to 0.435, \( E \) is a roughness factor equal to 9.0 for smooth surfaces and \( y^+ \) is defined thus:

\[
y^+ = \frac{U_t \delta}{\nu} \tag{15}
\]

where \( \nu \) is the cinematic viscosity and stress velocity \( U_t \) is:

\[
U_t = \left( \frac{\tau \rho}{\nu} \right)^{1/2} \tag{16}
\]

and \( \tau \) is the wind stress.

The boundary conditions for kinetic energy and its dissipation rate are obtained from:

\[
k = U_t^2 C_{1k} \frac{1/2}{k} \tag{17}
\]

\[
\varepsilon = U_t^3 / (k \delta) \tag{18}
\]

- **Free surface**

  The free surface yields the wind stress through an applied stress effort on the surface, so:
\[ \tau = C_d \rho_a U_{10}^3 \]  

where \( \rho_a \) is the air density, \( U_{10} \) is the wind velocity at 10 meters above sea level and \( C_d \) is the stress coefficient (23). This coefficient could be obtained by means of the following correlation:

When \( U_{10} \) is between 0 and 1 m/s:
\[ C_{10} = 0.5 U_{10}^{1/2} \times 10^{-3} \]  

When \( U_{10} \) is between 1 and 15 m/s:
\[ C_{10} = (0.8 + 0.065 U_{10}) \times 10^{-3} \]  

When \( U_{10} \) is larger than 15 m/s:
\[ C_{10} = 2.26 \times 10^{-3} \]  

**Estimated area**

The area is determined for each interval of time considering a certain minimal concentration of petroleum in each cell, by means of calibration of the model with experimental data.

This technique is approximate because, it depends of grid and of a minimal concentration of petroleum. However, a good calibration of the model allows to obtain an acceptable output. It is possible to make reasonable estimates of the area occupied by the skill, simply by considering a minimal concentration between \( 10^{-1} \) and \( 10^{-2} \) kg/m³. The expression for the calculation area is (1):

\[ A = \sum_n A_{n,c} \cdot C > 0 \]  

where \( A \) is a sum of the total areas in m², \( A_{n,c} \) is the area of the cell \( n \), which comply with the concentration criteria.

The average thickness is (1):
\[ h = \frac{V_R}{A} \]  

where \( h \) is the average thickness in m, \( V_R \) is the residual volume in m³ and \( A \) is the area of the slick in m².

**Coriolis Effect**

In this work, the model of Ekman is employed. The apparent force generated by the relative movement between the water body and the earth is represented by the following expression:

\[ \text{Coriolis force} = m \times 2 \Omega \sin \phi \times U \]  

where \( m \) is the mass of water, \( \Omega \) is the rotation velocity of the earth (7.3 x 10⁻⁵ rad/s), \( \phi \) is the latitude and \( U \) is the velocity of water.

**NUMERICAL SIMULATION CONDITIONS**

For the simulation bidimensional domain was utilized. It was of 1,000 x 350 m (350,000 m²) in the orientation East-West and North-South respectively, with a unitarian thickness.

In order to check the independence results of the division of domain several simulations were done with several numbers of cells (500, 1,750 3,750). A division of 50 cells in the East-West direction and 35 cells in the North-South direction was employed, because this was the best arrangement. It was also found that the relationship between the size of the cells in the East-West direction and North-South should be of 1 to 2, and that the size of the intervals of the domain should oscillate between 10 and 50 m.

It was observed that the results do not depend on the interval of the selected time; however, in order to compare the experimental and the simulation output intervals of time of about 300 s were employed.

The simulated spills occur in offshore conditions where the flow is free, for this reason, there are no boundary conditions to impede their flow. The beginning of the spill takes place near the West limit of the mesh (100 m from the boundary) and at mid point the half point (175 m) in the North-South orientation.

**METHODOLOGY**

Initially a wide bibliographic revision about the oil spill models was carried out, in order to predict their behavior, to classify and to determine their applicability; since, the use of some models require experimental or filed data not available.

The selected models were implanted in the PHOENICS code (Parabolic, Hyperbolic Or Eliptic Numerical Integration Code Series) (14); which is a code of Computational Fluid Dynamics. This code lets define the conditions of evolution of the slick of petroleum and at the same time resolves the equation of conservation (Eq. 6).

The methodology utilized of this work consisted of four fundamental stages (1). First, a base case was configured in which the conditions of simulation are employed the experimental data from a spill of 8.11 m³ (11). Second, varying only the initial conditions for spills of 2.06 and 3.02 m³ in order to evaluate the validity of the procedure. Third, an analysis of sensibility on the parameters that control the evolution of a slick of petroleum, such as: the area, the hydrodynamic and the diffusion coefficient were carried out. Fourth, the outputs obtained were evaluated with the proposed model and the correlations of spreading (6,22).

It was necessary to define the geometry of the domain where the spill occurred in order to monitor the evolution of the slick during their lifetime which requires an appropriate combination between the petroleum properties, the hydrodynamic conditions and the initial characteristics.

In order to determine the properties of the petroleum spilled secondary information from the Center of Environmental Technology from Canada (www.etcentre.org) was employed. The meteorology (11), the dynamic and circulation data (9) was combined to determine the hydrodynamic conditions. For the initial conditions, Fay’s spill criterions (3,4) were used in respect to the initial area, which said that an initial thickness of 2 mm, was observed by Fay for spills of less that of 30 m³.

**RESULTS AND DISCUSSION**

**Proposed Numerical Model**

Consider certain limit of normalized concentration to
determinate the area, based on the initial concentration of petroleum was necessary. At the beginning, the occupied cells for all the spill were considered by the black zone of spill (11). The cells occupied by a minor normalized concentration ($10^{-5}$ or $10^{-6}$) were considered as the sheen zone, for which there is not enough experimental evidence that allows to distinguish between the different zones and this small concentration could be result of numerical errors. In order to determine the limit concentration, several normalized concentrations were proved, which are introduced in Fig. 1.

**Figure 1. Estimated area for the base case**

In Fig. 1, the experimental data of the spill of 8.11 m$^3$ (11) is compared with the experimental correlation (12) and the output of the numeric simulation, in which several normalized concentrations are considered. This comparison allows to determine that for this case a normalized concentration equal to 0.01 is the better to represent the growth of the oil spill area.

According to previous data, the simulation up to 600 min was done to observe the behavior of the spill after the reports in the experimental data and to compare with the author’s experimental correlation (11,12). From the curves drawn, it is inferred that the proposed model is capable of predicting the evolution of the black area.

Using the evaluation methodology, a correlative factor of 0.95 was obtained. The differences between the observed and the calculated data were attributed at about 75% to the difficulties of the model in order to represent the test and about 25% to the random error of the experimental data.

Based on the presented output in Fig. 1, the elaboration of a compound function to calculate of the area was considered, for each the interval of time in the area was explained by a limit concentration (Fig. 2). This concept could be used in order to formulate an expression that allows to estimate the limit concentration based on the time when the experimental information is available.

In Fig. 3 (a, b, c, d), the evolution of the modeling spill for the base case is shown. The contours of the skill grow at the same time as the initial form becomes an elliptical form, as a result from the hydrodynamic effects. It is also show that the dimensions of the contours of a same normalized concentration grow to approximately 300 min. They later diminish, to the behavior illustrated by Fig. 1 (11).

**Figure 2. Estimate area with a composed function**

The elliptical form of the spill coincides with the observation (13) and the output of the numerical simulation introduced in the fig. 3. The proposed model describes the form of the skill without assuming that this is a circle, similar to some correlations (2,3,4,11,15) and in the majority of the numerical models (5,8,18,25).

Based on the described trajectory by the spill, it is not possible compare since the report data (11,12) does not include this information. However, the results of the proposed model allow have an idea about the trajectory and the morphology of the spill during the experiment.

**Comparison of the numerical model with spreading correlations**

The results of the experimental correlations (2,4) and the proposed model were compared with the experimental data (11). Fig. 4 shows the adjustment degree of the numerical model and correlations with experimental data. Those are detailed in Table 5. It could be inferred that under the employed conditions the proposed model is capable of predicting the behavior of the spill of petroleum, with an adjustment equal to 0.95 that is considered appropriate. On the other hand, the model can additionally predict the trajectory of the spill and the change in the principal hydrodynamic and meteorological parameters that are reflected in the area.

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1 The base case is corresponding a volume of 8.11 m$^3$, wind velocity of 5.1 m/s, equivalent current velocity of 0.015 m/s, initial area of 4,000 m$^2$. 

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Table 5. Evaluation of the area behavior

<table>
<thead>
<tr>
<th>Models</th>
<th>Adjustment</th>
<th>√MSEs</th>
<th>% MSEs</th>
<th>√MSEu</th>
<th>% MSEu</th>
<th>√MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propose (Base Case)</td>
<td>0.95</td>
<td>7,163</td>
<td>75.1</td>
<td>4,135</td>
<td>24.9</td>
<td>8,280</td>
</tr>
<tr>
<td>Fay (Viscosity)</td>
<td>0.81</td>
<td>13,979</td>
<td>96.5</td>
<td>2,658</td>
<td>3.5</td>
<td>14,229</td>
</tr>
<tr>
<td>Blokker</td>
<td>0.97</td>
<td>5,272</td>
<td>51.8</td>
<td>5,377</td>
<td>47.2</td>
<td>7,743</td>
</tr>
</tbody>
</table>

In Table 5 the Blokker’s correlation (2) has an correlative factor equal to 0.97 at 300 min, however, if the behavior of the spill is considered at 600 min, when there are not test data and the experimental correlation is used (11), only the proposed model is capable predicting the behavior of the spill (Fig. 4).

The good adjustment of the proposed model is shown at 295 min, when the experimental area of the black zone is equal to 55,714 m² and for the proposed model is equal to 60,000 m², for the Blokker’s and Fay’s (viscous regimen) models are respectively equal to 71,214 and 38,772 m². Now, the experimental area at 600 min is equal to 56,108 m², the proposed model area is equal to 51,800 m², where as for the Blokker’s and Fay’s (viscous regimen) models are respectively equal to 113,738 and 55,113 m².

The output of other models described in the paper (4,15) were not analyzed, because the results were out of the experimental data range (1).

CONCLUSIONS

A prediction model of oil spill based on the numerical solution of the equations of transport and conservation of mass was proposed to estimate the area, the thickness and the trajectory. The model is sensible to change from the principal parameters of simulation (hydrodynamic and meteorological conditions, the petroleum properties and the initial area of the spill). Through this model an correlative factor equal to 0.95 with the experimental data of the dark zone of the spill (11), both for their stage of growth, as their phase of decline was obtained. For this reason, it is concluded that the proposed model could be utilized in order to predict the behavior of the
petroleum spill for the experimental conditions.

A method for the estimation of the dark area of the oil skill was proposed. It is based on the sum of areas occupied by it and in a certain normalized limit concentration, which could vary between approximately 0.01 and 0.1, being 0.01 the more appropriate for the analyzed experiment (11,12). It is concluded that the proposed numerical model can predict the experimental behavior of the area for the studied case and the spreading correlations are not necessary.

Several empirical models about the evolution of the area of a petroleum slick (2,3,4,8,11,12,15) were compared with the field data (11,12) and only the Blokker and Fay- viscous regime models estimated the experimental area. Based on this, it is concluded that models could be used to estimate the dark area of the spill in their stage of growth, with an adjustment of 0.91 and 0.87, respectively.

However, they apparently can not represent the behavior of the black area in the diminished period, because the curves continue to grow. For this reason, it is inferred that at this moment the dominant regime is the superficial tension stage.

Additionally, the model of Fay- superficial tension regime was capable of predicting the behavior of the sheen area of the slick, with an correlative factor equal to 0.98 (1).

The current and wind speed cause a variation in the growth of the petroleum spill. This effect could be simulated by means of an equivalent current speed calculated based on the wind speed at 10 m over sea. For example, for the studied cases was found that a corrected factor of 0.003 is capable of integrating all the hydrodynamic and meteorological effects involved in the analyzed spills (11,12).

The most sensitive variables for the prediction of the studied oil spills on water are the equivalent current speed, the limit normalized concentration and the initial area (1).

The procedure employed in order to define the conditions of oil spill simulation is adequate, because this was used to predict the behavior of three experiments with correlative factor equals to 0.95 for two cases and 0.47. The difference for the third case was explained by the parallel current to the wind direction during the test, this effect still has not been incorporated in the numerical model (1).

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REFERENCES


