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Evaluation of Oil Spill in the Environment of Forno Port, Municipality of Arraial do Cabo, Brazil

Felipe Otavio Melo Jácome Gurgel[1], Paulo C. C. Rosman[2], and Marcos dos Santos[3]

1. Brazilian Navy, Brasil

2. Federal University of Rio de Janeiro, Brasil

3. Brazilian Navy, Brasil

Abstract: The present work deals with the need to establish the drift of an oil spill in the event of accidental spills in the port area of Forno Inlet in the municipality of Arraial do Cabo, providing subsidies to establish strategies for prevention and management of environmental impacts. It is emphasized that the city is embedded in a Marine Extractive Reserve and with a large part of its population, directly or indirectly, economically linked to marine activities. To develop this work, the Environmental Hydrodynamic Basis System, SisBaHiA®, was used through a Lagrangean transport model coupled to a hydrodynamic model. The results show that with usual North-East (NE) winds, Praia dos Anjos is the most affected. South-West (S-W) winds cause the spot to reach the Forno Inlet, Ponta d'Água e Porcos Island and with weak winds, the contaminant is over the tide domain.

Key words: Lagrangean model, oil split, SisBaHiA®, Forno Port

1. Introduction

The municipality of Arraial do Cabo, located on the east coast of the State of Rio de Janeiro has relevant social, economic and environmental importance due to tourism, fishing, and port activities. The port areas have a major concern oil leak.

The general objective of this work is to evaluate, through simulations of a hypothetical accident, the results of the oil spot drift by means of a Lagrangian model in the functions of the local barotropic forks, creating subsidies to the decision makers in the response actions in the Arraial do Cabo Inlets (ACI).

2. Material and Methods

In this study we used the Environmental Hydrodynamic Basis System, SisBaHiA® in Portuguese, which is a professional system of computational models of the Federal University of Rio de Janeiro [1].

The Lagrangean model is ideal to simulate the transport of scales that may be floating, mixed or occupying only one layer in the water column, making it more suitable to simulate the drift of contaminant stains or feathers, small in relation to the domain of the hydrodynamic model or that show strong gradients [2].

The transport of a contaminant mass is simulated by the movement of released particles that are advected by the currents computed through the hydrodynamic model in the Lagrangian model. It is dedicated to observing the trajectory of the particle, as opposed to the observation of the movement.

The modelling domain of the present study covers the surroundings of Forno Port, which are the ACI, including the islands of Porcos and Cabo Frio, the beaches of the Anjos, Forno and Lighthouse between latitudes 22º 57, 7'S and 23º 00,19'S and longitudes 041º 58,7'W and 042º 01,2'W.

Corresponding author: Felipe Otavio Melo Jácome Gurgel. M.Sc.; research areas/interests: oil split, surf zone hydrodynamics and coastal engineering for environmental enhancement. E-mail: fo.gurgel@gmail.com.

The largest vessel authorized to dock at Forno Port has a gross tonnage close to 40,000 metric tons. Ships of this size have the capacity to carry up to 1,500 tons of fuel. This volume is distributed in ten smaller tanks interconnected by networks [3].

Considering that the merchant's vessel owns about 90% of its nominal capacity (normally do not operate with their total capacity) which reduces the total value of oil to 1,350 tons. Dividing this value by the number of tanks that operate equalized to maintain the stability of the ship we have: 135 tons per tank.

The scenario would be the oil spill on the sea, due to structural failure of the tankers of the bulk carriers in the final docking or initial de-engagement phase. Simulating the disruption of only one tank, total value dumped at sea would be 135 tons of fuel.

For simulating a situation of leakage, we will use the total value of 135 tons or 136.67 m^3. The oil can take up to twelve hours to be poured over the sea [3]. However, in a real case, some measures to combat the malfunction may be adopted.

Measures such as the internal transfer of the fuel oil from the damaged tank to another onboard tank, closing all the embankments on the deck forming a containment dam to prevent oil spilling on the sea and applying absorbent on the oil coming out of the sighs of the tank can reduce the expected volume of the contaminant that will be spilled over the sea.

The effluent flow is defined by the total volume of the leak (136.67 m^3) and the total spill time (t) in 12 hours or 43,200 seconds. Following is other input data in the model: source coordinates (UTM) X = 806111.68 and Y = 7456261.50; effluent concentration = 987.7 kg/m^3; total volume of spilled oil = 136.67 m^3; spill time = 12 h and effluent flow = 0.00316 m^3/s.

The Lagrangean transport model in SisBaHiA® has two types of boundary conditions. The first is when the particle that crosses the segment of the open frontier, leaves the modelled domain and is lost. The second is when the particle reaches the coast and returns to the middle and may or may not suffer mass loss.

In the present work, the particle returns in the middle but has a portion of its mass absorbed in the stretch of the boundary reached. The absorbed fraction is given by the absorption coefficient along the boundaries of the earth with values between zero and one.

The modeler can specify a different value for each land border node, depending on the type of coast. In this paper, the following absorption coefficients (AC) were used in accordance with the Coastal Sensitivity Index (CSI) applied in the Environmental Sensitivity Chart to the Santos Basin Oil Spill (Barra de São João to Itaipuaçu Beach-RJ) [4]. Type: CSI 2 (waterproof substrates) AC = 0.01; CSI 3 (semipermeable substrates with low penetration) AC = 0.05; CSI 4 (substrates of medium permeability with moderate penetration) AC = 0.15 and CSI 6 (high permeability substrates with high penetration) AC = 0.3.

The CSI 2 are impermeable, medium slope substrates exposed with smooth, medium sloping rocky slopes in exposed sedimentary rocks located on the Cabo Frio and Porcos Island, usually subject to waves of one or more meters high with strong currents of the tide, and smooth artificial structures (commercial wharf of Forno Port).

The CSI 3 are semipermeable substrates with low penetration. The Atalaia beaches were considered medium to fine sandy beaches, with medium wave reflection, with a 3 to 5 degrees wide beach surface gradient and well-selected and generally compact sediments (bottom hard).

The CSI 4 are substrates of medium permeability and moderate penetration. In the region of study, the beaches of the Anjos and Forno (thin to medium sand beaches, sheltered) with the slope of the beach face between 3 and 10 degrees and partial burial of the oil.

The CSI 6 are substrates of high permeability and high penetration. They make up most of the continental coastline as the coast of Atalaia hill and the Forno Inlet, in addition to the breakwater of Forno Port. They are mostly rocky fragments with large steep areas.

The above values are empirical and aim only to differentiate stretches of coast with different degrees of permeability. If there is a need to perform prognostic simulations with greater quantitative accuracy, a careful analysis of the values that will be applied to different stretches of the coast is prudent.

Another input data in SisBaHiA® are the oil decay curves that differ according to their physicochemical properties of each type of hydrocarbon.

The oil decay curve was obtained from the characteristics of the fuel used by bulk carriers that docked at Forno Port, using the Automated Data Inquiry for Oil Spills (ADIOS2). The initial area of the stain was defined by mechanical scattering based on the models proposed by Fay's Theory used in ADIOS2 software. It is assumed that the stain is circular and that the thickness of the oil in the stain is homogeneous.

Forty-five days were simulated from July 19 to September 2 of 1999. The Lagrangian model was coupled to the 3D hydrodynamic model, the contaminant was simulated with a depth of 10 cm from the free surface. Further details of the hydrodynamic model [5].

3. Results and Discussion

The results were obtained in the deterministic form which is a general-purpose model for transport simulation. This type of modelling is especially suitable for simulations of oil spills, instantaneous or by a defined period. This form will be used in 3 scenarios, in extreme situations and well characteristic of the region of study that are the typical north-east (NE-E), south-west quadrant (S-W) winds, and a weak wind situation. In a situation of a cold front, winds with intensity around 7 m/s arriving at 8 m/s and direction ranging between 230º and 270º. Syringe tide filling. Maps (Figs. 1-3) were prepared for the following.

With NE-E winds, characteristic of the site studied, the winds were with intensity around 6 m/s. Maps (7, 8 and 9) were drawn for the following instants after the leak: two hours, six hours and sixteen hours.

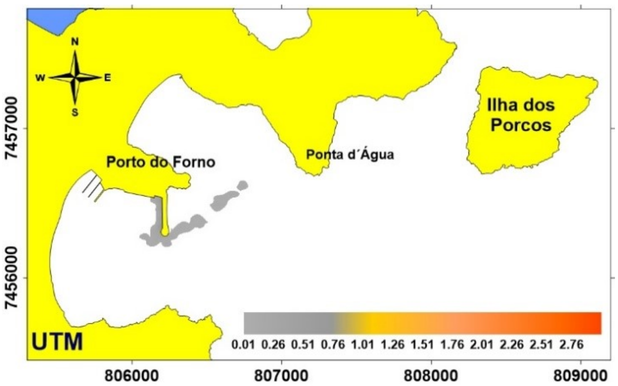

Fig. 1 The drift of the oil spot after one hour is divided into two parts. Part of it is between Oven Port and jetty. The other party wins the jetty of the Oven Port bypassing it and heads for Water Tip. The thickness of oil stain (mm).

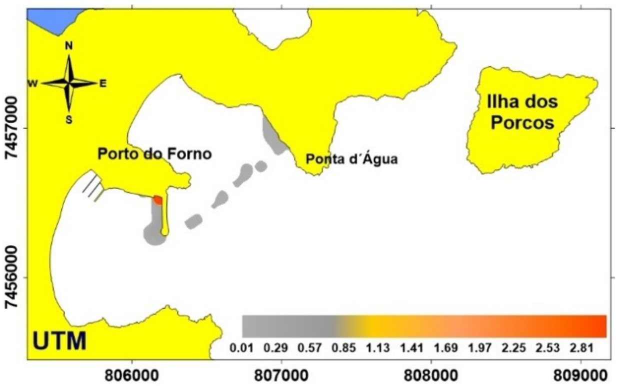

Fig. 2 After six hours the spot reaches Water Tip, but much of the oil is retained inside the port.

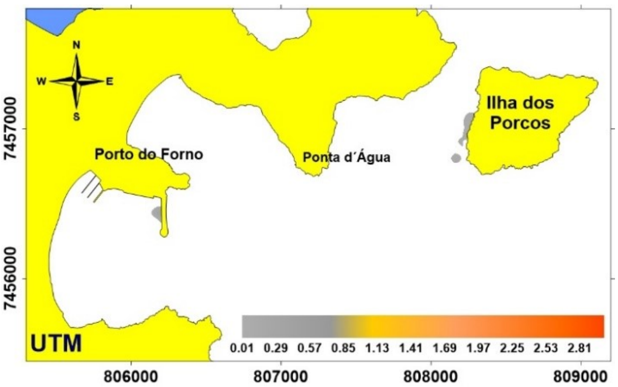

Fig. 3 After sixteen hours from the initial time of the spill, the spot reaches the Water Tip and drifts to the Pigs Island NE. There is also a reduced portion of the oil concentrated between the main port quay and the mole.

The spill simulations demonstrated, by the deterministic model that with SW quarter winds, the oil is concentrated largely within the port area at an initial time. The other part is directed towards the end of the rockfall, bypassing it and following towards the Ponta d'Água (Fig. 1). In Fig. 2, the oil reaches the rock and starts to move to NE due to the wind.

In Fig. 3, sixteen hours after the initial time of casting and four hours after its completion, some of this oil is directed to the Porcos Island drifting to NE. In all cases presented, a considerable portion of the oil remains between the quay of the port and the jetty.

With low winds, there is a small dispersion of the oil on the surface of the water during the 12 hours of simulation. The stain moves according to the tide.

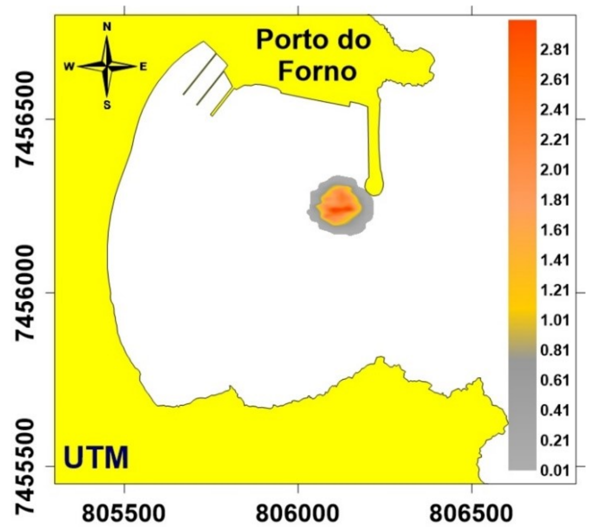

Fig. 4 Plot the situation after two hours from the start of the spill. The instant depicts a period of calm. The thickness of oil stain (mm).

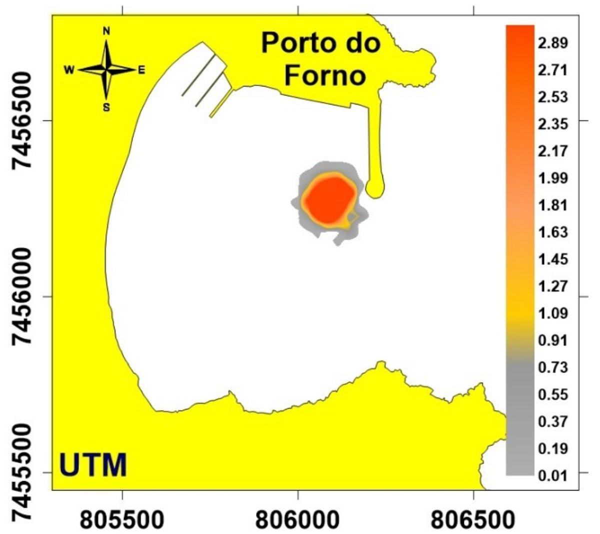

Fig. 5 Eight hours after the beginning of the leakage, the stain remains with the same fundamentals of the previous figure suffering only influence of the tide.

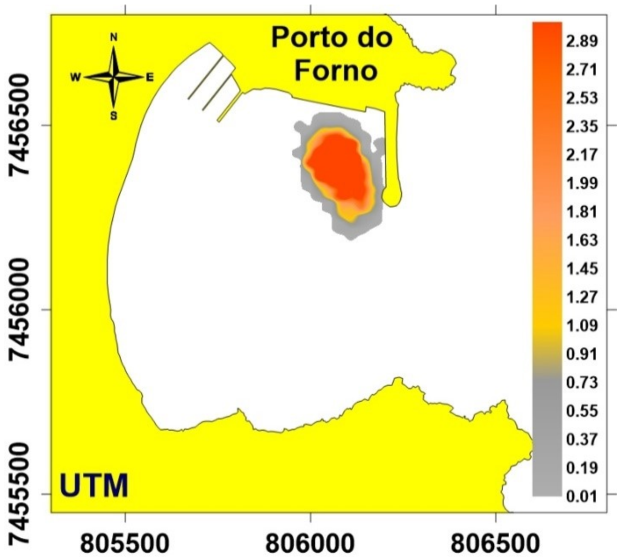

Fig. 1 After twelve hours the spot assumes the north direction, reaching the breakwater of the port. It is noticeable the increase of the perimeter of the spot with its dispersion due to the increase of the intensity of the wind in the place.

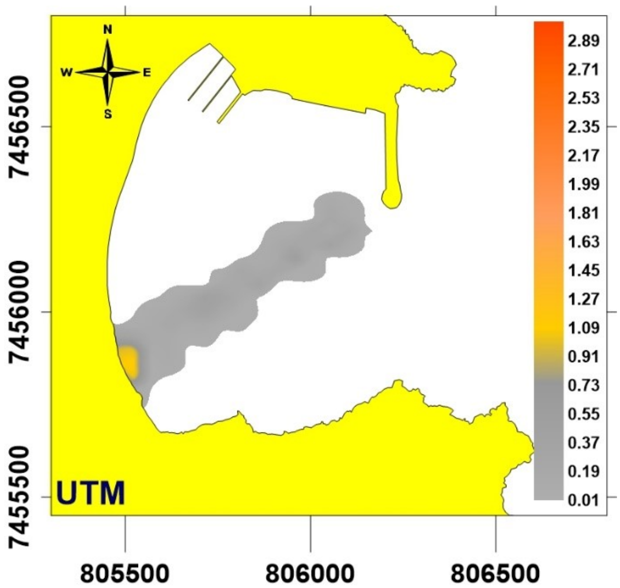

Fig. 7 A Deterministic model for oil leakage (136.67 m³) with winds from the N-E quadrant. In the figure above, it is observed the strong influence of the wind in the displacement of the spot after 120 minutes of the leak. The thickness of oil stain (mm).

From the initial time to 8 hours after casting, the stain only increases its perimeter and its thickness decreases with time. It is only after 12 hours (Fig. 6) that the spot touches the mole of the Forno Port due to the wind performance, even with low intensity (1 m/s

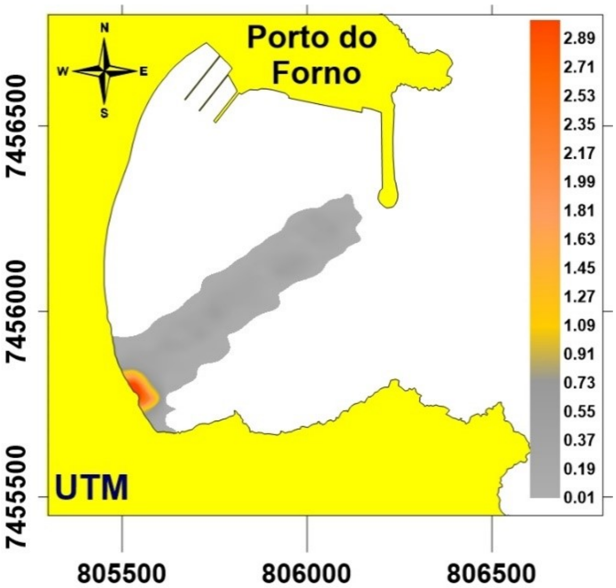

Fig. 8 After six hours the displacement of the stain remains the same as the previous figure. There is only an increase in oil concentration on the coast.

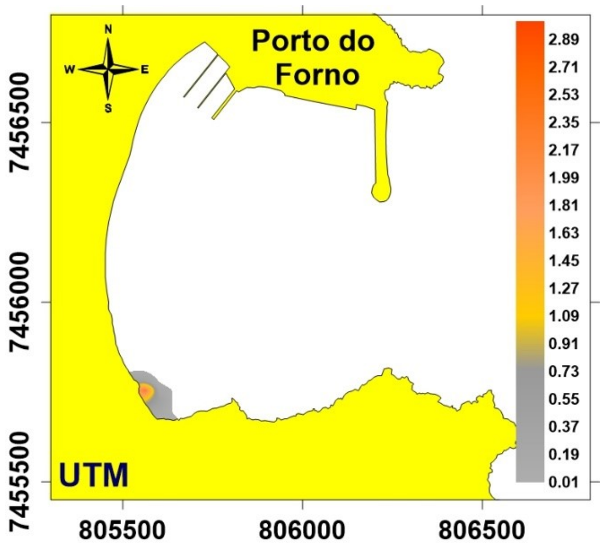

Fig. 9 After sixteen hours of the initial time and four hours after the end of the leak but remains with some concentration on the coast.

in the 180º direction), at the final moments of the simulation.

It is clearly seen that the winds from the N-E quadrant, prevailing good weather winds, tend to derive the oil stains to Anjos Beach. The contaminant reaches the southern flank of the beach, about 120 minutes (Fig. 7) after the initial time of the simulated spill.

This scenario remains for the entire period. Wind tends to be the main factor in oil drift to Anjos Beach (Fig. 8). After 16 hours (Fig. 9), the oil remains on the beach even after four hours from the end of the leak.

4. Conclusion

The importance of hydrodynamic modeling in studies and projects is unquestionable because of the complexity of the natural water environment, especially the estuaries and the adjacent coastal zone of the river basins. It allows a dynamic view of processes in these complex environmental systems.

We have verified that the oil in the condition of a floating contaminant moves with the intensity of the surface currents strongly sensitive to the effects of the wind.

The main consequences of the spill in the ACI, regarding socio-economic activities for the case studied, imply interruptions in the activities of the port, the Fishermen's Marina, local fishing activity, sightseeing and diving activities. The temporary cancellation of such activities causes serious damage to the local economy.

In relation to environmental impacts, such an accident would have undesirable effects on four compartments, namely: beaches, rocky shores, water column, and benthic environment.

In the face of possible socio-environmental damages resulting from an oil leak in the ACI, it is necessary that those responsible for it to comply with current environmental and safety standards.

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