

STUDY OF THE SPREADING OF OIL SLICKS ON SPOTS LOCATED IN THE VITORIA BAY CHANNEL AND RISK ASSESSMENT OF OIL REACHING ARIBIRI RIVER MANGROVE SWAMPS IN VITÓRIA BAY - BRAZIL

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RESUMO

O objetivo da pesquisa é obter maior conhecimento a respeito do movimento de manchas de óleo na Baía de Vitória, no Estado do Espírito Santo, Brasil. Ele enfoca a trajetória seguida por manchas de óleo sob as condições ambientais e avalia a influência de variáveis meteo-oceanográficas (vento, correntes de maré, etc.) no seu espalhamento horizontal, por meio de experimentos de campo e pela aplicação de modelo numérico 3D lagrangeano de trajetória de partículas. No presente trabalho foram realizados alguns derrames hipotéticos acidentais no canal do porto usando-se a técnica de traçadores. O aumento longitudinal e transversal da pluma de traçadores foi medido ao longo do canal utilizando barcos equipados com GPS. Fotografias e filmagens realizadas durante os experimentos de campo ajudaram no estudo do comportamento da pluma. Os experimentos de campo e as simulações numéricas mostraram que um derrame acidental de óleo na Baía de Vitória pode vir a atingir o manguezal do rio Aribiri e impactar a região.

ABSTRACT

The objective of the research is to achieve a better knowledge about oil patches behaviour existing in Vitoria Bay, in Espírito Santo State, Brazil. It aims to analyse the path followed by oil patches under environmental conditions and also to assess the influence of meteorological and oceanographic variables (winds, tidal currents, etc.) on their spreading, by means of field experiments and application of a 3D numerical Lagrangean dispersion model. In this work a few accidental spills taking place in the central part of the port channel were simulated using tracer technique. The longitudinal and transversal stretching of the plume was measured along the channel using a number of boats equipped with GPS. A set of photographs and film shootings taken during the field experiments helped to study the plume's behaviour. Field experiments and numerical simulations showed that an accidental oil spill in Vitoria Bay may reach the Aribiri mangrove and cause impact to the area.

Palavras-Chave: manchas de óleo, águas costeiras, derrame de óleo, experimentos de campo, modelo numérico 3D lagrangeano, manguezais.

1. INTRODUÇÃO

The booming oil and gas exploration and production activities on the Espírito Santo State shelf have been demanding specialised ports to supply the necessary equipment and materials and available areas to store the oil and gas produced. The Vitoria Bay port area has already been used for such purposes and there are plans to enhance its capabilities by the construction of another port. However the risk of accidental oil spills in the region poses a threat to the contamination of many sensitive areas as beaches, mangroves and swamps.

This motivated the realisation of three field experiments in the Vitoria Bay channel, under different environmental conditions and locations in the channel. The influence of tidal currents and wind on the spreading of the plume of the tracer were analysed as simulations of oil spill, using tracer technique to check whether it would reach the Arabiri river mangrove area .

2. FIELD EXPERIMENTS

In order to prepare the personnel involved and avoid unnecessary expenditures concerning materials and

equipment, two preliminary experiments were set out in the Vitoria Bay channel.

2.1 First Field Experiment

The first experiment was carried out on the 3rd October 2001. The main objective was to check the tracer's patch behaviour along the first minutes of the flood of a spring tide in the middle of the channel near the strait in the vicinity of the Morro do Penedo (Penedo hill) (Figure 1).



Figure 1 – Panoramic view of the Vitoria Bay.

Floating materials were used to simulate an oil spill. An operator equipped with a GPS (global positioning system) device had been instructed to record four extreme points on the patch contour which would help to map the plume. The pilot had to navigate carefully around the plume keeping a distance of approximately 3m away from the plume in order to disturb the spreading of the tracer plume.

At 10:42 a.m. at the day of the experiment, fifty-four floating materials were thrown in the channel and seven minutes later the GPS operator began the recordings. From the top of different buildings near the channel film shootings and photographs were taken.

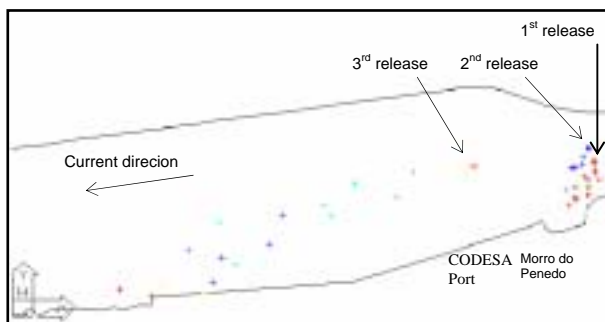


Figure 2 - Plume paths relative to the three releases for the 1st experiment.

The patch stretched rapidly and took an almost perpendicular path relative to the channel centre line straight away to the left side (Figure 2). Twenty-seven minutes later the floating material had reached the region of the CODESA port. Then the material was collected and another release was carried out using the same material. Forty minutes after the first release, the second release was made, but this time the tracer releasing location was a little ahead in the flow direction. The tracer was carefully placed in the water in order not to disturb the initial dispersion.

The plume behaviour was similar to the previous one. However, the path taken by the plume was less skewed. Thirty-five minutes later the material reached the channel left side. The material was collected and released once again approximately 220m ahead of the of the second release spot.

The plume spreading followed the same pattern as the previous two releases. The longitudinal stretching was more intense than the transversal one and the path was less skewed and longer.



Figure 3 - Floating material used for the 1st experiment.

Wind data obtained from weather stations in the region showed that prevailing northerly winds especially from the northeast were around 30 km/h during the experiment. This explains the skewed path taken by the patch through the experiment.

2.2 Second Field Experiment

On the 19th January 2002 an oil spill was simulated during an ebb period of a neap tide. The location chosen was near the Flexibras port. An anemometer was deployed in the area of the Viola Maio company on the channel side (Figure 4).

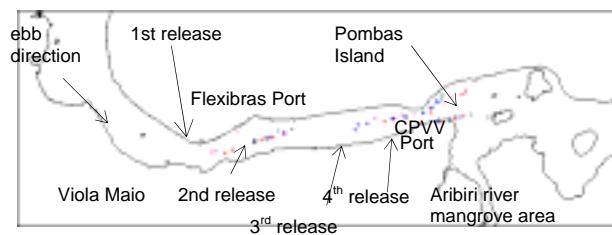


Figure 4 - Plume paths relative to the four releases for the 2nd experiment.

Two current meters were deployed near the release area to check the vertical velocity profile; one positioned at 1.5m and the other at 6m below sea level.

Four boats were used this time. One traveled ahead of the plume, one behind, one on the left and the last one on the right. GPS operators recorded the plume limits. Approximately one hundred floating materials were used this time.

Four releases were carried out along the channel following the ebb direction. By the time of the first release at 9:08 a.m. the flow was slow. The plume spreading following the first and the second releases took a skewed direction relative to channel centre line.

The third release took place about 500m from the collection point, in the centre of the channel. The current speed was very fast this time. The plume path followed almost a line parallel to the channel longitudinal line.

The fourth and final release was set in the channel strait near the Morro do Penedo (Penedo hill). As the traffic on the channel grew more intense the experiment had to be stopped thirty minutes after release. The material reached the Morro das Cobras and was then collected.

Anemometer data showed that south-westerly winds prevailed through the experiment and ranged 0.28-0.56m/s. Current meter data showed that current speed at 1.5m below sea level ranged 0.78-0.88m/s. The cloud spreading was greatly influenced by the wind for the first and second releases, taking a skewed direction relative do the ebb current direction.

2.3 Third Field Experiment

On the 2nd February 2002 a third field experiment was carried out in the Vitoria Bay Port channel. Another accidental oil spill was simulated in order to study the spreading of the patch and check a possible threat of contamination to the Aribiri river mangrove area.

The experiment was scheduled for two hours after the beginning of the flood period, when the flow would be strong enough to force the spreading along the channel. An Iroquois drogue was used to check the right time of the tide shift. Two current meters were deployed in the channel, in the vicinity of the release area, away from the ships and boats route, in order to check the vertical velocity profile. An anemometer was deployed on land at Praça do Papa (Pope Square) to record the wind behaviour during the experiment (Figure 5). Aerial photographs of the plume were taken from a helicopter in order to provide a less distorted view of the patch. Photographs were taken since the particles release and so on in a ten-minute time step through the experiment. Four boats were used to measure the patch limits through the experiment.

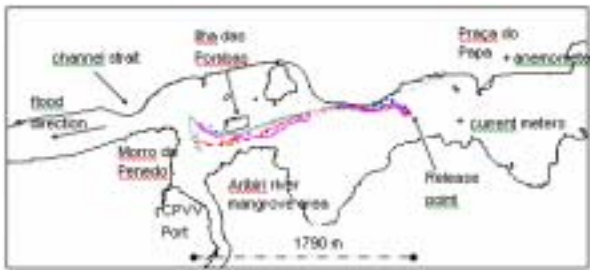


Figure 5 - Plume path relative to the 3rd experiment.

About thirty minutes after the release the patch almost reached the channel right edge near Clube Alvares (Alvares Club). Then, the plume changed direction heading the centre of the channel, crossing the usual track followed by ships and boats in the channel. Two hours after release, part of the plume had reached the region near the CPVV Port, a petroleum and gas exploration and production supply port, which is located near the Aribiri river mangrove area.



Figure 6 - Source-cell being lifted during the third field experiment.

Most of the particles headed the channel strait passing by the Morro do Penedo (Penedo hill) on its left, while a few remained in the CPVV Port vicinity. Thus, the

experiment was finished and the particles collected. The spreading proved to be so intense that only part of the particles could be recovered and returned to shore.

The experiment period was dominated by easterly winds, mainly from the southeast and only a very small period from the northeast about two hours after the release. Wind speed ranged 0.5-2.5 m/s, while current speed ranged 0.4-0.5m/s. The initial current velocity recorded by current meter # 1 deployed at 5.40m below sea level was about 0.10m/s, while current meter # 2 deployed at 1.60m below sea level was about 0.45m/s. Through the experiment current meter # 1 velocity increased gradually reaching about 0.40m/s by the end of the experiment, while current meter # 2, almost kept a constant value of 0.45m/s.

Although the behaviour of the patch spreading could be easily explained by the wind forcing at the beginning of the experiment, the change in direction occurred in the vicinity of the Alvares Club is still under investigation.



Figure 7 - Patch twenty minutes after release.

Data collected during this experiment associated with the channel bathymetry and tidal cycle data will be helpful to calibrate a three-dimensional particle-tracking model. This model uses a finite element quadrangular non-structured mesh, which can be refined in the channel region and coarse in the remaining area of the Vitoria Bay in order to save computing time. In fact, some primarily simulations using that 3D model based on scarcely existing data helped to predict some of patch behaviours for all the three experiments.

3. NUMERICAL SIMULATIONS

There were attempts to numerically simulate the path followed by the tracer plume during the third field experiments. The computational system named SisBAHIA was used for all the simulations. This system includes a 3D hydrodynamical model and a Lagrangian particle tracking one.

The best simulation result is shown in Figure 8. This was accomplished using real tide and wind conditions prevailing during the third experiment, except for the period 40 min - 1h 10 min after tracers release in which a northwesterly wind was applied to the plume. The amplitude of the random deviation was 0.5.

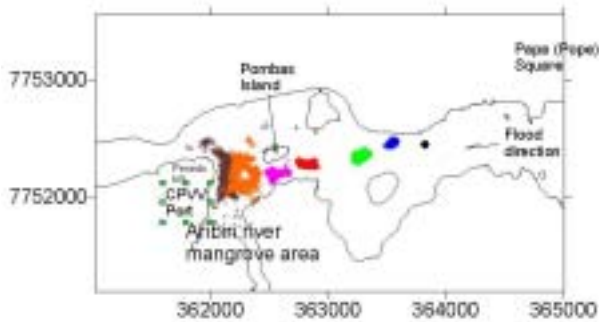


Figure 8 – Numerical simulation of the third field experiment.

4. CONCLUSION

Field experiments showed that wind direction and velocities are very important factors for the dispersion of contaminants on the Vitoria Bay water surface. These factors are most important during the initial and the last two hours of the tide period, when the tidal current velocity is slow. The wind tends to elongate the plume in its direction while lateral spreading remains very small.

The results of the field experiments showed that wind direction and velocity are very important factors for defining the arrival of pollutant floating materials to the Aribiri mangrove area.

The field experiment results could be used to help calibrate three-dimensional particle tracking models which should help to study several other oil spill scenarios, then assisting the environmental management of the region.

The floating materials used bear a density similarity to light crudes. The flow path behaviour of floating materials presenting different sizes were almost the same, except for the lighter ones that spread faster.

The utilization of GPS equipment associated with aerial photographs allowed the drawing of plume spreading maps.

Planning and execution for future similar field experiments in the region can take advantage of the experience acquired in the realization of those three experiments.

The experiments helped the understanding of the association between meteorological and oceanographic variables with the dispersion phenomenon. They also showed that oil spilled in the channel under similar environmental conditions prevailing during the third experiment, might possibly contaminate the Aribiri mangrove area.

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