MOHID OIL SPILL MODELLING IN COASTAL ZONES: A CASE STUDY IN BAHÍA BLANCA ESTUARY (ARGENTINA)

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1 INTRODUCTION

Half the world's production of crude oil is transported by sea (Clark 1992). A significant amount of oil is spilled into the sea from operational discharges, collision and grounding of tankers, well blow-outs and pipeline-breaks. Forty-eight percent of marine oil pollution is due to refined products and 29% to crude oil. Tanker accidents contribute 5% of marine pollution (Fingas 2001). Due to global economic growth, the demand for petroleum products is on the rise; hence one might also expect an increase in oil spills, especially along tanker routes. In Bahía Blanca estuary there are two monobuoys near the coast to discharge or load oil tankers. In recent years the international community has become increasingly aware of the risks due to major accidents occurring near populated and environmentally sensitive areas (i.e. the Prestige oil spill in 2002 (Galicia, Spain), the Hebei Spirit oil spill in 2007 (Taean, South Korea). There is also a growing need to ensure that health, environmental and safety issues are addressed as an integral part of social and financial development. Petroleum products that enter the marine environment have distinct effects, depending on their composition, concentration and the elements in the environment that are taken into consideration. Some effects can be related to transformations of the chemical composition of the environment and alterations in its physical properties, the destruction of the nutritional capital of the marine biomass, danger to human health, and changes in the environmental biological equilibrium.

The Bahía Blanca estuary coastal waters are noted for their heavy oil tanker traffic and, as a consequence, the risk of an oil spill occurring in these coastal waters is very real. The Presidente ILLIA oil tanker accident, in the middle part of Bahía Blanca estuary on May 19th, 1992, when the vessel due to strong SE wind spilled about 700 m^3 of crude oil over the sea water, is just one recent example of an accident with serious environmental consequences for the Bahía Blanca estuary coastal zone (Figure 1).

Numerical models are in principle able to predict the evolution and behavior of oil spilled in coastal zones, regardless of the atmospheric conditions, hence the vast interest in them. Mathematical modelling thus is a very powerful tool for management assessment after an oil spill accident, particularly for determining mitigating measures and to help monitor accident evolution. The latest information technologies have provided us with new tools that are capable of efficiently processing the great quantity of information needed to support accidental hydrocarbon spill management. These modelling tools are indispensable in the forecasting of oil slick evolution at coastal areas, as they allow measures to mitigate the negative impacts associated with hydrocarbon spills to be put in place. When integrated with other geographic information tools, the information provided by the model results can be analyzed easily and aid decision making.

Spill modelling is important to predict the trajectories and oil fate for devising suitable combating mechanisms. Hypothetical spill trajectories for different scenarios should be hindcast for the Bahía Blanca estuary, but as no real spill data exist to validate the model, results would still be uncertain. Concern exists about the 300 km^2 Bahía Blanca, Bahía Falsa and Bahía Verde natural reserve being hit by an oil spill event because of its sensitivity and ecological and economical importance (i.e. tourism).

Measurements of tides, currents, winds and hydrography close to the spill location were made available in order to validate and calibrate a hydrodynamical model for Bahía Blanca estuary. MOHID model was used to simulate trajectories (Leitão et al., Mateus and Fernandes, this volume). The present work is the first modelling study for a hypothetical oil spill in the coastal waters of Bahía Blanca estuary. The objectives of this study were: (i) to simulate hydrodynamics of the coastal waters; (ii) to generate a trajectory for a potential spill; and, (iii) to generate a training system to provide an oil spill response in Argentinian harbors and make decision support available in a short time to be applied to the contingency plans.

2 IMPACTS OF OIL SPILLS

The petroleum products that enter the marine environment have distinct effects, depending on their physical and chemical composition, and the environmental elements that are considered. The mechanisms of toxic action depend on the petroleum's characteristics. The toxicity of the various fractions of the pollutants is directly related to the distilled products, on a short-term basis, and related to the slow-action products, on a long-term basis. It is also related secondarily to the products degraded either biologically, through the action of bacteria, or through physical-chemical processes. Petroleum pollution can be detected through the modification of the environmental conditions and can be described by transformations of the chemical composition of the environment and alterations in its physical properties, destruction of the biomass nutritional budget or changes in the environmental biological equilibrium.

From the physical point of view, oil directly influences the marine environment, since gas transfer mechanisms are impaired by the presence of a pollutant layer on the surface. Self-purification processes are thus reduced. These processes can worsen by the increased oxygen consumption by growing micro-organisms, depending on the quantity of biodegradable organic matter present. This oxygen deficit could even create conditions for anaerobic life, giving rise to the death and disappearance of certain species and permitting the fermentation of organic residues.

From a biological point of view, the environmental effects of oil are varied and complex. While some are immediately obvious, others only manifest themselves after a long period. The degree of the effect is therefore different, whether in the animal or in the plant kingdom. In the case of crude oil, the volatile components and the aromatic compounds are the most toxic. In addition to possible direct intoxication resulting from the inhalation or ingestion of petroleum products, there is an indirect risk to humans from the consumption of certain marine animals (fish, crustaceans, etc.) that have been in close contact with the oil. The pollution's noxious effects can also be felt indirectly through its environmental and economic impacts; damage to biological resources (flora and fauna), affecting biodiversity; deterioration in seawater; shoreline quality and recreational waters, with negative effects on human and economic activities.

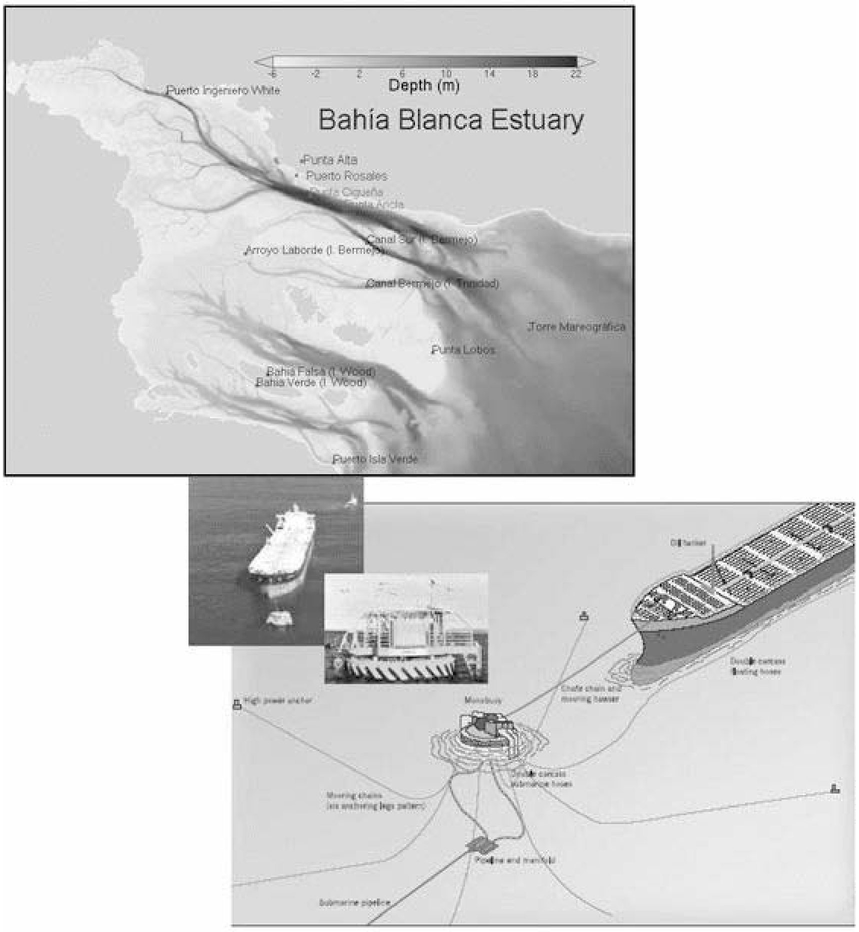

FIGURE 1: *Location of Punta Cigueña and Punta Ancla monobuoys, tidal gauges, bathymetry and single-point mooring system for Bahía Blanca estuary.*

3 CASE STUDY: MONOBUOY ACCIDENT MODELLING

In the middle of Bahía Blanca estuary, there are two monobuoys (Punta Cigueñas and Punta Ancla) where crude oil is loaded and discharged. The MOHID model was used to evaluate the fate of spilled oil under different wind conditions (NNO, SSO, NNE and SSE).

It is the first time that a simulation of these characteristics is performed in Bahía Blanca estuary and the results provide useful information to implement contingency plans and areas to guide the oil booms to another area could be considered, but require a discussion on the acceptance to sacrifice another area. The oil characteristics for the simulations were obtained from the typical NRN (Neuquen Rio Negro) oil composition, which is the type of oil loaded to the ships at the buoys (Table 1). For this experience it has been simulated an accidental discharge of 45 m^3 of oil type NRN (Table 1). The accident simulation starts at Punta Cigueña monobuoy (38°56'40.30" S and 62° 03'8.99" W) being subject to estuarine hydrodynamics and wind fields that play an important role in the oil transport processes. This accident simulation was performed to analyse their influence and also to test the surface oil slick transport model. The MOHID 2DH hydrodynamic model was used to quantify the current velocities in the coastal zone during the accident. Figure 1 shows the geographical extent, and the bottom topography (Pierini 2007).

The same hydrodynamical model configuration as applied in the case of bacterial pollution was employed. Figure 2 displays the instantaneous maximum tidal current velocities (during ebb and flood) at the accident area, produced by the calibrated and validated hydrodynamical model. The hydrodynamical model was used to calculate the tidal current velocities during the hypothetical accident period with the different wind scenarios. The wind directions (NNO, SSO, NNE, SSE) and intensities (average 10 $m\ s^{-1}$) used in the simulations were representative of the study area (Piccolo and Diez 2004). Figure 3 presents the spatial distribution of the oil with different wind directions. The wind clearly appears to have a significant influence on the oil transport process. The oil spill in Figure 3 can be seen floating along and over the coast, and out along to Principal channel. The coastal city of Punta Alta and Puerto Rosales harbor, lie near the oil spill.

- The region of Puerto Rosales Harbor, especially between the monobuoys, as well as the inner part of Bahía Blanca estuary, run a high degree of risk that increases during discharge or loading of tankers.
- The whole northern coast of the Bahía Blanca estuary, and especially the area to the east of Principal channel, including the Natural Reserve of Bahía Blanca, Bahía Falsa and Bahía Verde runs a high degree of risk.
- The Puerto Rosales area (near Punta Cigueña monobuoy) runs a high degree of risk with increasing winds from a SSE direction.
- The areas of Southern coast runs a low degree of risk which increases during periods with prevailing Northerly winds.

modelling could be taken a further step with the development of operational models that integrate meteorological models and wave models to force hydrodynamical models thus forecasting the hydrodynamical conditions during a possible event.

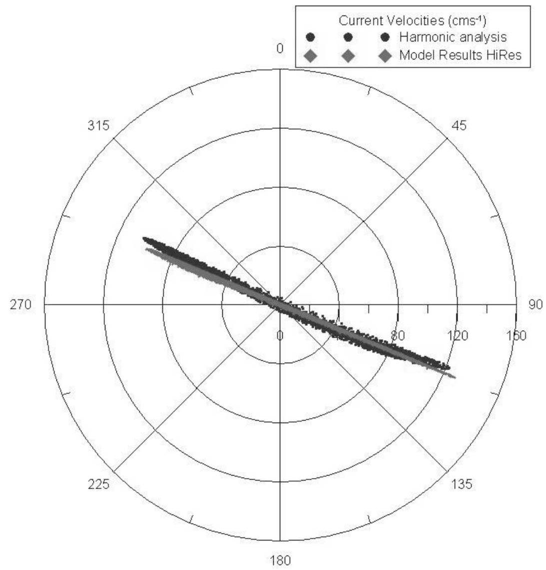

FIGURE 2: *Maximum tidal current velocities (during ebb and flood) at the accident area (Punta Cigueña).*

TABLE 1: *Properties of the oil type NRN (Source: OiltankingEbytem S.A., personal communication).*

Property	**Value**
Density (15 ºC)	844 kg m^{-3}
API	36.06
Water	0.05 %
Salts	35 grm^{-3}
Sulphur	0.40 gr %
Vapour Tension	2.91 lbm^{-2}
Viscosity (37.8º)	710 St
Pour Point	-9

In a precautionary approach, the MOHID model oil application for Bahía Blanca could help in defining management responses to an oil slick incident by identifying the areas where collection and protection operations would be most urgent. Moreover, in combination with socioeconomic information it could help defining a future integrated coastal zone management. It would be necessary in the future to improve the monitoring of the spills and to improve access to meteorological data in addition to an evaluation of a possible increase in the coastal observational network, to cover data gaps. Last but not least, we are greatly indebted to OiltankingEbytem S.A for their kind collaboration in this work.

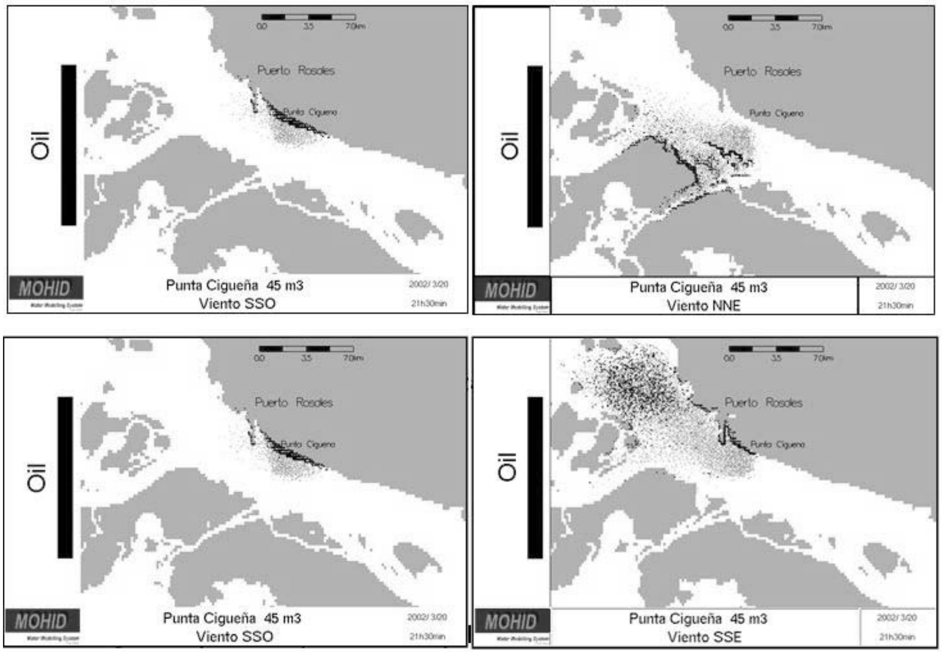

FIGURE 3: *Spatial oil spill distribution with different wind directions at the accident area (Punta Cigueña) and impact zones.*

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