Dynamic risk assessment of shoreline contamination from ships: integrating an oil spill model

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INTRODUCTION

Previously, pollution risks in coastal and marine environments were only quantified in a static mode, considering historical data, reference situations, and typical or extreme scenarios, in a planning stage.

The increasing predictive capacity of marine weather conditions and fate or behaviour of pollutants spilt at sea or costal zones combined with monitoring tools (e.g. vessel traffic control systems) provided the opportunity to develop an innovative methodology for dynamic shoreline risk quantification, integrating numerical metocean forecasts and oil spill simulations with the existing monitoring tools.

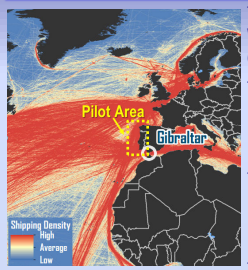
OBJECTIVES

The main purpose is to build a decision support system capable of quantifying variable shoreline risks of pollution from ships along the coast, integrating multiple information layers:

- instant vessel information (AIS)
- regional statistics information on vessels accidents history, coastal vulnerabilities
- instant metocean forecasting data,
- continuously simulated oil spill fate and behaviour from ships along the coast.

This system can be used to compute real-time and historical data analysis, since all the information needed is available in real-time and is continuously updated and recorded in a database.
The relevance of integrating the oil spill model and metocean data from forecasting systems in the risk algorithm is evaluated.

PILOT AREA



Shipping Density around Pilot Area
(Source: Shipping density data adapted from National Center for Ecological Analysis and Synthesis, A Global Map of Human Impacts to Marine Ecosystems)

The whole system is implemented in the Western Iberian Coast (Portuguese and Galician Coast):

- high shipping density zone, (more than 55,000 commercial vessels / year crossing this area)
- obligatory passage point between the Mediterranean Sea and Northern Europe or American Continent.
- Peripheral area - activities in the nearshore assume a very relevant role in the social and economic context (fishing, maritime commerce, recreational activities).

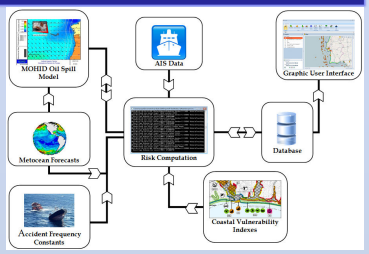
Methodology

RISK ALGORITHM

The risk rating combines the likelihood of an oil spill occurring from a vessel navigating in the study area with the assessed consequences to the shoreline:

- likelihood is based on dynamic marine weather conditions and statistical information (frequency constants for each accident type) from previous accidents.
- shoreline consequences reflect the shoreline impact from oil amount reaching shoreline and the environmental and socio-economic vulnerabilities.
  - The oil reaching shoreline is quantified with an oil spill fate and behavior model.
  - An additional modified risk rating is also computed, without the integration of the oil spill model for determine the shoreline impact (in this case, using vessel shoreline proximity as impact factor).

Shoreline risk is variable in time (variable vessel information and metocean conditions).



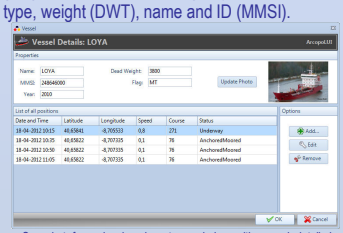
Data flow diagram of Dynamic Risk Tool developed

The simultaneous calculation of the risk posed by each vessel crossing a pilot area is integrated, allowing the generation of a dynamic shoreline risk map for that zone.

Type of accidents considered: grounding, foundering and structural failures, collision (with a ship or with port facilities), fire and explosion

VESSEL INFORMATION

Variable vessel information is used in the computation of risk. The properties used are the geographical position, cargo type, speed, vessel type, weight (DWT), name and ID (MMSI).

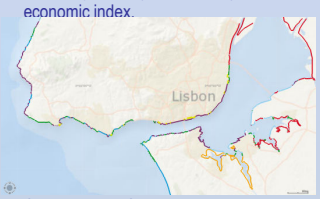


Snapshot from developed system: window with vessel detailed information

Vessels with less than 100 DWT, passenger vessels and fishing vessels navigating outside restricted waters are not considered. The vessel information is obtained from AIS data.

COASTAL VULNERABILITY

The environmental and socio-economic vulnerabilities are used in the quantification of the consequences, on risk algorithm. Different vulnerability indexes are used: environmental sensitivity index (NOAA – ESI) and socio-economic index.



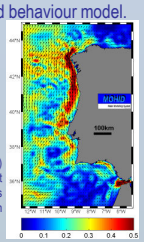
NOAA Environmental Sensitivity Index in a Portuguese region (Lisbon)

METOCEAN DATA

Variable wind, currents, waves and visibility are taken into account for the likelihood of an accident, which is modified with correction factors adjusted by those metocean conditions. These properties are also used to feed the oil spill fate and behaviour model.

All metocean parameters considered can be imported to system's database in real-time from online automatic forecasting systems covering the pilot area.

Metocean solutions presently used:
- MOHID-PCOMS (currents; water properties);
- IST-WW3 (waves);
- IST-MM5 (wind, visibility).

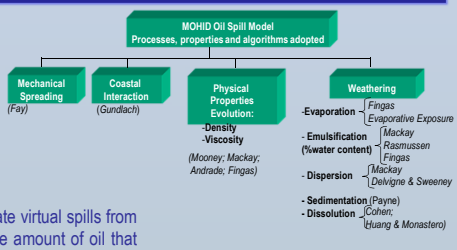


Sea surface currents (m/s) in the Western Iberian Coast (MOHID-PCOMS) used in this system

OIL SPILL MODEL

Integrated oil spill model - MOHID lagrangian particle tracking system:

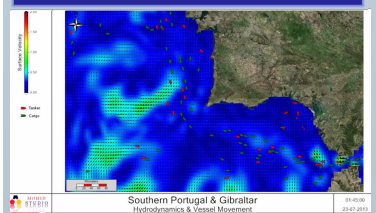
- operationally applied in different incidents, field exercises and studies
- allows the simulation of all major transport and weathering processes, including full 3D movement of oil particles, wave-induced currents, and oil-shoreline interaction



The dynamic risk tool continuously runs MOHID to simulate virtual spills from multiple vessels across the coast, taking into account the amount of oil that would approach the coastline.

Results

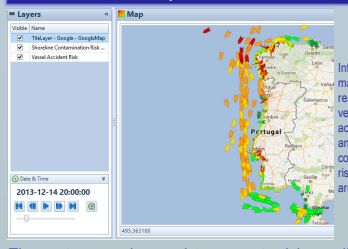
DATA INTEGRATION



Integrated map view of vessel traffic and sea surface velocity in Southern Portugal and Gibraltar

The decision support system permits visualization of vessel accident risk, shoreline contamination risk and vulnerability indexes, vessel traffic and details, isolated risks caused by specific vessels or isolated risks on specific zones.
System is implemented in a multifunctional GIS desktop system (MOHID Studio), allowing the integrated visualization of previously mentioned layers with metocean data, oil spill trajectories, or any other user-added layer.

REAL TIME | HISTORICAL DATA



Integrated map view of real-time vessel accident risk and shoreline contamination risk in the pilot area

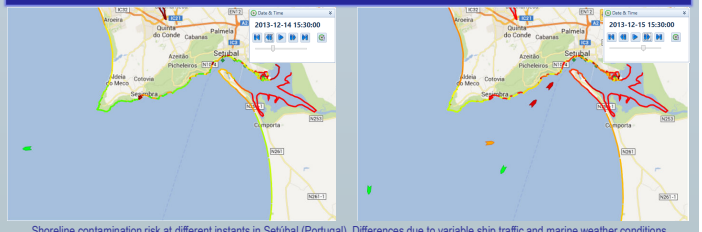
The system can be used to compute risks on live mode (real-time) or on-demand (using historical data).
Advantages of risk assessment from historical data:

- Identification of typical risk patterns and "hot spots"
- Development of sensitivity analysis to specific conditions

Advantages of risk assessment from live data:

- prioritization of individual ships and geographical areas
- strategic tug positioning
- implementation of dynamic risk-based vessel traffic monitoring.

DYNAMIC APPROACH



Shoreline contamination risk at different instants in Setúbal (Portugal). Differences due to variable ship traffic and marine weather conditions.

The integration of numerical models (oil spill + metocean) with AIS and coastal vulnerability in the quantification of shoreline risk algorithm allows:

- improvement of the decision support model
- a more realistic approach in the assessment of shoreline impacts:
  - more relevant in regions with greater variability in marine weather conditions
  - better understanding on risk in specific zones with calm and favorable metocean conditions but usually classified with high risk due to constant high cargo or tanker traffic in the nearshore.

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