



A STUDY OF THE RISKIEST POINTS IN FRONT OF AN OIL SLICK DUE TO AN ACCIDENT IN THE SPANISH MEDITERRANEAN COAST

F. X. Martínez^{1,2} and A.V. Esparza^{1,3}

Received 2 July 2010; in revised form 17 July 2010; accepted 7 November 2009

ABSTRACT

Pollution from shipping traffic poses a real risk to the Spanish coast. Memories of the Fedra bulk carrier disaster in the Strait of Gibraltar, the Prestige sinking in Finisterre or the Castor near accident off Almeria coast are still fresh. The main objective of this paper is to analyse, identify and quantify the Spanish Mediterranean coastal areas where spills from tankers are most likely to occur. The article is based on a study which uses a set of variables such as geographical peculiarities, climate, ship age and traffic density to feed an algorithm. This objective function weighs these parameters all along the coast and identifies the Spanish coastal areas having the highest risk of spills.

Keywords: Pollution, western Mediterranean, spill evolution

INTRODUCTION

The Mediterranean Sea covers an area of 2.5 million km², which is 5 times the area of Spain. Its east-west extent is approximately 3,800 km while its average north-south extent is 800 km. Its basin has a volume of 3.7 million km³ with an average depth of 1,500 m, a value significantly lower than the ocean's average. The Mediterranean Sea is connected to the Atlantic Ocean by the Strait of Gibraltar, which is about 14 km wide and 300 metres deep. From a hydrological point of view, other secondary passes connect with the Black Sea and the Indian Ocean through the Red Sea. Geo-

¹Universitat Politècnica de Catalunya, Tel. +34934017920, Fax. +34934017923, Pla de Palau, 18 08003, Barcelona, Spain.

²Titular professor, Email: fmartinez@cen.upc.edu. ³ PhD candidate, Email: amableesparza@hotmail.com.

graphically speaking, we can identify two clear basins connected by the Strait of Sicily called Eastern and Western Mediterranean.

The Mediterranean basin (particularly the north coast) is identified by limited agricultural, forest, cattle and even fishing resources, including energy, but also by large reserves of natural gas and hydrocarbons on the south coast. In a parallel sense, there is a population of 500 million people and about 300 million tourists are expected to visit the region annually during this decade. In addition, most of the main hydrocarbon export ports are located in Libya, the Mediterranean country with the largest reserves. Also worth mentioning are the port of Marseilles (French coast), the biggest import port in terms of volume, with overall annual imports of 65 million metric tons, and the three main ports of hydrocarbon traffic, located in Italy, with an added volume of 90 million metric tons.

From an internal point of view, the Mediterranean hydrocarbon traffic routes go north- south- and east-west, but we should add crude oil traffic in transit, which accounted for 421 million metric tons in 2006, from which 72 million were transported between non-Mediterranean ports (UNCTAD, 2007).



Figure 1. Crude oil tanker MT Venture spirit in Hong Kong, 2003.

THE LEGAL SCENARIO

Such traffic intensity has sometimes had disastrous consequences in the form of spills. An example occurred in 1967 when the Torrey Canyon spilled 120,000 tons of oil after striking a reef off the coast of Cornwall, England. The incident raised awareness among the international community about the severity of accidents involving ever-larger tankers. From a historical perspective, since 1970 the number of accidents and associated volume of spills has decreased globally by about 86%, probably due to the enforcement of the MARPOL 73/78 convention (IMO, 1978), OPA 90 (DoT, 1990) and ISM Code (IMO, 1996). The number of spills used to be directly related to the volume of oil transported. However, this has changed in recent years



because crude oil exchanges have increased but the amount of spilled oil has proportionally decreased.

Analysis of spills in the last four decades has revealed that most occurred during routine tanker operations at ports or terminals. The volume of oil spilled in operations has declined and 90% of spills are less than 7 tons whereas 86% of accidental spills (due to collisions or stranding) resulted in the loss of 700 tons. Among the most disastrous are Torrey Canyon in 1967, MT Jakob Maersk in 1973, MT Urquiola in 1976, MT Amoco Cádiz in 1978, MT Castillo de Bellver in 1983, MT Exxon Valdez in 1989, Aegean Sea in 1993, MT Erika in 1999 and MT Prestige in 2010.

Nevertheless, as said above, awareness of the problem has simultaneously grown, also in the Mediterranean community as it witnesses the degradation of its own sea. In 1969, the CGFM (General Commission of Fishing) of the FAO (UN) and the CIECM (Intergovernmental Oceanographic Commission) met in a working group and in 1972 a report considered the first complete study on Mediterranean pollution was

issued. According to this document, hydrocarbon spills at sea (Cantano, 2004) can be classified based on their origin (see Table 1).

It is widely known that the Mediterranean Sea is one of the most polluted areas in the world due to hydrocarbons spills, with almost half a million tons of spilled oil annually compared with the estimated world volume of 3.2 million tons.

Table 1. Causes of accidents involving spills up to 2004.

Causes	Average
Natural	10%
From shore	64%
Tanker operations	7%
Accidents	5%
Oil rigging at sea	2%
Other than tanker ships	12%

Source Own based on Cantano, A.

It is worth noting, however, that the Mediterranean represents only 1% of the world's sea water while its shipping traffic is 30% of the total international traffic.

The 1976 Barcelona Convention established the protection of the Mediterranean Sea against pollution by application of the UNEP (United Nations Environment Programme). In June 1995, the convention and its name were modified, and additional protocols were adopted. In 1993, Spain ratified the 1990 International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC 90). The protocol on Preparedness, Response and Co-operation to Pollution Incidents by Hazardous and Noxious Substances was approved in 2000 (OPRC-HNS Protocol) but entered in force in June 2007. MARPOL 73/78, the strongest pillar of international regulations on ship pollution prevention, had its first steps in November 1973, accumulating up to 20 amendments. The last part to enter into force was Annex VI, in May 2005.

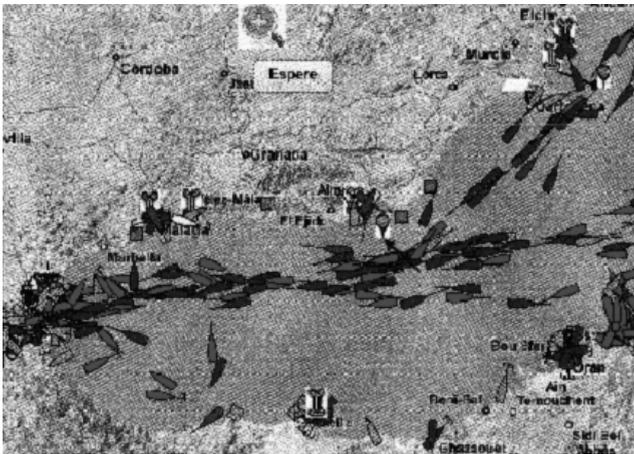
At a national level, we should note the National Contingency Plan for Accidental Marine Pollution passed by an order communicated on 23 February 2001, which was followed by other autonomic or regional contingency plans for the Mediterranean

littoral. More generally speaking, in the last four decades fighting mechanisms against sea pollution have improved, residue recovery being still one of the most important problems to solve. Moreover, new technologies such as air patrols or satellite surveillance which, together with dispersion models, help predict the evolution of oil slicks, are being incorporated into spill detection and tracking.

THE OPERATIONAL SITUATION

Hazardous goods traffic is particularly intense in “longitudinal routes” such as the Suez – Gibraltar and Bosphorus cases and in “latitudinal routes” like those connecting the North of Africa and the petrochemical complexes on the European coast, mainly in Italy, France and Spain. Freight identification is not a problem today because of unified and electronic data transmission systems like EDI manifests, Unified Customs Declaration, and specifically related to ship safety, the AIS system and the new LRIT, (IMO, 2008) in force as of 1 January 2010 and almost at 90% penetration now. 70% of Euro-Mediterranean traffic occurs in Spanish waters. In order to reduce density-related risks, the OMI has approved several Traffic Separation Schemes (TSS), e.g. for

Figure 2. Traffic in the Alboran Sea at 08:13 GMT on 28 July 2009.



Source: www.localizato.com

the Strait of Gibraltar in 1968, off Cabo Gata in 1998 and off Cabo Palos and Cabo Nao, both in 2002. According to data from the Spanish State Ports Agency, oil refinement activity in Spanish port terminals is now at maximum level. Nonetheless, the number of tankers calling at port is lower compared with the 1980's because of the growing size of ships. In addition, the use of

the oil pipeline network by the Compañía Logística de Hidrocarburos (CLH) led to a reduction in coastal traffic in the early 90's. However, this trend was reversed towards the end of the decade due to an increase in consumption and the saturation of Spanish oil refinement capacity.

The main routes served by tankers were analysed with 2006 and 2007 data from the Spanish State Ports Agency. The results are presented in the following table:



Table 2: Oil traffic volumes in Spanish waters.

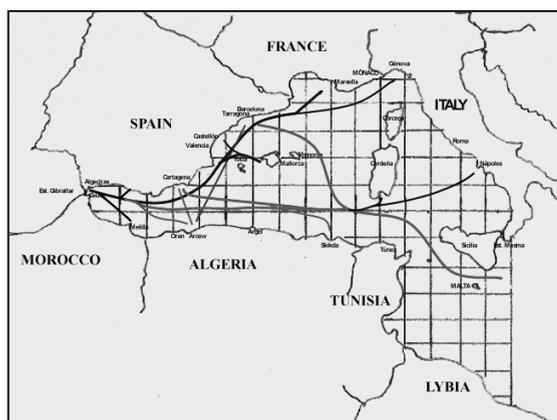
Corridor	Hydrocarbons or derivates, traffic	Rate
Alboran Sea/Strait of Gibraltar	19,194,581	29.39 %
Spanish Med., Gulf of Lyon, Genoa	6,515,835	9.98 %
<i>Subtotal Spanish coast</i>	<i>25,710,416</i>	<i>39.37 %</i>
Arcew – Tarragona, Castelló	5,757,334	8.82 %
Arcew – South of Spain	433,076	0.66 %
Skikda	346,805	0.53 %
South-Western Italy	755,094	1.16 %
East-West	31,763,107	48.64 %
Balearic Islands	534,766	0.82 %
Total	65,300,600	

Source Own, based on Ports Authority data.

METHODOLOGY OF STUDY

In order to obtain a risk value for Spanish coastal areas, several parameters, like maritime traffic and climate, coastal morphology and fleet age, were chosen for the study.

Figure 3. Main hydrocarbon transport routes calling at the main Spanish Mediterranean ports.



Source Own, based on Ports Authority data.

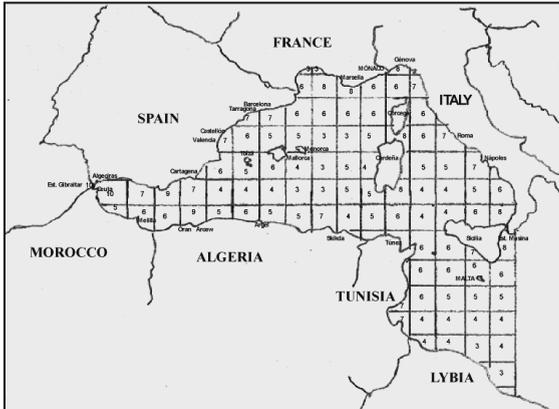
Shipping traffic in the Mediterranean Sea, and especially the East-West axis, is particularly intense. In 2006, up to 4,224 tanker shipments carrying 421 million metric tons of crude oil were reported, as opposed to 457 shipments in non Mediterranean waters, which accounted for 72 million tons in transit (REMPEC, 2008).

With 34% of berthings, the ports in the Strait of Gibraltar area have the largest number of tanker calls in the entire Spanish port system, followed by Tarragona and Barcelona with

20% and 16%, respectively. The number of calls at the Strait area is expected to exceed 4,000 within a year since 105,954 ships crossed the Strait in 2007. In 2006, 19% of ships in transit through the Strait of Gibraltar were tankers, accounting for 32% of the total tonnage. In order to have a geographical distribution, we divided the Mediterranean into squares and assigned them a risk rate from 0 to 10 depending on the volume of traffic occurring in the area.

The wind and wave regimes were also analysed with data from REMRO, XIOM and HIPOCAS projects. Data of most Eastern zones were obtained from the “Instituto Superior per la Proteziona de la Ricerca Ambientale” through its Rete Ondametrica Nazionale - RON. On the other hand, the information related to the Libya Sea was obtained from the EuroWeather-

Figure 4. Risk weight for all Spanish Western Mediterranean areas.



Source: Own, based on Ports Authority data.

Meteomed, Mediterranean marine forecasts. Scores were given based on the average significant wave height data.

The third main parameter was Western Mediterranean morphology. Nautical and bathymetric charts gave depth information, together with other secondary data. Finally, fleet age was analysed as it is one of the factors affecting accidentability and probability of ship malfunction.

In the last decade, fleet age has decreased drastically. For example, tanker age dropped by approximately 32.7%, with an average age of 10 years. In developed countries, tankers were newer, with an average age of 7.7 years in January 2007. About 70% of crude oil that crossed the Mediterranean Sea was carried on board tankers younger than 10 years old and only 4% exceeded the age of 20 years. A collateral factor to ship age is the registry flag. The analysis of tanker flags shows that 65% of cargo capacity of tankers calling at the main Spanish Mediterranean ports is from western countries and less than 10% is under third countries' flags. It should be born in mind that some convenience flag vessels are managed by western owners who choose this flag for cost or fiscal reasons only. The ports of Tarragona and Escombreras in Cartagena, which boast refineries of the Spanish company Repsol YPF, receive approximately 56% of cargo capacity under western flags. About 81% of carried hydrocarbons is moved by tankers not directly related to oil companies or states since oil the former sold their fleets some time ago.

PRELIMINARY RESULTS

After examining the four main risk factors, we calculated the risk point census. The weighting factor of each parameter was obtained from questionnaires sent to several relevant stakeholders in the maritime sector. The results were 60% to traffic, 15% to waves, 10% to morphology and 15% to fleet age. After applying the suggested weights to each area, the six points in the following table were identified as the riskiest in the Western Mediterranean.

**Table 3:** Weighing of the most risky areas in the Western Mediterranean.

	Strait of Gibraltar	Cape of Gata	Ceuta	Algeria Arcew	Sardinia	Marseilles
Traffic	6.00	5.40	6.00	5.40	4.80	4.80
Climate	0.75	0.90	0.60	0.45	1.05	0.90
Morphology	0.70	0.80	0.10	0.70	0.80	0.70
Fleet age	0.90	0.90	0.90	0.75	0.60	0.60
TOTAL	8.35	8.00	7.60	7.30	7.25	7.00

The affectation potential risk of the Mediterranean littoral is closely related to the prevalent wind and current in each area of study. This means that oil slicks will be affected by the weather conditions, and therefore the weather forecast for the area should be considered. This is, however, out of the scope of this paper.

Wind values in the Mediterranean area were recorded by a network of deep water buoys (REDEXT net) and meteorological stations (REMPOR net) placed at fixed positions. Wind intensity and direction were measured daily at time intervals of one hour on a long term basis. In this way, both instantaneous information and long term data can be obtained. For the riskiest points in the Spanish Western Mediterranean, the annual average wind speed was calculated with the origin data from the above web sites and the Spanish State Ports Agency.

Mediterranean currents mainly develop on the surface and are caused by the action of the wind. Nevertheless, there exists another current resulting from the difference in density of Atlantic and Mediterranean waters which circulates anticlockwise, flowing eastwards off the coast of northern Africa from the Strait of Gibraltar up to Port Said on the Egyptian coast. There, it turns north off the coasts of Israel and Lebanon and flows further to the west.

The set of currents was obtained from the Oceanographic section of the Spanish State Ports Agency, the Mediterranean Sailing Directions or Pilot Books and web sites like www.poseidon.hcmr.gr, www.meteofrance.com, www.hidromare.it, www.eurometeo.com and www.freemeteo.com. Wind and current data were classified according to the average movement of an oil slick advancing at 3% of the surface wind speed (IMO, 2005). The average speed of movement of an oil slick was calculated

by an approximate formula that combines wind speed and direction effect with the existing current, as shown in the following table.

Table 4: Approximate speed of movement of an oil slick in some Western Mediterranean areas.

Geographical areas	Speed in km/h
Strait of Gibraltar	9.307
Cape of Gata	5.225
Arcew (Algeria)	3.001
Marseilles	3.958

Speeds of movement and directions of oil slicks were estimated for winter and summer, which gave different values of, for example, the time required by slicks to reach the coast.

CONCLUSIONS

International tanker fleets have been renewed in recent years. In OCDE countries, the tanker fleet had an average age of 7.7 years while the world’s average was 10 years, that is, slightly higher than that of container carriers.

New ballast management, tank cleaning and residue recovery technologies, among others, have improved operational safety and reduced accidentability to unbelievable levels some decades ago. As can be seen in Table 4, two of the four riskiest points in the Western Mediterranean are situated in the south of the Iberian Peninsula, specifically in the Alboran Sea, and Arcew is on the coast of Algeria. A spill off Marseilles, the fourth area, can affect the north-east of the Iberian Peninsula. On the other hand, despite being areas of intense shipping traffic, a spill off Cape of Gata or Arcew is less likely to have a pollutant impact on the Spanish coast due to the action of sea currents.

Table 5: Approximate speed of movement of an oil slick in some Western Mediterranean areas.

Areas	Summer Oil slick direction	Winter Oil slick direction
Strait of Gibraltar	North Coast, Strait and Coast of Málaga	Coast of Málaga
Cape of Gata	Coast of Algeria	Coast of Algeria
Arcew (Algeria)	Coast of Algeria	Coast of Algeria/Open sea
Marseilles	Marseilles/Open sea	Catalan Coast/Open sea

An oil spill off Marseilles could affect the Catalan coast (NE of Spain) since the continental plateau speeds up the current. Thus, the spill would reach the coast off the Natural Park of Cape of Creus in about 2 days. The most vulnerable area is the Strait of Gibraltar. Traffic density and the high number of tankers sailing its waters and calling at the Bay of Algeciras increase the risk of accident considerably. In the event of an oil spill, the time required by the slick to reach Spain up to the coast of Malaga would be between 2 and 6 hours depending on the wind intensity.



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UN ESTUDIO DE LOS PUNTOS MÁS ARRIESGADOS DELANTE DE UNA MANCHA DE ACEITE DEBIDO A UN ACCIDENTE EN LA COSTA DEL MEDITERRÁNEO ESPAÑOL

ANEXO

El Objetivo fundamental de este artículo es el de analizar, identificar y posteriormente cuantificar, las áreas de la costa Española Mediterránea, con mayor riesgo de sufrir un derrame de hidrocarburos procedente del tráfico marítimo de hidrocarburos. En el estudio que fundamenta este artículo, se han tomado en consideración una serie de variables, de entre las que destacamos, las peculiaridades geográficas, climáticas o la densidad de tráfico, que alimenten una función aleatoria. Esta función objetiva ponderará los diferentes puntos de la costa e identificando los que tengan una mayor probabilidad de riesgo.

En la investigación aquí presentada, se pretende evidenciar dónde pueden ubicarse las áreas del Mediterráneo Occidental español donde puede haber mayor riesgo de derrame potencialmente.

En los puertos del Estrecho de Gibraltar, es donde escala el mayor número de buques tanque del sistema portuario español; alcanzando aproximadamente el 34% de las escalas, seguidos de Tarragona y Barcelona con un 20% y 16%, respectivamente. Considerando las escalas de Gibraltar, en el área del Estrecho se sobrepasaría la cifra de 4.000 al año, siendo importante reseñar que durante el año 2007 cruzaron el Estrecho de Gibraltar 105.954 buques. Según los datos del 2006, de los buques que navegan por el Estrecho de Gibraltar en tránsito hay que destacar que el 19% corresponde a buques tanque, representando el 32% del GT. El tercer factor que se estudia es la morfología del Mediterráneo Occidental. A través de las cartas náuticas obtenemos la sonda del área, asignándole un coeficiente del 0 al 10 a cada cuadrícula en función de la sonda.

Se valora también el factor de la edad de la flota. Es evidente que el riesgo de averías crece con los años y, por tanto, también el número de siniestros. En la última década, la edad de la flota se ha reducido notablemente. Otro factor importante colateral a la edad del buque es su bandera de registro. Analizando las banderas de los buques tanque, la conclusión del conjunto de los puertos ha sido que, del orden del 65% de la capacidad de carga de los buques tanques que escalan en los principales puertos del Mediterráneo Español lo hacen bajo pabellón de países occidentales, y menos de un 10% lo hace bajo pabellón de terceros países. No debemos olvidar que algunas flotas que están bajo pabellón de “conveniencia” se encuentran gestionadas



por armadores de países occidentales, y que el abanderamiento se limita a una cuestión fiscal y/o de costes.

A las distintas cuadrículas del Mediterráneo Occidental se le asigna un coeficiente del 0 al 10, consecuencia del estudio de la edad de la flota y su pabellón.

Una vez analizados los cuatro factores de riesgo, procedemos al cálculo del censo de los *puntos negros*. Para ello, y tras las diferentes conclusiones obtenidas a lo largo del estudio y a la opinión de relevantes profesionales del sector, materializada a través de encuestas mandadas, le asignamos un valor porcentual a cada factor de riesgo del 60% al Tráfico, 15% al Oleaje, 10% a la Morfología, 15% a la Edad de la Flota.

Los puntos con mayor riesgo son los cuatro citados en el cuadro anterior, encontrándose tres de ellos en el sur de la Península, en las inmediaciones del mar de Alborán, y el cuarto en Marsella, pudiendo afectar a la costa Nororiental del litoral de Cataluña (Cap de Creus). De los cuatro *puntos negros* (PN) determinados, dos de ellos tienen un riesgo relativamente inferior de que la marea negra llegue al litoral español, aún cuando concentran un importante tráfico. Los PPNN de Cabo Gata y el de Arcew, tienen una probabilidad menor de impacto de la marea negra en la costa española, debido a las corrientes marinas existentes.

En caso de marea negra, el PN de la zona de Marsella podría tener incidencia en el litoral de la costa catalana. Concretamente, el primer lugar donde podría impactar es en el Cap de Creus. En esa zona, la plataforma continental se hace muy estrecha, agudizándose con el Cañón de Creus, disminuyendo aún más la plataforma continental en esa área, pudiendo llegar la marea negra hasta la costa del Parque Natural de Cap de Creus. Como orden de magnitud, tenemos dos días para evitar que la marea negra pueda llegar al litoral catalán desde el PN de Marsella.

El cuarto PN y potencialmente más peligroso es el Estrecho de Gibraltar. El elevado tráfico que soporta y el gran número de buques tanque que surcan sus aguas, muchos de ellos recalando en la Bahía de Algeciras, lo convierten en el *punto negro* con mayor riesgo potencial. En caso de vertido accidental en el transporte de hidrocarburos, el efecto de la corriente y del viento haría que la costa Norte del Estrecho se viese afectada, al igual que la costa de la provincia de Málaga, desde Manilva hasta Fuengirola. Todo ello dependiendo de la época del año y de las condiciones climatológicas reinantes. Además, como orden de magnitud, el tiempo que se dispone para reaccionar es de entre dos y seis horas, en función de la época del año y la parte del litoral que se viese afectada.