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A Prototype Statistical Approach of Oil Pollution in the Mediterranean Sea

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Abstract

In this paper, we present a detailed statistical survey of oil pollution in the greater area of the Mediterranean Sea (with a preference in the Greek Seas: e.g. the Aigean Sea or the Ioanian Sea and the respective Greek fleet). The Mediterranean Sea exhibits a noticeable increase of oil pollution within the last 15 years as documented by data that presented within this work. A new electronic data base tool with a multitude of operational capabilities that utilizes data from the REMPEC Organization in raw format is introduced. We further present a statistical analysis of the data which differentiates each incident according to the volume of spilled oil and we conclude with some interesting results and comments.

1 Introduction

Pollution of the marine environment by hazardous materials is a critical problem with world-wide ecological consequences. Figure 1 depicts the sources of marine pollution according the International Conference for Environment and Development held in Rio, 1992 (HCG[9]).

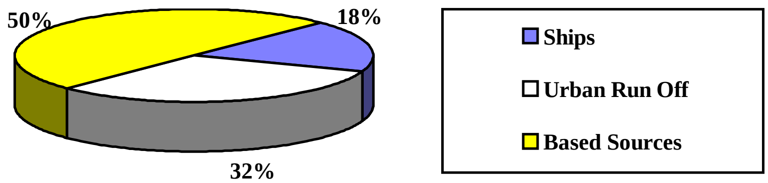

Figure 1: International Sources of Marine Pollution

Unfortunately, the Greek Seas and even further the greater area of the Mediterranean Sea exhibit accordingly an increased pattern of marine pollution and especially of oil pollution as it can be seen by Table 1 that exhibits the concentrations of oil up to 100m of depth (Thomas [6]). The Mediterranean Sea is considered of extreme importance for the oil trade and transportation, due to its nodular position. At least 22% of the aggregate world volume of crude oil and 19% of the respective quantity of refined products are being transferred through the Mediterranean Sea by Med countries alone (REMPEC [5]).

Table 1: Comparative Concentrations of Oil up to 100m of Depth

Year	Area	Concentrations (μg/l up to 100m of depth)
1981	Med/North Sea	2/0.02
1993	Med/North Sea	5/2.5 (forecast)

The significant increase of concentration of oil within the North Sea between the years of 1981 and 1993 can be explained by the plethora of platform activities. On the other hand, the doubling of oil concentration within the Mediterranean Sea for the same time period is a very upsetting trend which requires further investigation.

Marine oil pollution is similar and quite unsettling for the Greek seas. Even though the Greek seas and coasts are considered among the cleanest within the Europe Union. However incidents of oil pollution pose a significant threat and must be dealt with extreme caution. Figure 2, presents the various polluting substances (e.g. oil, petroleum products, chemicals etc.) for the Greek seas according to the number of relative incidents for the calendar years 1995 and 1996 (HCG [9]).

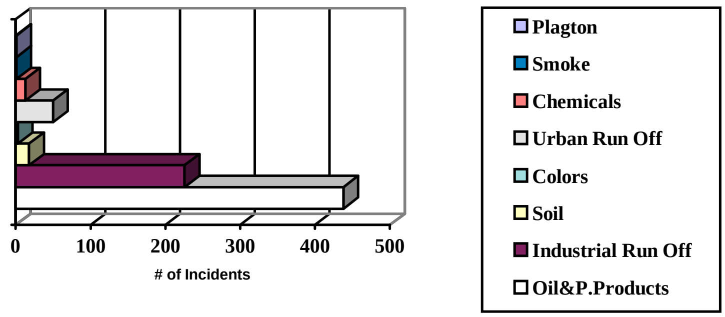

Figure 2: Polluting Substances for the Greek seas

As it is evident from Figure 2, the incidents of oil pollution were the most common ones for the Greek seas within the 1995-1996 period.

We further present the development of "SPILLASE" (an oil spill data base) in section 2, the respective statistical analysis in section 3, some indicative results in section 4 and we finally conclude with section 5.

According to our knowledge this effort is one of the very first in the literature to quantitatively analyze and characterize the marine oil pollution in the Mediterranean waters.

2 SPILLASE: An Oil Spill Data Base

In order to proceed with the statistical analysis, some reliable oil spill data concerning the area under investigation had to be found. Unfortunately, such an effort in Greece resulted in a dead end; neither the Ministry of Mercantile Marine (including the Hellenic Coast Guard), nor the National Statistical Service could provide any significant help. Finally, data were provided by the Regional Marine Pollution Emergency Response Center for the Mediterranean Sea (REMPEC) which is the most authoritative organization for oil spill data collection.

The data were acquired in a hard copy format and covered a fairly long time period from 1978 up to 1995 and they totaled up to 200 records of real and falsely reported oil spill incidents. The latter account for some incidents that even though they were initially reported as oil spill incidents finally no oil pollution was verified. Naturally, the limited number of records for such large time period cannot form a thorough data base (instead just an indicative one), but by all means it was the best sample that could be found by the authors. One sensible explanation that can shed some light to the low number of records is the fact that REMPEC does not gather all these data through an independent mechanism but instead, it depends either on some international publications (e.g. Lloyds Casualty List), or on the information that it gets from the local authorities (e.g. for Greece from the Hellenic Coast Guard).

We have developed an electronic data base tool named "SPILLASE" which handles all the aforementioned data of oil spill incidents. "SPILLASE" is developed under a WIN95 and MSACCESS95 environment requiring just the standard capabilities that can be found in an up-to-date personal computer (Pentium 133 MHz, 16MB RAM). None of the various operations of the electronic tool require more than 10-15 seconds.

In "SPILLASE", each spill record contains the following attributes (some of these attributes were not provided by REMPEC (REMPEC, 1996), but were collected from the FAIRPLAY data base): the Date of the incident, the Lat and Long of the area of the incident (where possible), the Area and Country of the place of the incident, the Cause/Accident (e.g. collision, fire, grounding, terminal operation, etc.), the Name and Type of Ships Involved, the Flag of Ships Involved (e.g. GRC: Hellas, FRA: France, ITA: Italy, ESP: Spain, etc.), the DWT, the GRT, the Year of Built, the Cargo (e.g. Crude, Fuel, Diesel Oil etc.), the Quantity of the aforementioned Cargo, the Source of Information (Local Authority, Lloyd's, Media, National Authority), the Type of Spilled Oil, the Quantity of Spilled Oil (in tons), the Surface of Oil Spill (in m^2), the Response which describes the actions taken to mitigate against an oil spill and the Remarks (additional information).

"SPILLASE" handles the aforementioned database of oil spill incidents in a multi-fold manner:

- it can represent the data base in a formulary or tabular mode,
- it can execute all the standard operations for a data base (add a record, edit a record, etc.),
- it performs multiple simple queries,
- it performs multiple complex queries with validated results and
- it can perform some basic and advanced useful automated statistical operations concerning the records of the specific database (utilizing some general factors for the specific each time part of the fleet under examination).

3 Statistical Analysis

It is the first time, to the best of the authors' knowledge, that such a statistical approach was developed for the portion of the Greek fleet that operates in the Mediterranean Sea and pollutes this area. This approach focuses on the true importance and environmental impact of each slick event. Hence, two (2) oil spills of different magnitude should not be treated the same or as equivalent events. Consequently, the various amounts of oil that finally reached the Mediterranean Sea for each event were first studied and then correlated to some general parameters. Such a parameter could be the transported oil through the Mediterranean Sea (in spite of the authors' efforts relevant data could not be obtained for the specific part of the fleet) or the tonnage (gross or net) of the part of the fleet that was chosen to be examined. This correlation was performed in order to estimate some comparative frequencies (named "venturousness" and defined at the end of this section, a special frequency format type that can provide reliable and meaningful results) for several interesting attributes of the fleet under investigation.

The main contribution of the proposed statistical analysis is the newly introduced term of "pollution potential" or "pollution load" of each ship or incident for a specific geographical area. "Pollution potential" is a magnitude that characterizes the "possible" pollution inflicted by a vessel. This "pollution potential" depends on the magnitude of the spill (x_0) and a plethora of other factors such as:

- type of accident or incident (x_1),
- type of involved ships (x_2),
- total embarked oil (x_3),
- environmental sensitivity of area (x_4),
- proximity to the coast (x_5),
- type of coast (x_6),
- season (x_7),
- type of spilled oil (x_8) etc.

Hence, the "pollution potential" ($\widetilde{P}_R$) is a function of multi-vector that can be generally defined as shown in Eqn (1):

$$\widetilde{P}_R = \widetilde{P}_R(x_0, x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, \ldots) \qquad (1)$$

Currently, the function that describes the dependence of the "pollution potential" on the above factors is under development. Indicatively Table 2 provides a way of correlating the "pollution load" with the amount of spilled oil (x_0) and the number of incidents (relaxation of "pollution potential"). The results present the same skewed distribution of spill volume with Devanney's and Stewart's, 1974 (Ventikos [4]).

Table 2: Ratios of Various Factors of Oil Pollution

1978-1995	Ratio Tankers : Rest Types of Ships
Amount of Spilled Oil	10 : 1
# Incidents	2 : 1

From Table 2 it is evident that based solely on the amount of spilled oil and on the number of incidents which finally result in oil pollution, tankers show a much greater "pollution potential" than the other types of vessels, while more specifically tankers present twice the number of accidents, the same time that they "produce" 10 times more amount of spilled oil than other types of ships. At the completion of the proposed methodology the definition of the "pollution potential" will include several more input factors.

The great advantage that arises from the usage in the statistical concept of the "pollution potential" is its flexibility. For the calculation of the "pollution potential" a multitude of factors affecting the damages are being taken into account ensuring in that way for hopeful results. The usage of the "pollution potential" also provides a "safe" way to circumvent the existing lack of monetary values of damage assessment, especially for the Mediterranean waters.

The mathematical techniques that were utilized for the conduct of the statistical analysis involved mainly the usage of relative frequencies and moving averages. Furthermore, the analysis included some standard Poisson probability estimations in order to explore the degree of the fitting of the existing historical data into the theoretical case of a Poisson distribution. The final results of this effort, though, are not included in this paper. For a detailed discussion of this analysis see Ventikos [4].

The relating frequencies consist of a ratio of the amount of oil that was spilled in the presumed time unit (or sometimes the according number of incidents) by the total amount of oil that was embarked into the same time period. When that was not possible other relevant sizes, such as total gross or net tonnage or the according number of ships operating in the greater area of the Mediterranean Sea etc. for each time unit were used. So using the aforementioned frequencies together with the moving average process (which is ideal for long-lasting surveys) the total averaged "venturousness" can be estimated for the time period under consideration.

$$venturousness = MA(N) \qquad (2)$$

where: MA(N)→ the moving average of N observations of x_i/y_i. In this case, were used a sample of 18 years,

x_i→ the amount of oil that was spilled in the presumed time unit (or sometimes the according number of incidents) and

y_i→ the total amount of oil that was embarked into the presumed time unit (see above).

For the scope of the statistical analysis the “venturousness” is used for comparative purposes (e.g. for the identification of the type of vessel most likely to provoke oil pollution) and for revealing the trend of some factors throughout time (e.g. the oil polluting pattern of Greek tankers the last 20 years).

4 The Results

In this section we present some indicative yet interesting results for the part of the Greek fleet that operated in the Mediterranean Sea for the period of 1978 to 1995. Naturally the quality of these results is dependent on the respective quality of the data used in the analysis.

Figure 3 presents the “venturousness” of the various types of Greek ships related to a common tonnage. The results documenting the tankers as the most “dangerous” type of Greek vessel are intuitively sound. On the contrary, it seems that passenger-ferries are more prone for oil pollution than cargo carriers, which is quite interesting. A probable explanation for the specific result is the nature of the source of the data. REMPEC does not have a self- contained mechanism to gather in-situ data and at the same time Greece has a major passenger fleet operating very close to the coastlines. Therefore, it is only natural that every incident of oil pollution concerning this part of the Greek fleet is under the scrutiny of public opinion and the relative information reaches easily the REMPEC organization.

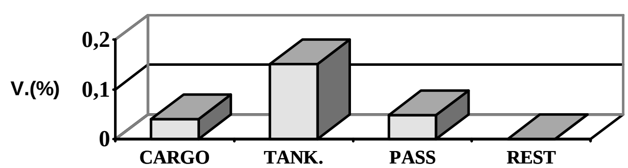

Figure 3: The “Venturousness” of Greek Ships

In Figure 4 the trend of oil pollution course of Greek tankers (their participation and contribution according to their annual “venturousness”: vertical axis) in the Mediterranean for the time period 1978-1995 (: horizontal axis) is being presented.

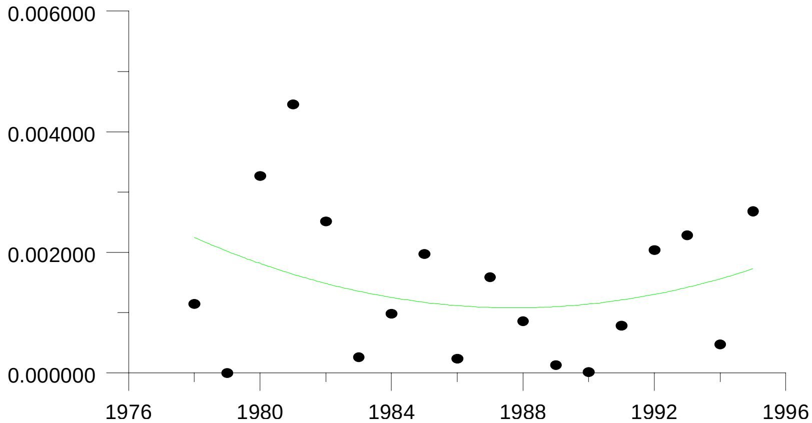

Figure 4: The Trend of Tanker Participation in Pollution

While up to the year 1988 a significant decrease of the contribution of Greek tanker fleet in the polluting of the Mediterranean Sea was recorded, from there and on a serious increase was recorded. This increase is mainly due to the increase of the size of the Greek tanker fleet and the respective amount of oil that it carried.

In Figure 5 the comparison of the Greek tankers’ “venturousness” according to ship age (again related to a “nominal” tonnage) is depicted.

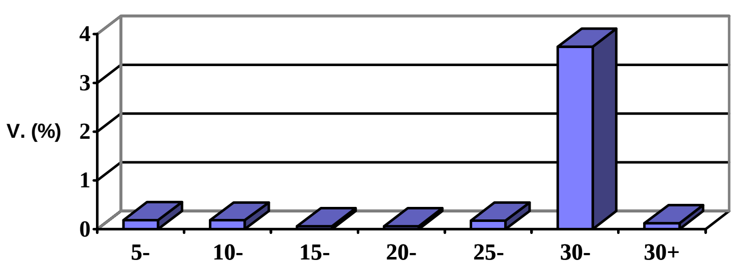

Figure 5: The “Venturousness” According to Ship Age

It is quite clear that the most “dangerous” age group of Greek tankers is that of 25-29 years old. The extreme low percentage of the even older Greek tankers is probably due to lack of relevant data (as provided by REMPEC).

Finally, we present the relationship between the number of oil pollution incidents-accidents and the type of accidents independently of oil pollution of the Greek fleet. The basic accident types that were chosen to be examined were the following: Sinking, Grounding/Stranding, Fire/Explosion, Collision/Ramming, Engine Trouble and Rest (e.g. hull damage).

Table 3 contains the frequencies of all the types of accidents under examination.

Table 3: Oil Polluting Accidents / All Accidents (%)

Type of Accident	% of Accidents that Resulted in Oil Pollution
Sinking	0
Grounding/Stranding	1.800
Fire/Explosion	1.542
Collision/Ramming	11.020
Engine Trouble	0
Rest	9.258

The results of Table 3 are again intuitively sound: Collision/Ramming is the most “dangerous” category of accidents. The percentage though of this category is surprisingly high, while the respective percentage of Fire/Explosion and Grounding/Stranding is quite low.

5 Conclusions / Comments

We have presented the development of an oil spill database that handles oil spill related data provided by REMPEC. We then presented a statistical analysis of oil spill incidents in the Mediterranean waters related to the Greek marine fleet. We finally provided some indicative results of the analysis.

Summarizing the results of the analysis we can conclude:

- the quality and density of the primary data are essential for a reliable analysis,
- the analysis which was presented here was mainly based upon the amount of oil spilled into the sea, taking account this way of the real

environmental importance of each incident,

- the newly introduced term of “pollution potential” or “pollution load” is a promising perspective into the analysis of the oil pollution situation of Greek seas,
- the analysis which was presented in this paper used for the first time the concept of “venturousness” as a basic process for getting reliable results &
- a complete statistical analysis needs to explore thoroughly each problem under examination.

Acknowledgment

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