GIS-BASED RISK ASSESSMENT OF OIL SPILL ACCIDENTS AT SARONIKOS GULF, GREECE

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ABSTRACT

An oil spill accident is a serious threat for all marine and coastal environments. Several oil spill accidents have occurred worldwide with severe environmental and economical consequences. This is becoming more important for areas having high environmental, social and/or touristic value, like Saronikos Gulf in Greece. A serious and scientifically rigorous identification of the risk related to oil slicks is becoming mandatory and Geographic Information Systems (GIS) prove to be a useful tool for such an emergency management. In the present paper, a GIS-based methodology of oil spill risk assessment is implemented at Saronikos Gulf. Risk assessment of oil spill accidents refers to those actions that can prevent or mitigate the impact of oil dispersal at sea and adjacent coasts. The accident risk is defined as the product of hazard and vulnerability. The result of the present methodology is a risk map where the areas most at risk from oil spill accidents are indicated.

Keywords: oil spill accident, marine pollution, risk assessment, hazard, vulnerability, GIS, Saronikos Gulf

1. Introduction

Oil spills into coastal waters and open seas have the potential to cause significant adverse impact on marine environments. Subsequently, in the last decades many oil spill risk assessment studies have been performed aiming at understanding, predicting or facing the issues that result from oil spill accidents (Papadonikolaki *et al.*, 2015). The issues that come over after an oil spill accident are not only ecological, but also socioeconomic and legal, so these studies are very important and helpful.

An oil spill risk assessment includes hazard identification and estimation of its results. Specifically, an oil spill accident risk assessment includes all the actions taken that can lead to the prediction of an accident, the mitigation of its consequences or even to its prevention. Generally it is used to enhance oil spill preparedness and to develop contingency planning that sometimes directs the response operations. It can provide the authorities all the information needed and in case of an emergency it could help them react in the most appropriate way avoiding wasting time and money. GIS prove to be a reliable tool for emergency management during all the phases of an oil accident (e.g. planning, mitigation, preparedness, response and recovery) and therefore constantly gaining favour in risk assessment and the development of long-term mitigation strategies (Cova, 1999).
In the present paper, a GIS-based methodology of oil spill risk assessment is implemented at Saronikos Gulf. Saronikos Gulf includes more than 30 ports of different uses including Piraeus. Piraeus is the largest port in Greece and one of the largest ports in the Mediterranean and plays a crucial role in the development of international trade as well as the local and national economy. Piraeus Port connects continental Greece with the islands being also an international cruise center and a commercial hub for the Mediterranean, providing services to ships of any type and size. Besides, along the coasts of the Saronikos Gulf, there are several beaches and natural protected areas with cultural and touristic value.

2. Presentation of methodology

Maritime accident risk could be defined as the expected losses (of lives, persons injured, property damaged, and economic activity disrupted) due to a particular hazard for a given area and reference period. Based on mathematical calculations risk is given by equation (1) as the combined result of hazard identification and vulnerability analysis (Olita *et al*., 2012):

$$[\text{ACCIDENT RISK}] = [\text{HAZARD}] \times [\text{VULNERABILITY}] \quad (1)$$

The term 'Hazard' refers generally to characteristics (e.g. earthquakes, volcanoes, oil spills) that may cause an emergency, that is a deviation from planned or expected behavior or a course of events that endangers or adversely affects people, property or/and the environment (Johnson, 2000). 'Vulnerability' is the measure of how the elements at risk in a landscape would be damaged if they experience same level of hazard (Coburn *et al*., 1994). It is the degree to which an area, people, physical features or economic assets are exposed to the loss, injury or damages caused by the impact of the hazard. Like hazard, vulnerability is multidimensional and each element will be affected differently by hazards of different severity (Udoh and Ekanem, 2011).

3. Implementation of methodology

3.1. Area of Study

Saronikos Gulf is located in east-central Greece, bounded by Attica and Peloponnesus coasts and connected to the Aegean Sea to the south by an open boundary about 40 km long, extending from cape Sounion to the coast of Peloponnesus. The water depth is highly variable with some shallow areas, but also deeper parts with depths of about 400m in the western part (Otay *et al*., 2013). The gulf geometry is also complex and includes several islands, the largest ones being Aegina, Salamina and Poros. Prevailing winds are from northerly directions.

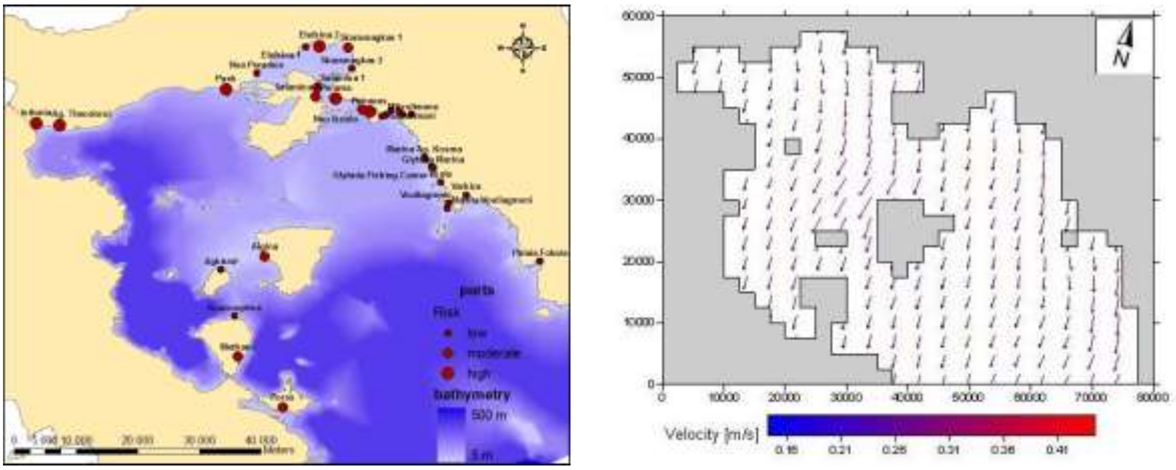
3.2 Hazard modeling and Vulnerability modeling

Hazard is calculated based on these elements of Saronikos Gulf: a) bathymetry b) ports c) oil spill accidents data during the past decade (2003-2012) d) traffic lines e) coastal industrial facilities and f) the hydrodynamic calculations resulted from FLOW-3DL hydrodynamic model (Figure 2b) developed by the researchers of the National Technical University of Athens (NTUA), Applied Hydraulics Laboratory (Papadonikolaki *et al*., 2015).

Each of these elements was imported as a raster layer in GIS. Then each one of them was reclassified into three zones of hazard: high, moderate and low (Queensland Government, 2000) based on their perceived probability to cause an oil spill accident. For example, regarding the bathymetry layer, the accident frequency is expected to be highest in shallow waters in the vicinity of coastal areas rather than deep waters.

Figure 1: (a) Study Area: Saronikos Gulf (source: google.com/earth)

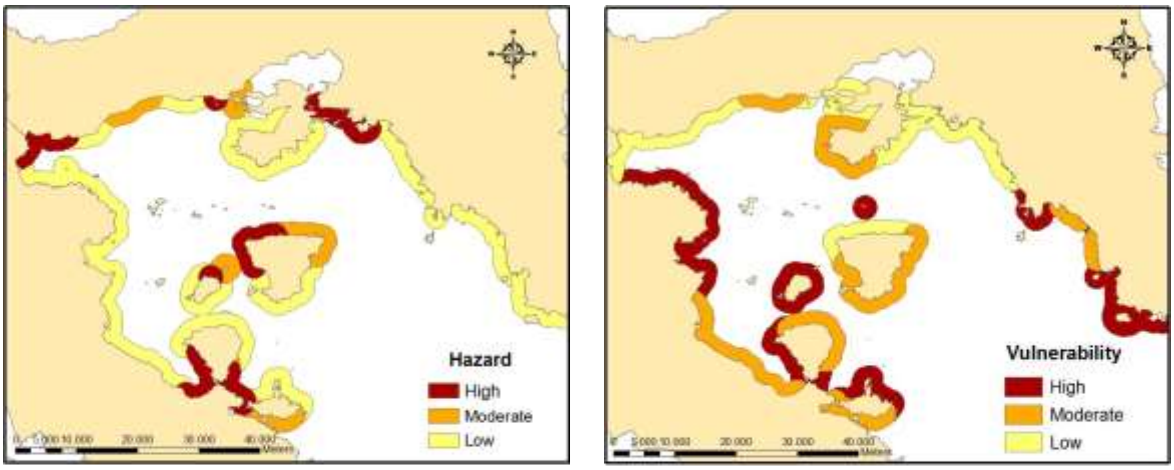
Concerning the ports layer, they were classified for hazard potential according to their sort of use, maritime traffic and the size of the serviced ships. In determining the final hazard surface, all the above mentioned elements were equally weighted and combined into a single hazard layer using the single output algebra of Arcmap (Udoh and Ekanem, 2011). As an indicator of the probability of experiencing a hazardous event, the hazard zones prioritize hazard of different severity as shown in Figure 3(a).



(a) (b)

Figure 2: (a) Bathymetry and Ports of Saronikos Gulf and (b) Saronikos Gulf surface currents for N wind of 4 Bf (Papadonikolaki *et al.*, 2015)

Vulnerability is calculated by analyzing the sensitivity parameters that include a) land use b) blue flag beaches c) fisheries and d) coastal natural protected areas (Natura 2000, Corine), special protected environments and natural and cultural areas, according to the 'Filotis' database for the natural environment of Greece and the Open Greek Database (http://geodata.gov.gr/geodata/). The above mentioned selected vulnerability layers were each reclassified into three zones of vulnerability based on their identified elements at risk and then equally weighted and combined into a single vulnerability layer using the single output algebra of Arcmap (Udoh and Ekanem, 2011). The output was then reclassified and zoned into three vulnerability categories (high, moderate, low) as shown in Figure 3(b).



(a) (b)

Figure 3: Final (a) hazard and (b) vulnerability maps of Saronikos Gulf

4. Results

As mentioned, risk assessment is the combination of likelihood and impact. This study aims to focus on evaluating the likelihood of an adverse impact (oil spills) occurring rather than the severity of its impact in order to emphasize on the great meaning of people's preparedness and the usefulness of a contingency plan (Gunton, 2013). For this reason, in order to create the final risk surface, the hazard and vulnerability layers were weighted as follows: hazard (60%) and vulnerability (40%). Then they were combined into a single risk layer using the single output algebra and then the buffer wizard tool for a more legible result. The resultant map was reclassified and zoned into three risk zones: high, moderate and low.

The result of the methodology is a risk map, where the coastal areas are indicated according to their likely level of exposure to oil contamination due to oil spill accidents within the gulf (Figure 4). The areas at highest risk, as shown below, are the coastal areas near Piraeus Port, the north-western coasts of the island of Aegina, north-western end of the Gulf near the town of Isthmia and the south area of the Methana peninsula.

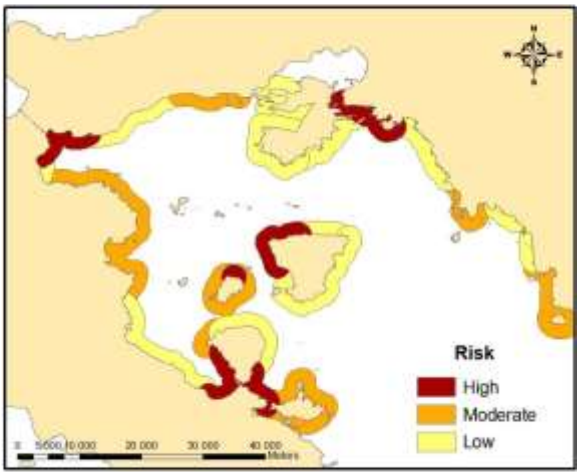


Figure 4: Risk map of the study area as a combination of hazard and vulnerability map

5. Conclusions

A GIS-based risk assessment of oil spill accidents was presented in Saronikos Gulf, Greece. The study identified and modeled oil spill hazard and vulnerability, the combination of which created the risk surface. The resultant map was classed into three risk zones of high, moderate and low risk.

A risk assessment study could be very helpful for the responsible authorities. According to this methodology, the authorities should focus on the areas most at risk and could be educated and prepared. The decontamination in case of an accident is a very costly process both for the government and the naval company. The key to control and reduce costs is to avoid disasters resulting in the environment and property. The best strategy to reduce these disasters is to remove as much oil as possible from the environment and to prevent the oil from hitting the coast and other sensitive areas. The only way for an effective decontamination process is the rapid activation, which is possible only if studies analyzing risk of oil spill accidents have been proceeded.

To minimize the harmful effect of oil spill, there is need for a comprehensive contingency GIS-based plan for oil spill management in the study area. GIS provides a dynamic, user-friendly interface to explore a number of different attributes and physical information gathered from a spill; foremost, it provides the mechanism to speed up decision making (Aukett, 2012). This methodology could also be implemented, with the necessary changes, to other areas that may face oil spill risk so that environmental and economical problems could be efficiently avoided.

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