Modelling and simulation of oil spills in coastal waters

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Abstract. Over the years many navigation incidents took place in coastal areas or in ports. As a result of these incidents (collision between vessels, groundings, flooding, etc.) many wrecks remained. Due to the inability of authorities to manage these situations, or the lack of interest for the repercussions that may occur in such an incident, many problems may arise in medium and long term. The impact on the environment and local economy may prove to be important if no pollution measures are taken in order to prevent ecological disasters. In this paper the case of a sunken vessel in the Romanian Black Sea coastal area, in terms of management of a possible leakage of hydrocarbons, is analysed. The method used in the paper allows the modelling and simulation of oil products spreading, through specialized software solutions, thus providing the authorities with a starting point in managing the response to the emergency situation.

1. Introduction

The aim of this paper is to show how a simulation software can be used in monitoring a potential oil spill in Romanian Black Sea coast. Although no major spills were recorded in the Romanian waters and the general trend of oil spills worldwide has a downward trend, the limited equipment owned by the authorities responsible impedes that exercises and simulations should be conducted, as the latest incident dates February 2018 in Constanta port.

The main causes of large oil spills in coastal areas occur due to collision or grounding of vessels, hull or equipment failure, fire or explosions on board and illegal discharge of oil contaminated water. Most of the oil spills float on the sea surface and can be easily spread over a wider area due to wind, waves and currents. Usually, the impact of the spills can be found in the upper areas of the waters, but some type of oil can sink and affect the seabed.

Constanta port and the Black Sea are important regions, being the link, in term of trade, between Europe, Asia and Africa and the number of vessels passing through this region is increasing yearly. Also, this region is widely known for its underground resources which consists of large amounts of oil and natural gas. If we also take into consideration that all these resources are near the coastal area, an accidental oil spill can have a major economic, social and environmental impact.

The impact on the environment is portrayed as a long-lasting disaster, and it affects not only the wildlife, plankton, fish, mammals, seabirds, but also the human activities in the near vicinity of the spill. Also, the environmental regeneration will last for years to come after the incident and it involves human resources and large amounts of money.
2. Oil spill statistics and causes
The latest statistics in the field published by ITOPF show a tremendous downward trend in the last five decades for spills over 7 tonnes. While in the ‘70s the average number of incidents was 79, since 2010 this number decreased to no more than 7 incidents per year (Figure 1). This important decrease is the result of combined efforts of the governments and the shipping industry stakeholders which act in order do prevent pollution and increase safety at sea. Nonetheless, oil is still spilt each year, by accident or willingly, so the risk of pollution still remains.

In the last five decades, most of the oil spills occur while vessels were underway in open or inland/restricted waters, 67%, while only 9% of the incidents occurred while the vessels were performing loading/discharging operations. Other noticeable spills occurred while the vessels were at anchor in open or inland/restricted waters, 6%, and the last 18% are unknown.

In terms of causes, the main causes are related to grounding, 32%, respectively collision, 29%. Other noticeable causes are related to hull or equipment failure, fire and explosions onboard or are of unknown causes (Figure 2).
3. Case study – Medy wreck
In order to simulate the evolution in space and time of an oil spill, PISCES II (Potential Incident Simulation, Control and Evaluation System) simulation software was used. This system was developed by Transas Ltd. and it has the ability to simulate mathematical models of oil spills on water, calculate the trajectory and also model the interaction between the spill and response forces such as skimmers, booms or chemical dispersants. By simulation one incident, multiple plans for intervention can be developed and according to the results, the most effective one can be put in force. Thus, this system can provide not only simulations for training of response teams, but it also has the capability to conduct real-time actions.

On the 1st of September 2010, M/V Medy (Figure 3), a 6358.9 tdw cargo loaded with 3427.4 of scrap metal, left Constanta South – Agigea at about 1 AM. Due to an incorrect ballasting procedure, little after 3 AM the cargo captain issued a distress call for sinking and after the successfully rescue of the 17 member of the crew the vessel sank at 12:51 AM. Her tanks were fully loaded with 22 tonnes of fuel and 2.33 tonnes of lubricating oil, making the vessel a potential pollution factor. In an effort to evaluate the seriousness of the situation, a team of divers was sent to wreck. Unfortunately, two of them died as the meteorological conditions were harsh and they could not get back to the surface. All other actions were stopped by the Romanian National Authority.

In our research, we simulated the possible leaks of fuel and oil from Medy wreck, based at 4 nautical miles from the shore, near Cape Tuzla, with the following coordinates: 44°00.567' N and 28°45.471'E. For visualization capability, Transas TX-97 charts were used, similar to the ones used by ECDIS.

Regarding the environmental conditions, several databases were consulted in order to establish the most realistic meteorological characteristics for the western part of the Black Sea. One of the most influent factor in oil spills is the current. According to Mihailov et.all. the current for the westerns part of the Black Sea has the following characteristics: speed between 0.5 and 1.2 knots and direction between 200° and 220°. In our research we used a speed of 1.2 knots with a general direction of 210°.

Regarding the wind conditions, a mean value of 6,17 m/s with direction 67° from 01.04.2017 to 30.04.2017 was loaded into PISCES II system. The same period was considered for the water surface temperature of 6°C and 10°C as an average air temperature. In term of the sea state, Douglas scale was used with an average value of 4 – moderate sea, resulting in wave heights up to 2.5 m. Water density was extracted from nautical publications and the value used for this region was 1025 kg/m³.

As mentioned above, the vessel had 22 tonnes of diesel fuel with a density of 837 kg/m³ and 2.33 tonnes of lubricating oil, with a density of 874 kg/m³. These exact products were used as pollutants and the simulation scenario was started on the 1st of April at 12.00. The next figures show the initial conditions and the general trend of the pollution path.
When analyzing the simulation, it was found out the oil spill will reach the surface of the water after 10 minutes since the beginning and its general trend is following the current. After $H + 1.30$ minutes the oil spill starts to disperse and it starts evaporating, maintaining its direction towards SW. After $H + 6$ hours the oil spill is near Mangalia harbour, but since the quantity is quite low it is dispersed in proportion of 95.5% while the other 4.5% has already evaporated. Simulation was run up to $H + 60$ hours and the parameters remained the same, taking into consideration the above mentioned hydro-meteorological parameters.

In this case, no part of the oil spill reaches the shoreline, thus no major environmental effects would occur on the shore (Figure 6).

In order to underline the seriousness of an oil spill in this region of the western Black Sea coast, another simulation was conducted with the same hydro-meteorological parameters, but with a larger quantity of pollutant: 220 tonnes of diesel fuel with viscosity $837 \text{ kg/m}^3$. 
Again, 10 minutes after the start of the simulation, the oil spill reaches the surface, but in this case, it covers a larger area and immediately starts dispersing. After $H + 6$ hours the oil spill will reach Mangalia harbour and has contact with the shoreline, northbound and southbound of the harbour. The simulation was kept for 60 hours and the oil spill kept going south having contact with both Romanian and Bulgarian shoreline, showing that a major environmental disaster can take place in this case (Figures 7 and 8).

4. Conclusions
The simulations presented in this paper prove that PISCES II is a state of the art software that can be used for space – time prediction of oil spills, as well as providing the necessary tools for developing an intervention scenario. By being able to simulate multiple environmental situations for the same incident, this system may help the authorities in charge to choose the best way of intervention in order for the impact to be at a minimum. Nonetheless, by developing complex scenarios, PISCES II can also be used for conducting trainings for crisis management in case of oil spills. Thus, research and obtained results from PISCES II will increase the readiness for action.

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