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Water pollution

MODELLING THE NAVAL TRANSPORT ASSOCIATED HYDROCARBON POLLUTION RISKS IN THE DANUBE DELTA BIOSPHERE RESERVATION

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Abstract. Although large accidental pollution incidents are now rare, accidental or operational pollution is still rampant across the world, and has a severe impact on the environment, especially in sensitive areas, like natural reservations. The unique simulation environment for oil spill modelling, composed of various maritime and technological simulators represents a valuable aid for battling oil spills, assessing proper containment solutions and assessing the associated pollution risks. The core element, Potential Incident Simulation, Control and Evaluation System (PISCES 2), is a response simulator intended for preparing and conducting command centre exercises and area drills. PISCES 2 provides an interactive information environment based on the sophisticated mathematical model of an oil spill interacting with surroundings and combat facilities, computing spill trajectory and weathering in both real-time and fast-time modes, interactions with models of booms, skimmers, chemical dispersant systems, absorbent resources, complex coastlines, and user-defined zones containing at-risk assets. The available resources will be used for evaluating the overall risks, associated to the hydrocarbon pollution, by considering a case study, which follows real situations and threats in the Danube Delta area.

Keywords: risk assessment, pollution containment, threat modelling.

AIMS AND BACKGROUND

Water pollution, regardless of its causes, has a major impact on the environment. Almost 40 up to 70% of accidental water pollution are caused by oil spills[1]. Oil spills often have significant, long-term impact on wildlife, fisheries, coastal habitats, socioeconomics and human activities in affected areas. Also, the environmental regeneration lasts several years and requires big involvement of human resources and money. The major causes of oil spills in the coastal areas occur due to boat accidents, oil transfer to ships in open sea and in ports and because of illegal discharge of water contaminated with oil[2].

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Although, the average number of large oil spills (> 700 t) between 2010 and 2015 is around 7% of that during the 1970s, it can not be excluded the occurrence of such an incident. The amount of oil spilt due to shipping activity varies considerably each year, with a few very large spills being responsible for a high percentage of the total annual quantity. During the period 1970–2015, 50% of large spills occurred while the vessels were underway in open water and 17% while underway in inland or restricted waters. The main causes of large spills were collisions (30%) and groundings (33%). Other significant causes include hull failures and fire/explosion[3].

In present paper, Danube Delta area is analysed in terms of consequences related to an oil spill. The Danube Delta is positioned at the intersection of Danube, the second largest river of the old continent (2860 km), and Black Sea. Along with the great number of aquatic and terrestrial plants, colonies of pelicans and cormorants live or come to hatch or hibernate. It can be stated that with these diversities of the habitats and life forms that hosts into a relatively small area, Danube Delta represents a true museum of biodiversity, a layer of natural genes, which is invaluable for the universal natural heritage. Many species of vegetables or animals also framed important natural resources, economical exploitable, which drawn people to these places. These characteristics represented the arguments that led to the declaration of the Danube Delta, by the Romanian Government in 1990, to become a biosphere reservation, decision confirmed afterwards by the Romanian Parliament, through law No 82/1993. The universal value of the reservation was recognised by its inclusion in the international network of the biosphere reservation (1990), within the programme 'Man and Biosphere', launched by UNESCO in 1970 (www.ddbra.ro/en/danube-delta-biosphere-reserve).

RESULTS AND DISCUSSION

Improvements in modelling methods assisted by computers allow the user to forecast the dispersal of oil spills and to elaborate response plans for each type of disaster[4]. The effects caused by an accident, dependent on many factors (type and quantity of the pollutant, topography of the area, direction and magnitude of the wind, currents, water temperature and salinity, etc.) can be integrated and analysed using specialised modelling sollutions.

Examples of oil spill modelling software include Oil Drift 3, model used by the Norwegian Meteorological Institute Oil Spill Forecast System, Météo France Oil Spill Model, used by the Météo France Oil Spill Forecast System and GNOME model used by the Emergency Response Division of the United States Office of Response and Restoration[5]. In present study, research was carried out by using PISCES 2 (Potential Incident Simulation, Control and Evaluation System) software designed by TRANSAS. Software provides both prediction of the evolution in space and time of an oil film and the substantiation of recovery strategies for many scenarios.

Simulation approach, development and results. The initial conditions of the scenario were established by considering the actual gross tonnages limits imposed in the Maritime Danube Area. It was considered a 30 000 t deadweight (tdw) container ship (the maximum gross tonnage allowed in the area is 35 000 tdw, accordingly with the data available on the Romanian Maritime Authority rules). Normally, a vessel like the one considered for this case study will be able to carry a bunker of 1500 t of fuel (either Heavy Fuel Oil or Diesel Oil). During the scenario, and accident will be considered, around coordinates identified in Fig. 1, upstream Patlageanca village, before Danube division into secondary streams. After the accident, a major collapse of the structural elements of the ship was considered, resulting with the spillage of the entire bunker quantity available onboard.

Fig. 1. Geographical area for the initial conditions of the simulation

The origin of the spillage was intentionally chosen in this area, since the Danube Delta reservation has its boundaries in the proximity. In order to assess the Danube surface currents, the reference month was considered to be March[6]. The current data were extrapolated from the reference point, to July–August interval, where the Danube flow and current values are decreased. Within the entire area used for the simulation, the Danube surface currents were considered to have velocities between 0.5–1.5 km/h, in accordance to the velocities profiles determined for each area.

In the developed scenario, the influence of the hydrocarbon spillage on the existing fauna in the area was also modelled. PISCES 2 has implemented a database with environmental impact on several species existing in the area. The data are presented in Table 1.

Table 1. Impact of hydrocarbon spillage on different species in the Danube delta

Group	Subgroup	Name	Lethal hydrocarbon concentration (kg/m^3)	Lethal exposure time (h)
Reptiles	amphibians	amphibian	3	48
Invert	annelida	annelida	3.5	24
Invert	crustaceans	crustacean	15	48
Fish	fishes	fish	6	48
Invert	insects	insect	0.2	96
M_mammal	mammals	mammal	70	96
Invert	molluscs	mollusc	20	48
Bird	birds	bird	48	48

The simulation area is represented in Fig. 2 and it has 28°30′E – 29°30′E longitude and 45°N – 45°30′N latitude boundaries. The simulation starts with developing the spillage. At the beginning of the exercise, the spill is compact, covering a 0.1 km^2 area and with a maximum thickness of the hydrocarbon film of 16.8 mm (Fig. 3).

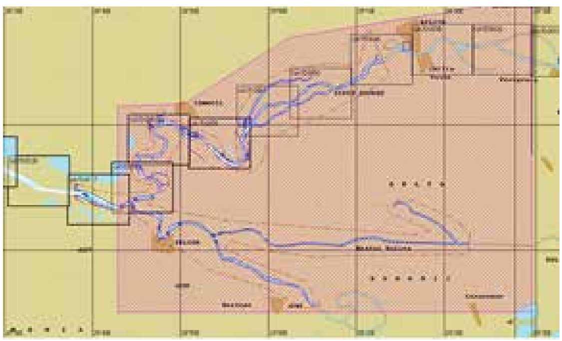

Fig. 2. Simulation boundaries

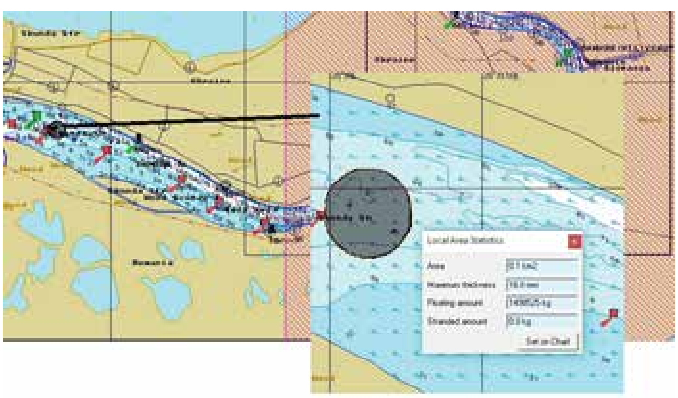

Fig. 3. Spillage at the beginning of the simulation

The oil slick touches land first time on the Ukrainian part of the Danube, after 2 h and 12 min from the beginning of the exercise, at approximately 2 km from the Chilia and Tulcea arm confluence (Fig. 4). At this moment, the maximum thickness of the oil slick is 38.8 mm. Approximately 500 kg will be evaporated after 2 h.

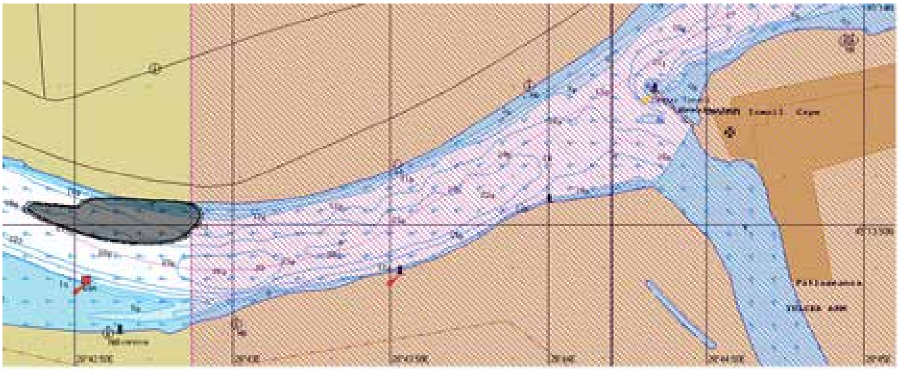

Fig. 4. Moment of the first land contact

After another 1 h and 30 min, the oil slick will touch the breakwater installed at the Ismail Cape (Fig. 5) and it will divide in two (Fig. 6). The Chilia arm oil slick will carry 225.36 t of oil and the area will keep 74.5 kg of stranded oil; the Tulcea arm oil slick will carry the remainer of 1261.51 t of oil and the area will keep 146 kg of stranded oil.

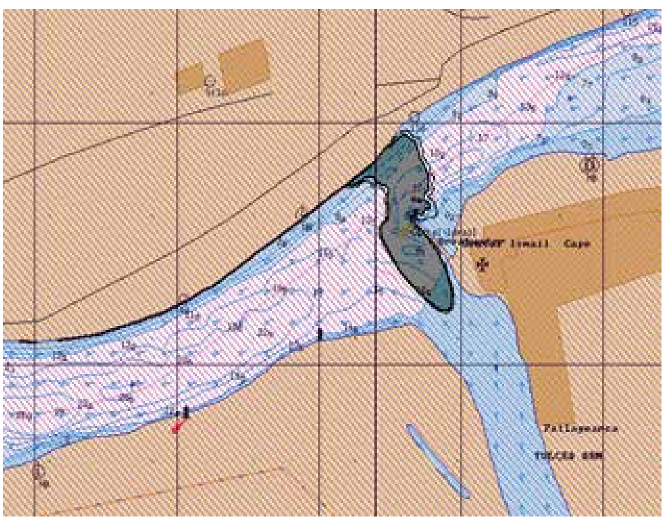

Fig. 5. Oil slick touches the breakwater from Ismail Cape

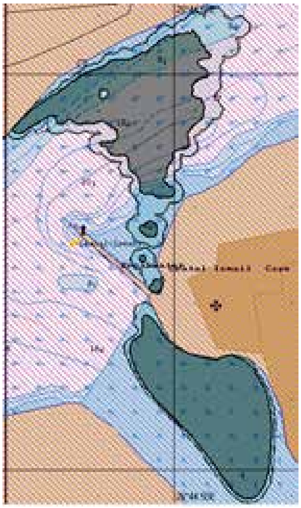

Fig. 6. Oil slick division

After 11 h, the main slick will touch Tulcea area (Fig. 7). The slick will cover 0.3 km^2 and will carry 1202.6 t, with a maximum thickness of 12 mm. The stranded oil amount will be 6.403 t.

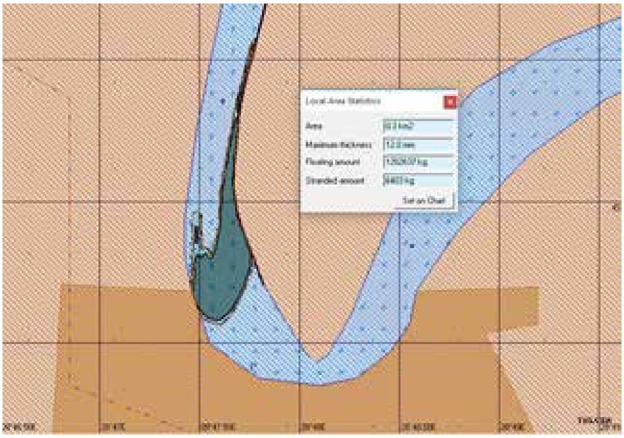

Fig. 7. Oil slick particularities when reaching Tulcea area

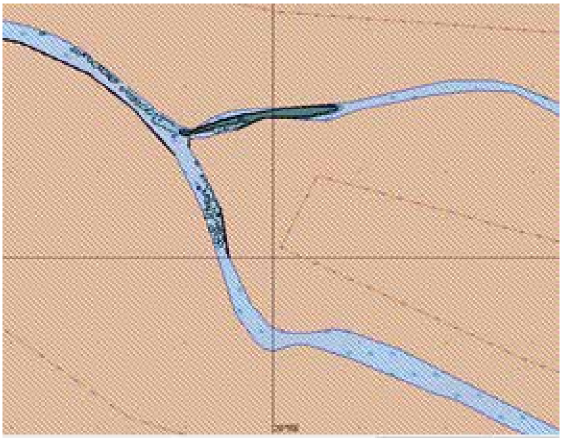

Fig. 8. Oil slick behaviour in the Sulina and Sf. Gheorghe arms confluence

After 24 h from the simulation start, the oil slick will reach the confluence between the Sulina and Sf. Gheorghe arms (Fig. 8). The current velocities in the area allow the most of the oil slick to enter the Sulina arm. A part of it will be dispersed and will follow the Sf. Gheorghe arm. The oil slick division from the Sulina arm will cover a 0.4 km^2 area and will hold an oil quantity of 1007.9 t. The stranded oil amount in the analysed area is 1220 kg. The Sf. Gheorghe slick will cover 0.2 km^2 and will hold a 62.63 t of oil. The stranded oil amount will be 4.3 t in the area[6,7].

After 48 h, the oil slick on the Chilia arm is fully dispersed, due to higher current velocitiy and higher turbulence level. On the Sulina arm (Fig. 9), the oil slick is still fully developed; it covers a 0.3 km^2 area and holds 928.266 t. At this point of scenario development, the coastline pollution statistics are presentated in Table 2.

Table 2. Coastlines pollution parameters

Stranded oil mass (kg)	236249.00
Stranded oil volume (m^3)	247.00
Parcel length (m)	754362.00
Clean part length (m)	703142.00
Polluted part length (m)	51220.00

The pollution footprint after 48 h (Fig. 10) shows that a pretty big area is affected by the spillage, which covers both inhabited and wild areas within the Danube Delta reservation.

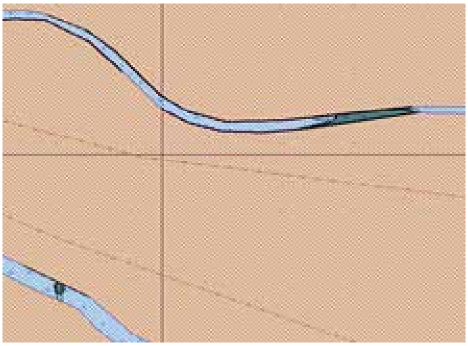

Fig. 9. Oil spillage after 48 h

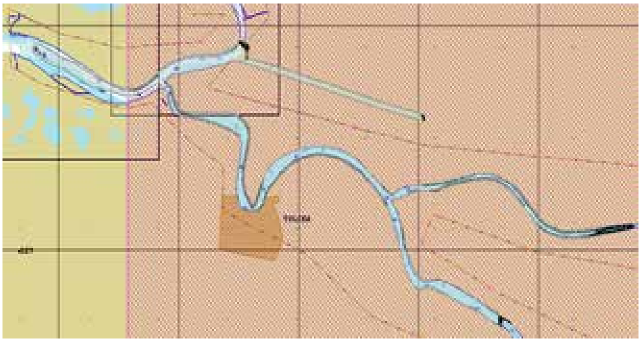

Fig. 10. Pollution footprint after 48 h

The environmental impact after 48 h shows that on short term the death levels are generally low, for most of the species depicted at the beginning of the case study, excepting the insects that are living at the water level, for which was registered a 1% death level in the first 48 h. The spillage statistics are presented in Figs 11 and 12.

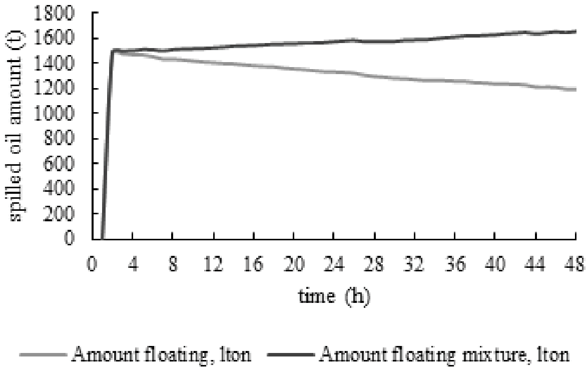

Fig. 11. Oil amount floating, separate and in mixture

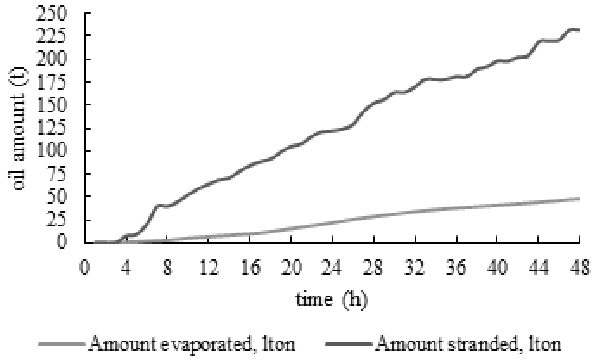

Fig. 12. Oil amount stranded on the Danube river banks or evaporated

By considering the above presented development of the situation, there can be identified a possible area for intervention, for having a good intervention timing and appropriate results. Since the oil slick will firstly be divided after two hours from the accident, and since the closest intervention facility is located in Tulcea, at a 15.5 km distance from the accident, the best place for intervention seems to be the confluence between the Tulcea arm and Chilia arm.

After a 30-minute mobilisation time, and considering that the workboats that are transporting the booms can develop the appropriate speeds, the confluence point, located at 8 km can be reached in maximum 1 h, which gives about 30 min for booms displacement.

CONCLUSIONS

The possibility to forecast the evolution of an oil spill through analysis of data and to elaborate various scenarios of intervention represents a powerfull tool in risk assessment and response planning of the decision makers.

Present paper has treated the issue of an oil spill in a protected area of Romanian Danube Delta, area that houses a variety of animals and plants. Spreading analysis of hydrocarbons, resulting from a shipping incident, for more than 48 h revealed how oil move through Danube arms, what quantity reaches the coastline and how much is evapored. Also, by modeling this scenario was identified another threat, namely the lethal impact of oil on various species of animals, whether interventions lasts more than 24 h.

In this regard, is essential that oil spill preparedness for such protected areas to be increased and simulation exercises to be performed periodically. Otherwise, an unfortunate incident complemented by a failed or delayed intervention, may compromise the area for many years and in some cases, definitive.

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