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COMPUTER SIMULATION OF AN EMERGENCY SITUATION - ACCIDENTAL DISCHARGE OF HYDROCARBONS IN THE BLACK SEA

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Abstract
The paper below presents a computer simulation conducted by the authors, using POTENTIAL INCIDENT SIMULATOR EVALUATION AND CONTROL SYSTEM (Pisces II) software, a model program for assessing the consequences of oil pollution of the sea water. Simulation of a large number of scenarios in various emergency situations and environmental conditions is of great use to predict evolution of oil spillages, in time and space.

Keywords: pollution, hydrocarbon, simulator, emergency, Black Sea

1. INTRODUCTION

The work consists in interpreting the results obtained from computer simulation of an accidental discharge of a quantity of crude oil in the Black Sea due to a crack in the oil pipe that connects the central oil platform and tank park at Midia Oil Terminal.

2. UNFOLDING EVENTS

On 05.01.2008 at 01.00, a foreign-flagged vessel transits and anchoring without approval (about 26 km from the Midia terminal) in the area where the pipeline was carrying crude oil from the Central Oil Platform to Oil Terminal Midia. The anchor of the ship damages the pipe, so a part of the crude oil is pumped out into the sea. When observing the pollution, the captain of the ship decides to lift anchor and leave the scene without letting know the authorities.
Since the accident takes place at night and the pressure at the receiving station at Midia Terminal oil has not dropped below 1 bar, the accident goes unnoticed so at 05.00 according to the Midia Terminal protocol, is drawn the volumes of oil transported through the pipeline, so one could saw a difference of 83 t. The decision was taken to order the Central oil platform to stop pumping so in 10 minutes the pumping is stopped and authorities are announced on the accident and pollution that took place.

3. DATA ENTRY

To simulate the emergency situation generated by the crack in the pipeline that carries crude oil, authors have used the POTENTIAL INCIDENT SIMULATOR CONTROL AND EVALUATION SYSTEM (Pisces II) software, product of TRANSAS, fitted to the Department of Environmental Engineering at the Constanta Maritime University, on a simulator designed to handle real situations such as oil sea pollution. (Voicu&colab., 2011)

The PISCES is an incident response simulator designed for preparing and conducting command centre exercises and area drills. The application is developed to support exercises focusing on oil spill response. Therefore, the oil spill mathematical model should take into account human response activities in addition to such environmental factors as coastline, field of currents, weather, sea state, ice conditions and environmentally sensitive areas. (Delgado&colab., 2006)

The main point of the method is to extend the Lagrangian approach by introducing interactions between oil particles. This innovation allows some essential disadvantages of the traditional Lagrangian method to be compensated, in particular the impossibility of describing oil interaction with different kinds of natural and artificial barriers like coastlines and booms. The tuning of the interparticle interaction was made via multi-stage parametric optimization with the aid of the alternating-variable descent technique, and includes the verification with known semi-empirical solutions as well as with different logical tests. (Delgado&colab., 2006)

The model takes into account the main physicochemical processes occurring in the oil slick, which include evaporation, dispersion, emulsification and viscosity variation. Simulation is carried out with regard to the following environment factors: coastline, field of currents, weather, sea state, ice conditions and environmentally sensitive areas. In addition, models of response resource application including booming and recovery have been developed. (Delgado&colab., 2006)

The following input data were used for the simulation:

a) Hydrometeorological observations:

- water temperature [°C]
- air temperature [° C]
- wind speed and direction [m/s; ^{0}]
- current speed and direction [m/s; ^{0}]
- sea state [m]

Hydrometeorological observations were taken from the Research Laboratory for Danube, Delta and the Sea, for Gloria Platform between 05.01.-08.01.2008. (Table 1 and Table 2)

Table 1. Hydrometeorological observations for 05.01.-08.01.2008

Date	Hour	Wind		Sea surface conditions (degrees)	Wave elements				Temperature		Current		Visibility (km)
		Direction	Speed (m/s)		Direction	Length (m)	Period (s)	Height (m)	Air (^{0}C)	Water (^{0}C)	Direction	Speed (m/s)	
05.01.2008	1	340	14	6	N	40	5,4	4,5	-7,0	5,5	S	26,3	10
	7	360	12	5	N	35	5,0	3,5	-6,4	5,5	S	25,0	10
	13	340	11	5	N	35	5,0	3,3	-5,2	5,5	S	25,0	1.5
	19	340	10	5	N	30	4,5	2,8	-5,2	5,5	S	18,5	10
06.01.2008	1	360	10	4	N	30	4,3	2,2	-2,0	5,5	S	14,7	20
	7	90	5	3	NE	50	6,7	1,2	1,0	5,5	V	15,2	20
	13	140	6	3	NE	50	6,8	1,2	3,0	5,5	V	15,9	20
	19	140	6	3	NE	50	6,7	1,0	4,0	5,5	V	13,5	20
07.01.2008	1	140	9	4	SE	25	3,8	1,6	3,0	5,5	NV	14,1	20
	7	140	13	4	SE	30	4,2	2,4	5,0	6,0	NV	25,0	20
	13	290	10	5	SE	40	6,9	3,2	5,3	6,0	N	25,0	10
	19	320	8	4	NV	20	3,4	1,5	2,6	6,0	ESE	13,5	10
08.01.2008	1	320	9	4	NV	20	3,5	1,5	0,7	6,0	SE	13,5	4
	7	340	9	4	NV	25	3,8	1,8	1,5	6,0	SE	20,0	10
	13	20	9	4	N	35	4,4	2,4	4,1	6,0	S	20,0	10
	19	20	9	4	N	35	4,6	2,2	4,0	6,0	S	20,0	10

b) Physical characteristics of oil:

- density: 830 kg/m^3
- surface tension: 0.0173 N / m
- viscosity: 15 cP
- maximum water content: 40%
- pour point: -10 ^{0}C
- flash point: -4 ^{0}C

Physical characteristics were taken from The Oil Laboratory of Câmpina.

c) Other features:

- Midia Teminal distance: 26 km
- inner diameter pipe: 291.95 mm
- average speed of movement of oil through the pipeline: 0.32 m/s
- water density: 1015 kg/m^3

The calculations revealed that the total volume of oil discharged is 85.2 tons - in these conditions the volume is rather small so it is cathegorised as a medium pollution, which can still degenerate into a large-scale environmental issue.

4. RESULTS

The pollution development scenario obtained from the PISCIS Simulator:

a) An hour after the start of pollution: - amount spilled: 20.6 tons;- amount floating: 15.8 tons;- amount evaporated: 1.2 tons;- amount dispersed 3.6 tons;- amount floating mixture: 23.9 tons;- maximum oil film thickness: 4 mm;- spill area: 37979 m^2;- viscosity: 71.9 cP. (PISCES29-PL, 2008) (Fig. 1)

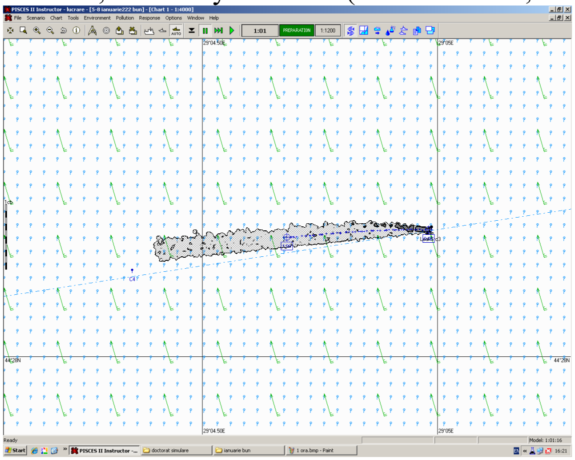

Figure 1. Evolution of oil spill after one hour after the accident

b) At 4 hours after of the start of pollution:- amount spilled: 83 tons;- amount floating: 53.7 tons;- amount evaporated: 11 tons;- amount dispersed 18.3 tons;- amount floating mixture: 90.7 tons;- maximum oil film thickness: 5.8 mm;- spill area: 203353 m^2;- viscosity: 210 cP. (PISCES29-PL, 2008) (Fig. 2)

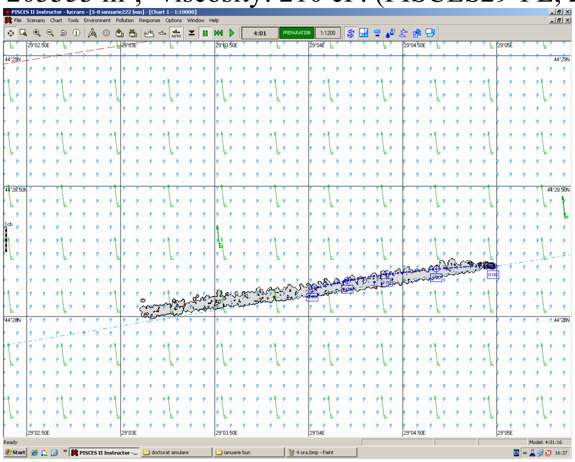

Figure 2. Evolution of oil spill after 4 hours after the accident

c) After 6 hours of the start of pollution:- amount spilled: 85.2 tons;- amount floating: 44.7 tons;- amount evaporated: 16.1 tons;- amount dispersed 24.3 tons;- amount floating mixture: 79.7 tons;- maximum oil film thickness: 1 mm;- spill area: 242396 m^2;- viscosity: 449 cP. (PISCES29-PL, 2008) (Fig. 3)

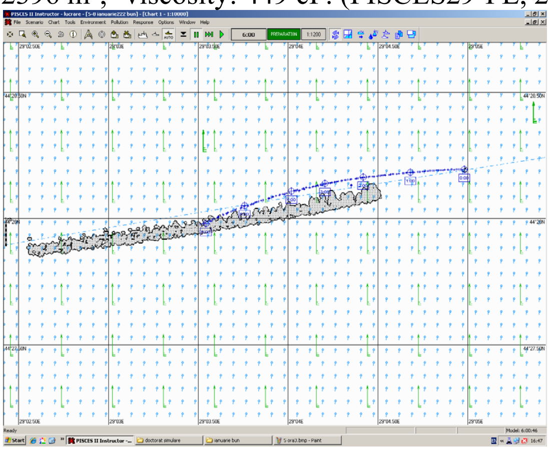

Figure 3. Evolution of oil spill after 6 hours after the accident

d) After 12 hours of the start of pollution:- amount spilled: 85.2 tons;- amount floating: 31.2 tons;- amount evaporated: 20.7 tons;- amount dispersed 33.3 tons;- amount floating mixture: 55.4 tons;- maximum oil film thickness: 0.9 mm;- spill area: 278516 m^2;- viscosity: 780 cP. (PISCES29-PL, 2008) (Fig. 4)

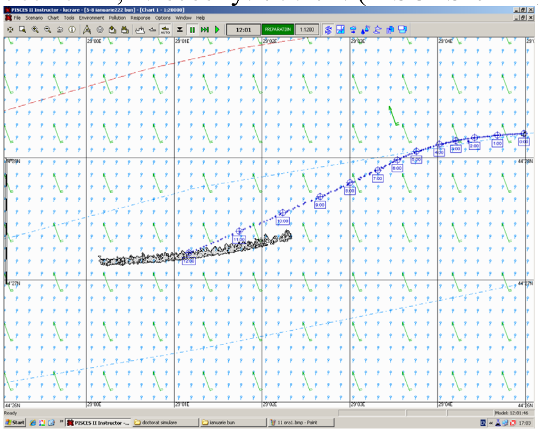

Figure 4. Evolution of oil spill after 12 hours after the accident

e) After 24 hours of the start of pollution:- amount spilled: 85.2 tons;- amount floating: 24.9 tons;- amount evaporated: 23.5 tons;- amount dispersed 36.8 tons;- amount floating mixture: 41.1 tons;- maximum oil film thickness: 0.5 mm;- spill area: 337970 m^2;- viscosity: 1094 cP. (PISCES29-PL, 2008) (Fig. 5)

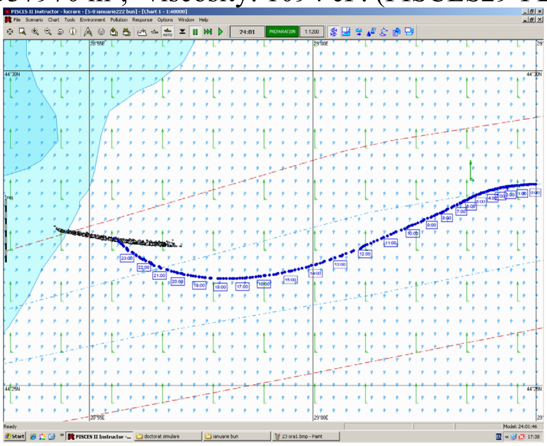

Figure 5. Evolution of oil spill after 24 hours after the accident

f) After 36 hours of the start of pollution:- amount spilled: 85.2 tons;- amount floating: 23.5 tons;- amount evaporated: 24.7 tons;- amount dispersed 37 tons;- amount floating mixture: 41.5 tons;- maximum oil film thickness: 0.5 mm;- spill area: 282293 m^2;- viscosity: 1252 cP. (PISCES29-PL, 2008) (Fig. 6)

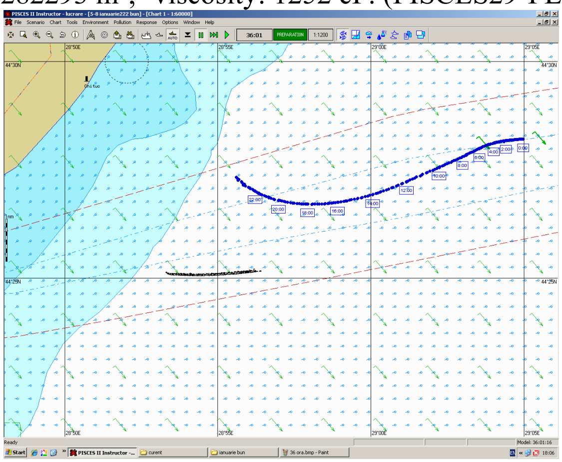

Figure 6. Evolution of oil spill after 36 hours after the accident

g) After 48 hours of the start of pollution:- amount spilled: 85.2 tons;- amount floating: 22.6 tons;- amount evaporated: 25.4 tons;- amount dispersed 37.2 tons;- amount floating mixture: 39.9 tons;- maximum oil film thickness: 0.5 mm;- spill area: 247458 m^2;- viscosity: 1365 cP. (PISCES29-PL, 2008) (Fig. 7)

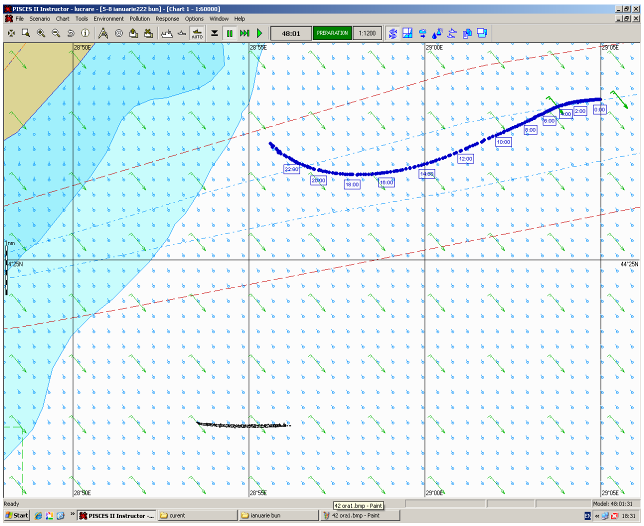

Figure 7. Evolution of oil spill after 48 hours after the accident

h) After 60 hours of the start of pollution:- amount spilled: 85.2 tons;- amount floating: 20.3 tons;- amount evaporated: 26.3 tons;- amount dispersed 38.6 tons;- amount floating mixture: 35.9 tons;- maximum oil film thickness: 0.4 mm;- spill area: 287430 m^2;- viscosity: 1467 cP. (PISCES29-PL, 2008) (Fig. 8)

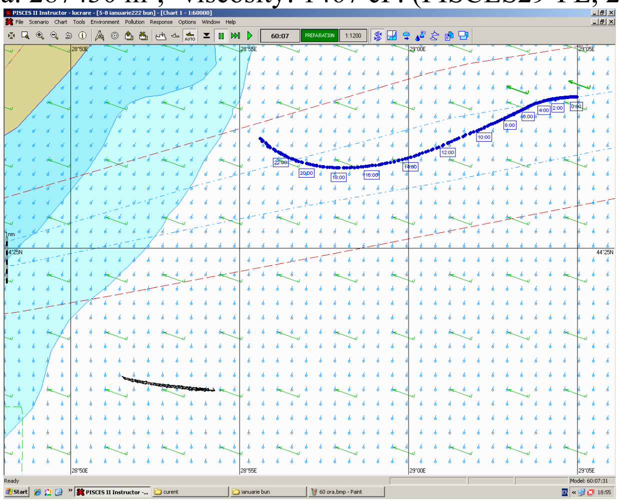

Figure 8. Evolution of oil spill after 60 hours after the accident

i) After 70 hours of the start of pollution:- amount spilled: 85.2 tons;- amount floating: 19.4 tons;- amount evaporated: 26.9 tons;- amount dispersed 38.9 tons;- amount floating mixture: 34.3 tons;- maximum oil film thickness: 0.3 mm;- spill area: 392949 m^2;- viscosity: 1564 cP. (PISCES29-PL, 2008) (Fig. 9)

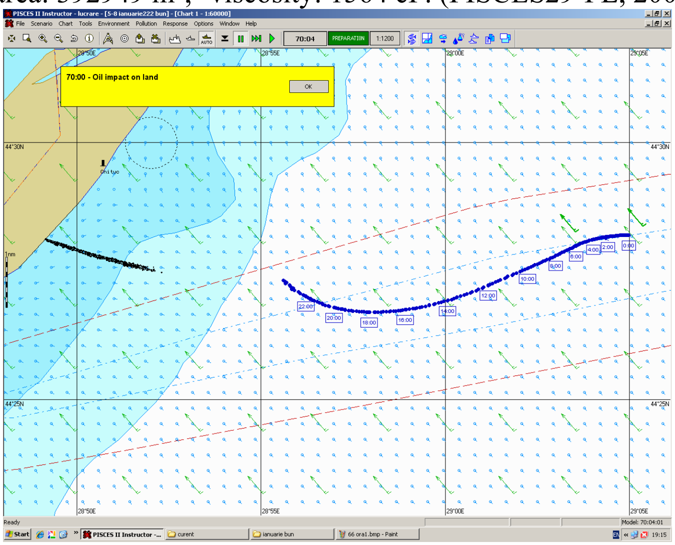

Figure 9. Evolution of oil spill after 70 hours after the accident

j) After 74 hours of the start of pollution:- amount spilled: 85.2 tons;- amount floating: 0.1 tons;- amount evaporated: 27 tons;- amount dispersed 39 tons;- amount floating mixture: 0.3 tons;- maximum oil film thickness: 0.2 mm;- spill area: 6052 m^2;- viscosity: 1585 cP;- amount stranded: 19 tons. (PISCES29-PL, 2008) (Fig. 10)

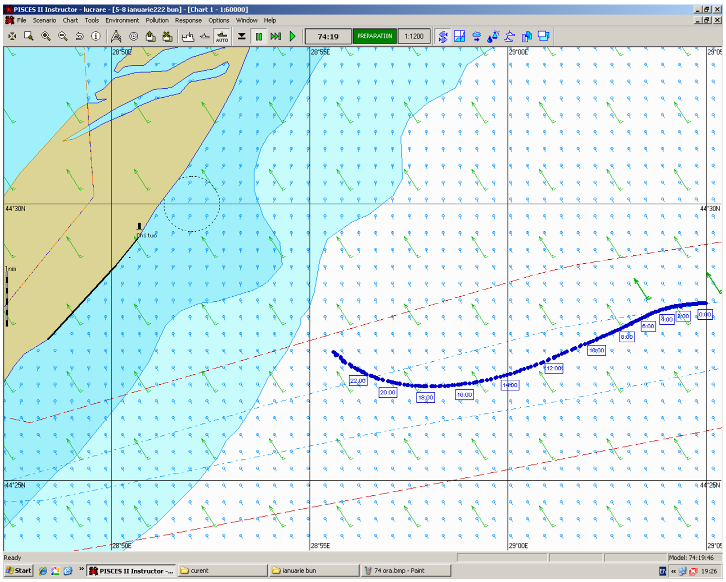

Figure 10. Evolution of oil spill after 74 hours after the accident

5. CONCLUSIONS

Purpose is to determine in the actual environmental conditions, the direction and speed of the oil spill, the size of area affected, the time that authority have to intervene, and areas that could be affected provided the intervention is on time.

It is clear from the simulations performed in the present conditions, that the most important factor that distinguishes between the shoreline pollution and effective intervention of the Romanian Agency Rescue Vessel of Life at Sea for remediation is the minimum distance from shore at which the pollution occurs.

In this case the pipe was broken at a distance of 17.6 km from the shoreline and 26 km from Midia Terminal so in real terms during the studied environmental shoreline pollution could not be earlier than 70 hours after the beginning of pollution, so that Rescue Vessels Romanian Agency Life At Sea, completely equipped for decontamination have enough time to collect timely interventions and oil debris so it can be avoided ecological disaster in the Grindu Chituc Natural Reserve. Other factors that influence the size of pollution (environmental disaster) are: wind direction and speed / current, water temperature, air temperature, sea state. It is considered necessary to draft a large number of scenarios on emergency situations arising from oil pollution to better forecast the evolution in time and space to spillages of oil.

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