International Journal of Engineering & Technology, 7 (2.23) (2018) 24-27

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Numerical simulation of oil spills based on the GNOME and ADIOS

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Abstract

The Exxon Valdez oil spill emergency has shown that simulation of oil spills trajectory is the main action in planning response measures. Modeling the trajectory of the oil slick allows predicting in advance the direction of the motion of the stain, the time it will take to reach the shore and assess the possible environmental consequences for the contaminated coastal zone. In this paper, the Exxon Valdez oil spill trajectory was analyzed using two different models, the GNOME model and the HAZAT trajectory model. Conclusions are drawn about the reasons for the differences in the results provided by the two models. The accuracy of the simulation is strongly related to the input of geographic and meteorological data. In addition, ADIOS software was used to predict the weathering process of the modeled emergency event. It was found that the main factors influencing the change in the physical and chemical characteristics of oil dispersed in the water body are the wind speed and direction, water temperature and wave height.

Keywords: *Adios model, Exxon Valdes oil spill, GNOME mode, Oil spill, Oil spill trajectory.*

1. Introduction

Reserves and oil production are distributed on territories of the different countries unevenly that necessitates oil transportation from one country to another. Transportation of a half of oil extracted on the world shelf is provided by tankers. The inevitable satellite of any tanker operations are accidents. Oil spills negative impact on the environment.

The Deepwater Horizon explosion in the Gulf of Mexico in 2010 year is the largest oil spill in the oil industry's history. The second largest in USA waters after this emergency is the Valdez spill, in terms of volume released. It is considered to be one of the most devastating human-caused environmental disasters. Major oil spills have shown that oil spill trajectory prognostication is fundamental for planning the response.

Scientists use a variety of different models to predict oil spill trajectories. Coastal zone oil spill model (COZOIL) has been tested against data from the 1978 Amoco Cadiz oil spill off Brittany, France. This model designed to simulate oil spill fates both before and after a coastal contact [1].

The simulations of several theoretical oil spill scenarios occurring in the vicinity of the Brazilian east coast were performed by the OSCAR (Oil Spill Contingency and Response) [2]. OSCAR is model system provides a tool for quantitative, objective assessment of alternative oil spill response strategies.

Author [3] applied Oil Spill Model and Response System (OILMAP) to simulate the scenarios of the oil spill event at Damietta Port. The transport process of oil membrane in the condition of different wind and current was observed in Qinzhou by this model [4].

In the study [5] MEDSLIK-II is used to assess potential oil spill scenarios at four pilot areas located along the northern, eastern, and southern Mediterranean shoreline.

The MEDESS4MS (Mediterranean Decision Support System for Marine Safety) multi-model oil spill prediction system, which allows access to several ocean, wave and meteorological operational model forecasts was using for an exercise at sea was carried out to collect a consistent dataset of oil slick satellite observations, in situ data and trajectories of different type of drifters [6].

The new regional oil spill model (i4OilSpill**)** for the Bohai Sea is developed, which can simulate oil transformation and fate processes by Eulerian-Lagrangian methodology [7].

Authors from Turkey [8] studied the oil spill and predicted the future accidents likely to be encountered around the Bay of New York, trajectory of the oil spill in the Shell North Sea Gannet Alpha platform [9], in the Bohai Sea [10], Arabian Gulf and the Sea of Oman [11], in the Gulf of Mexico [12] and around Rajaee port of Bandar Abbas [13] were research using GNOME (General NOAA Operational Modeling Environment) model.

In this study the GNOME model for oil spill trajectory simulation was chosen. It is a publicly available oil spill trajectory model that simulates oil movement due to winds, currents, tides, and spreading [14].

Oil spilled at the sea will normally break up and be dissipated or scattered into the marine environment over time. This dissipation is a result of a number of chemical and physical processes that change the compounds that make up oil when it is spilled. The processes are collectively known as weathering [15]. There are

many different models for estimating the oil spill weathering. MEDSLIK predicts the oil spill on a sea surface; dispersed, evaporated, stack on coast, oil spill volume, oil spill viscosity, oil density. The model has been used for simulating of weathering along the coast of Lebanon [16], the coast of central Israel [17], in the Levantine Basin [18].

The POSEIDON-OSM simulates process of the evaporation, the emulsification, the beaching and the sedimentation. It is used for the Aegean [19-20], Baltic [21] and Greek Seas [22]. ADIOS (Automated Data Inquiry for Oil Spills) is NOAA's oil weathering model. ADIOS model how different types of oil weather (undergo physical and chemical changes) in the marine environment [23]. It have been used by numerous authors [11; 24-25].

In this study was used ADIOS because this program quickly estimates the expected characteristics and behavior of spilled oil in any area. Working from a database of more than a thousand different crude oils and refined products, ADIOS quickly estimates the expected characteristics and behavior of spilled oil [23].

The objective of this paper is twofold. Firstly, it is studding the oil spill trajectories of Exxon Valdez oil spill using the GNOME model. Although for modeling essentially requires only a few basic input parameters and weather data the GNOME model assesses adequately an emergency. The created model was compared with HAZAT trajectory model. One of the findings of the study is the models differences causes. Secondly, weathering oil spill was analyzes with using ADIOS. High winds and storms accelerate the oil slick dispersion process. Simultaneously with the oil spill spreading process evaporation begins. The rate the weathering process depend on structure oil, turbulence and temperatures of the sea, high wind and size of the oil slick.

2. The numerical simulation of oil spills based on the GNOME

2.1. GNOME-based oil spills simulation

GNOME are used to predict how winds, currents, and other processes might move and spread oil spilled on the water, to learn how predicted oil trajectories are affected by inexactness ("uncertainty") in current and wind observations and forecasts, to see how spilled oil is predicted to change chemically and physically ("weather") during the time that it remains on the water surface. GNOME shows movie with oil spill trajectory [14].

The Exxon Valdez oil spill occurred in the Prince William Sound, Alaska, March 24, 1989, when Exxon Valdez struck Prince William Sound's Bligh Reef at 00:28 am local time was chosen to predict. 257 barrels of crude oil spilled over the next few days. The emergency has caused tremendous damage to the environment [26, 27].

2.2 The simulation of Exxon Valdez oil spill

For the start is necessary to add geographic parameters in the order to create a simulation model in the GNOME. The electronic version of the Prince William Sound's map can be downloaded from the NOAA Official website [14]. On the map it needs to enter the emergency place, which has 60°50'49"N 146°52'2"W coordinates.

After adding the information is necessary to enter data about speed and wind direction in analyzable period of time. The change of the Exxon Valdez oil spill was research from 24 March at 00:28 till 30 March at 00:00 1989. Data of speed and the direction of wind for each hour were entered.

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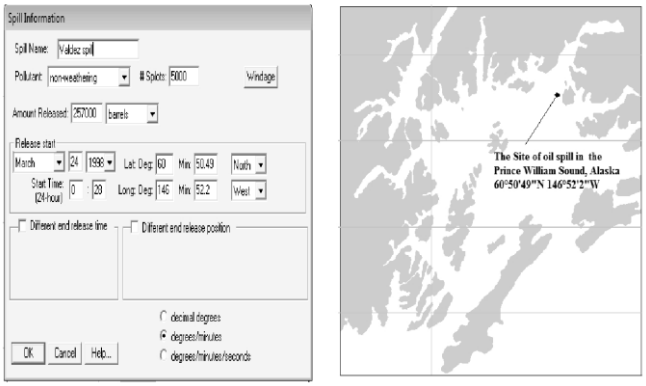

Fig. 1: The Map of the Prince William Sound (Alaska) and adding the data

26th, 27th, 28th March 1989 year in the Prince William Sound was storm. Speed of wind reached 50 km/h with rushes to 65 km/h. The oil spill have shifted because of the storm to remote areas.

Results of the simulation could be obtained by adding the data about change of the speed and wind direction with time. The figure 2 are presented results of the simulation of the Exxon Valdez Oil Spill based on the GNOME.

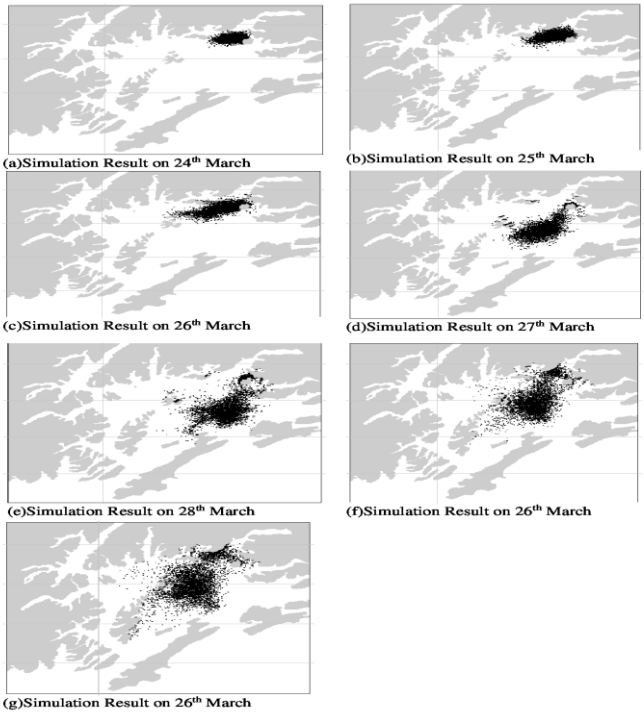

Fig. 2: The simulation of Exxon Valdez oil spill based on the GNOME

On the first, second and third days oil spill is near from accident place – Bligh Island and moves in the southwest direction. For the fourth day oil spill is McPherson Bay and pollutes coast of the Naked Island. Fifth, sixth and seventh day oil spill promptly moves in the southwest direction. This trajectory of the oil spill is due mainly tospeed and wind direction. Wind has primarily southwest direction. In the first days low-windy weather is observed (3-4 m/s) therefore the oil spill extended not to considerable distance. The next days was storm. Wind gusts reached 20 m/s. The oil spill extend to considerable distance and is on the coast the Knight Island.The most part of an oil spill is concentrated in the Prince William Sound.

2.3 The simulation of Exxon Valdez oil spill by HAZMAT

Hazardous Materials Response and Assessment Division (HAZMAT) created own model of the Exxon Valdez oil spill. It is shown on the figure 3.

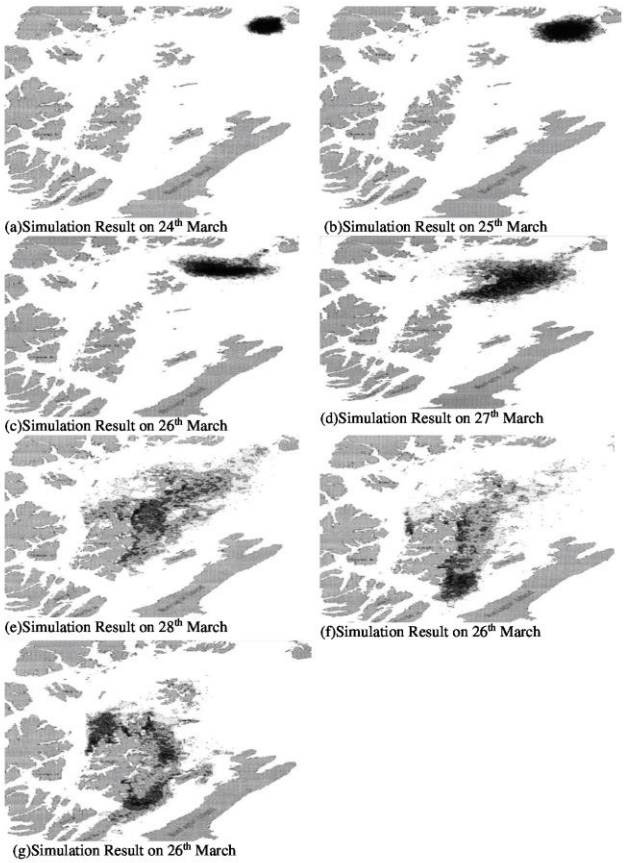

Fig. 3: The simulation of Exxon Valdez oil spill by HAZMAT

On the Figure above one we can see that oil spill extends quickly. For the fourth day oil spill pollutes coast the Knight Island and on the seventh day since the accident it is on the coast the Latouche Island.

2.4 The comparison of simulated results

By comparing this simulated results and HAZMAT trajectory model it can be concluded that:

- the first and the second days: results are differ insignificantly. The next days have essential differences.
- the third day: on the model that have been created oil spill is the Bligh Island and has more extended form.
- the fourth day: the oil spill on the first model is to the east. On the second model the oil spill pollutes northern, western and east coasts of the Naked Island.
- the fifth and sixth day: on the first model the majority of volume of oil is in the Prince William Sound and moves in a northern and southern directions. Valdez Arm and Port Valdez are polluted. Oil spill of the HAZMAT trajectory model is coast the Knight Island and has more extended form.
- seventh day: on the model that have been created oil spill is the Prince William Sound and Valdez Arm.

On the second model the oil spill continues to move in the southern direction and pollute the Latouche Island. Majority of volume of oil is coast of the Knight Island.

The possible reasons of models differences could be as follows:

1) geographical parameters are insufficiently precisely entered
2) different sources of data about speed and wind direction were used
3) oil spill trajectory predicting difficulty in a storm

3. ADIOS-based Simulation of Oil Spill Weathering

The first step is enter type of pollution substance (choose the type of oil). For analyzes is chosen the type of Alaska North Slope oil which has the characteristics: API=26,8; Pour Point= -8 °C; Density=0,904 g/cc at 0 °C; Viscosity= 42,4 cSt at 0 °C; Adhesion= 0,28 g/m^2

The second step is adding the data about wave height, speed and wind direction.

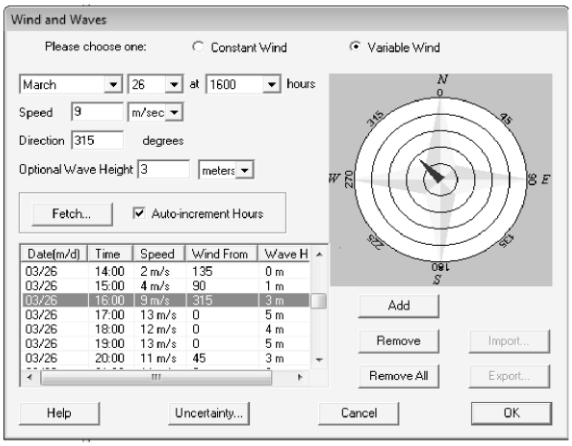

Fig. 4: Adding the data about wave height, speed and wind

The third step is enter data about temperature and salinity of water. Water temperature was 8 °C, water salinity was 32 ppt (g/kg) at the end of March.

The fourth is choose the type of the source of pollution: Instantaneous Release, Continuous Release, Leaking Tank, Containing Release. Continuous Release was chosen. The analysis beginning time and volume of spilled oil is entered at this stage.

Weathering of the Exxon Valdez oil spill from 24 March till 28 March 1989 was analyzed by ADIOS. Volume oil spill is 257000 barrels. Results of calculations are presented in Figure 5.

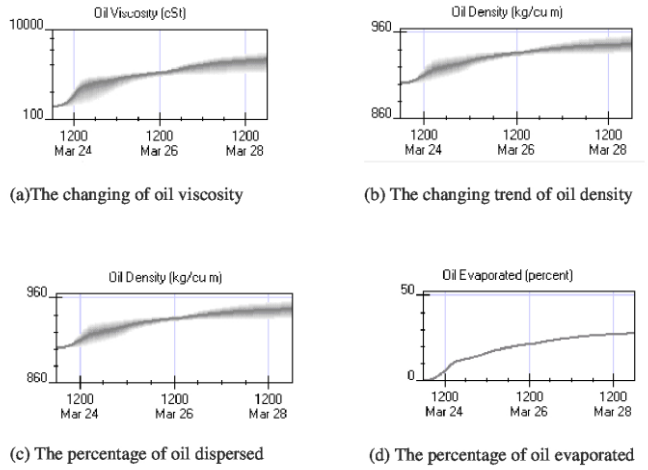

Fig. 5: ADIOS-based simulation of the change of the characteristics of Exxon Valdez oil spill

The modeling results analyzes show that characteristics of the oil spill remained unchanged early in the morning on 24 March. Evaporation and dispersion of oil begin at 10 a.m. The evaporation of oil show a trend towards an increase with time: on March 24 evaporates 12 %, March 26 - 23%, March 28 - 27%. From March 24 to March 26 the oil dispersion percent increases evenly. The sharp increase is observed on March 27. Dispersion becomes stable at about 8% on 27 March. The viscosity and firmness increases with time. Their rates are 750 cSt and 950 kg/m^3 on 28 March.

4. Conclusion

The Exxon Valdez oil spill trajectory modeling with using GNOME model was implemented. The trajectory of the oil spill is due mainly to speed and wind direction. The oil spill extended to considerable distance in the storm under the influence of high winds and was on the coast the Knight Island. The most part of an oil spill is concentrated in the Prince William Sound. The model of the Exxon Valdez oil spill was compared with the HAZAT trajectory model. In the early days results differ insignificantly. On the seventh day on the HAZMAT trajectory model the oil spill extended more considerable distance. The reasons of models differences probably could be related to using different sources of weather information and also oil spill trajectory predicting difficulty in a storm.

The conclusions are drawn about the oil change of under the influence of various factors with program ADIOS. The changes are influenced by the wind, tide and weather. The modeling results analyzes showed that characteristics of the oil spill remained unchanged early in the first hours. Evaporation and dispersion of oil began in 10 hours since the accident. . Dispersion becomes stable at about 8% in 3 days. The viscosity, density and evaporated of oil have increased over time. The weathering simulation the oil spill is in line with the changing laws of oil spill weathering.

Acknowledgement

The presented research was financially supported by the Russian Science Foundation (grant no. 17-77-30006).

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