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# Disaster risk management in the maritime area of Romania. Case study: risk of oil pollution by modeling and simulation

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**Abstract**. Among the threats to the internal security environment, due to the associated risks, can be identified the economic activities that take place in the western part of the Black Sea coast: maritime transport, exploitation of resources in the maritime economic zone, economic objectives located in the coastal zone and so on. The paper identifies the risk of marine pollution with oil or other hazardous substances / goods, as a possible threat, with major economic, social, political and environmental implications. From this perspective, the paper emphasizes the need to identify solutions that increase the capacity to respond and intervene in order to counter threats and ensure resilience. The paper identifies a specialized tool, integrated in an innovative scientific approach, to support the authorities in managing the risk of marine oil pollution in the Romanian maritime area through modeling and simulation.
**Keywords.** maritime area of Romania, oil spill, risk management.

## 1. Introduction

Sustainable development of society can only be achieved on the basis of a dynamic model, which takes into account the risks associated with the key components for society, in terms of: economic, technological - energy and environmental. From this perspective, a threat to national security and defense may also be the materialization of risk factors responsible for the occurrence of regional ecological disasters [1].

In terms of associated risks, the analysis is reduced to activities in the maritime sector, this will include a number of activities and issues considered relevant: maritime transport, port activities, services to ships and goods, shipbuilding and repairs, offshore activities, the actions of the navy, the risks associated with wrecks sunk along the coastal area, etc.

International events have shown that environmental threats are diverse in terms of the activities and issues mentioned above, both in terms of the sources of risk and their magnitude and impact, with marine pollution from oil or other hazardous substances / goods being identified as significant threat to the entire maritime sector [2].

Under the highlighted risk conditions, in accordance with The Black Sea Contingency Romania has developed the National Plan for preparedness, response and cooperation in case of marine oil pollution, [3,4]. Within this plan, Romania undertakes to apply the provisions of the International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC) in the area of the Romanian coast, in the area of the territorial sea and in the exclusive economic zone of Romania, in order to respond effectively and efficiently to a possible marine pollution with oil or other dangerous substances / goods.

In the phase in which this plan was elaborated, it was wanted to organize at national level the preparation, cooperation and intervention in case of pollution. According to the analyzes carried out by

the European Maritime Safety Agency (EMSA), Romania's preparedness and response capacity in the field of pollution intervention (response capability criteria, specialized intervention equipment, specialized intervention vessels, specialized response teams) is non-existent or very limited, exposing to potential risks the maritime area and the coastal area of Romania, vulnerable protected areas, economic and social activities, port infrastructure and last but not least the marine environment [5]. At this time, although the existing specialized technical authorities at national level have some of the appropriate capabilities for intervention, there are still no bodies / structures / institutions with the expertise to scientifically assess oil pollution. International experience in the field highlights the need to permanently identify and assess the risks associated with activities / entities in maritime areas. Globally, national and regional contingency plans include studies and analyzes using specialized tools for modeling and simulating pollutants in time and space, which make it easier to estimate the maximum foreseeable consequences if the risk materializes. The results obtained by modeling and simulation are used to develop the intervention strategy in case of pollution by oil or other hazardous substances.

In this context, the PLATMARISC project aims to build an intervention strategy based on an integrated risk management system. Within this strategy, from the perspective described above, the paper proposes an innovative solution for the management of the risk of oil pollution. In this paper, are presented in an organized way the following sections: literature review, sources of oil pollution in the analyzed areas, research method, identification of the software solution to be used in pollution risk management, conclusions and future research directions.

The research was carried out within the project POC/163/1/3 120201 *Platforma maritima integrata inovativa destinata intervenției în timp real prin asistenta simulata in gestionarea riscului la dezastre în zonele costiere si portuare* (*Innovative integrated maritime platform for real-time intervention through simulated assistance in disaster risk management in coastal and port areas*) - PLATMARISC.

## 2. Literature review

Marine oil pollution takes various forms, being associated with the main activities carried out. The analysis of the risk of disasters in the maritime area of Romania highlights the fact that maritime transport, the activity in the port of Constanța but also other activities or related aspects are assimilated as potential sources of pollution. To these are added the objectives and economic activities carried out in the coastal or offshore area, the concession for the exploitation of oil resources in the western Black Sea basin, the activity of the Midia Marine Terminal, the activities of taking over the finished products to / from the Petroleum Plant Midia etc.

The existence of wrecks in the area of the Romanian coast is identified as an important risk factor, as over time the hull of sunken ships will yield structurally, and the fuel on board will be able to cause pollution of the marine environment.

Relevant scientific papers highlight the risk of oil spills associated with the maritime transport activity [6-9]. In particular, these risk factors are materialized in the form of maritime accidents due to: current ship operating activities [10,11]; loading / unloading operations of oil tanks and bunkering of other ships [12,13]; unloading of oil waste at the terminal [14,15].

The analysis reveals that a high pollution risk characterizes the activities carried out in the port terminals, with priority in the terminals for petroleum products (on-shore or off-shore terminals), in the oil refineries located in the coastal area [16-18. The risk of pollution is also present in the activities of offshore drilling rigs [19,20] or in case of possible damages to the submarine oil transfer pipelines from the extraction area to the land facilities [21,22].

From another perspective, the existing wrecks in the area of the Romanian coast are an insufficiently approached problem. In the records of the Romanian Naval Authority there are an important number of wrecks sunk in the area of the Romanian Black Sea coast. As stated, over time, the hull will yield structurally, and the fuel on board can lead to pollution of the marine environment. For these reasons, an assessment of the causes that may lead to structural failure and pollution risk management associated with wrecks is needed [23,24]. Carter et. all [25] shows that each case in this risk category must be

addressed in a timely manner depending on the specific situation on the ground, a risk assessment methodology is needed [26].

In the conditions set out above, the analysis of the risk of disasters, in particular that of the risk of pollution of oil / other harmful substances, shows that in all cases the risk factors are of a high complexity [27,28]. The literature shows that the determination of the maximum foreseeable consequences / associated potential impact depends on a number of variables: the amount of oil and the type of oil, the time and place of the spill, the hydro-meteorological conditions [21,29]. Under these conditions, the risk assessment can be supplemented by geographical information on oil spills in the coastal / coastal zone [18,30].

Thus, the issue of marine pollution by oil or other hazardous substances is globally identified as a major threat to the maritime field. International practice shows that in many cases, when analyzing the risk of disasters associated with maritime areas similar to the maritime area of Romania, it is necessary to develop a methodology to facilitate the development of a common approach to environmental risk assessment / ecological risks [31-34].

From scientific approach, the authors directed the research to study the components of systems in coastal / port maritime areas on the Black Sea with a role in generating disaster risk and identifying dynamic parameters that could be modeled and simulated. The study will facilitate the identification of the main sources of pollution, which will be classified according to the level of risk assessed, both in case of accidental pollution and in case of operational oil pollution (from ships, oil terminals, submarines, to offshore platforms, from wrecks, etc.). The results of the research will be used in project POC/163/1/3 120201 - PLATMARISC to scientifically assess the risks and to model and simulate in time and space the pollutant, facilitating the estimation of the maximum foreseeable consequences, serving to develop the intervention strategy in the event of pollution by oil or other dangerous substances.

## 3. Sources of oil pollution in the maritime and fluvial area of Romania

Within the PLATMARISC project, the sources of stationary and mobile oil pollution located in the area of the port of Constanța and in the area of the Romanian sector of the maritime and fluvial Danube were identified.

The potential sources of risk in the analysis area are:

- activities carried out in the economic maritime area of Romania, figure 1 (activities of the main specialized terminals in the port of Constanța; activity of Midia Marine Terminal; off-shore activities);
- the main maritime transport routes in the western part of the Black Sea, figure 2.


Figure 1. Delimitation of Romania's economic zone on the Black Sea (adaptation after [41])

Figure 2. Maritime transport routes in the western part of the Black Sea

**Table 1**. Summary of the activity of the main specialized terminals in the port of Constanța

| The port terminal | Type of cargo operated | | | | | | Operating berths | Characteristics of the analyzed location | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | B | L | C | R | Iw | | A (ha) | $L_d$ (m) | $C_D$ | A (m) |
| Comvex | | | | | | | 80-84, 94-96 | 70 | 1.400 | 200.000 | 18 |
| DP World (CSCT) | | | | | | | 121-130 | 76 | 636 | 42.000 | 16,5 |
| APM Terminals | | | | | | | 119 | 3,8 | 273 | 2.890[2] | 14,5 |
| Midia Marine Terminal (MMT) | | | | | | | MD 1-4, 9 and SPM | 13 | 970 | 500[3] | 8,2 |
| North Star Shipping | | | | | | | PL1, PL3-5 | 5,4 | 440 | 260.000 | 13,5 |
| Oil Terminal | | | | | | | 69-76, 79 | 250 | 2420 | 90.000* | 13,5 |
| Chimpex | | | | | | | 54-63 | 18 | 2.263 | 600.000[1] | 13,5 |
| United Shipping Agency | | | | | | | 31-33, 102-103 | - | - | - | - |
| Socep | | | | | | | 35-37, 41-43, 51-52 | - | - | - | - |
| Canopus Star (TTS) | | | | | | | | 4 | 310 | 50.000[1] | 13,5 |
| Silotrans | | | | | | | 113-114 | - | - | - | - |
| DB Schencker | | | | | | | 108-112, 115-118 | 24 | 2.200 | 1.100.000[1] | - |
| Minmetal | | | | | | | 45-46, 64-66, 85 | - | - | - | - |
| European Metal Services | | | | | | | 91-93 | - | - | - | - |
| Umex | | | | | | | 38-40, 44, RoRo3 | - | - | - | - |
| Decirom | | | | | | | 23, 47-50 | 9,18 | 960 | 22.000[1] | 13,5 |
| Kronospan | | | | | | | 131 | 11 | 225 | 60.000[1] | 16,5 |
| Eurotranzit 2000 | | | | | | | MD5-8 | - | - | - | - |
| Romned Port Operator | | | | | | | 0-7 | - | - | - | - |
| Phoenix | | | | | | | 8, 22 | - | - | - | - |
| Frial | | | | | | | 19, 53 | 5,2 | 334 | 27.000 | 13,5 |
| Romcargo Maritim | | | | | | | PL6 and 120 | - | - | - | - |
| Barter | | | | | | | DPL7 | 3,35 | 200 | 60.000[1] | 14,5 |

*Note: D - solid bulk goods; B – general non-containerized goods; L – bulk liquid goods; C – containers; R – Ro-Ro; Iw - iron waste. Occupied area (A-ha); The length of the berth (Ld m); Storage capacity (CD expressed in: 1tons/year; 2TEU; 1qm/h); Maximum depth (A-m);*

The research highlighted the fact that the potential sources of pollution in the Romanian coastal area are located in the industrialized coastal areas (Constanța, Midia-Năvodari and Mangalia) and in the continental shelf, intended for offshore activities. In industrialized coastal areas, the pollution is due to companies, sewage treatment and treatment plants, cargo ships in operation or in the anchorage area, etc. The activity in the main Romanian ports is oriented both for the operation of the ships and for the processing of a part of the goods, which are the object of water transport.

The research carried out by the authors analyzed the main activities that take place in the ports of Constanța, Mangalia and Midia in order to identify risk factors. The documentation was executed for each port operator, the relevant information being centralized in table 1. The research showed that the main economic objectives with potential pollutants are: Oil Terminal berths 69-79, offshore oil terminal Midia Marine Terminal, shipyards in Constanța, Midia, 2 Mai Mangalia, Danube ports, Danube-Black Sea Canal, Danube River.

From an economic perspective, the oil and natural gas reserves in the Black Sea are of major importance for the regional economy. Their exploitation also poses a significant risk of marine pollution. Starting from this situation, it is necessary to remember that the accidents of the oil platforms Ixtoc (1978), Piper Alpha (1988) and Deepwater Horizon (2010) each resulted in huge spills of oil in the marine environment (of the order of hundreds of thousands of tons) question's the safety of the marine environment.

A detailed analysis shows that part of Romania's economic interests in the Black Sea area are associated with maritime routes, which transit the coastal area of the Romanian coast.

Thus, maritime transport is one of the main contributors to pollution of the marine environment. Accidental pollution, due to oil tanks, often has a major impact on the environment, affecting large areas of seas and oceans but also coastal areas, including protected areas that are particularly vulnerable [35]. In addition to oil tanks, other cargo ships operating on established North-South trade routes parallel to the coast and east-west to Ukraine, Russia and Georgia or on the navigable Danube are also a source of risk of oil pollution [35].

In the geo-political and military context of 2022, potential accidents that could result in oil spills call for a responsible analysis of the causal chain and the maximum foreseeable consequences, following which decision makers must decide on the current framework and practices in terms of safety but also the capacity for preparedness and intervention in case of pollution. The results and information obtained in this section of the paper will be used to determine the risk of oil pollution corresponding to activities and entities located in the maritime area of Romania.

## 4. Research methodology

### *4.1. Oil pollution risk assessment for the maritime area of Romania*

As stated, the economic, social, political and military context in the western part of the Black Sea coast motivates all stakeholders, who have responsibilities in carrying out identified activities, to maintain ecological balance and conserve biodiversity in Romania's maritime area. To assess the risk of oil pollution for each of the activities / entities presented in Table 1, the research was structured in 3 stages, Figure 2: POL-RISK1, POL-RISK2 and POL-RISK3.

POL-RISK 1. In the first stage, is made a synthesis of the information resulting both from the analysis performed in the field / in-situ and from the analysis of the literature. The study aimed to collect qualitative and quantitative information on economic entities carrying out activities similar to those analyzed in Table 1. Where appropriate, the investigation reports of accidents involving oil spills or dangerous substances in the period 1990-2020 were consulted and analyzed. The relevant information was organized in classes and analysis groups, to clarify the following topics: sources of pollution, operated goods, causes of pollution accidents identified in the analyzed period and establishing a history of risk, consequences / impact on the environment resulting from a pollution etc.

POL-RISK 2. In the second stage, specialists in the following fields were consulted: maritime transport, port activities, services provided to ships and goods, shipbuilding and repair, offshore activities, activities specific to the navy, depollution operations, ship refloating actions.

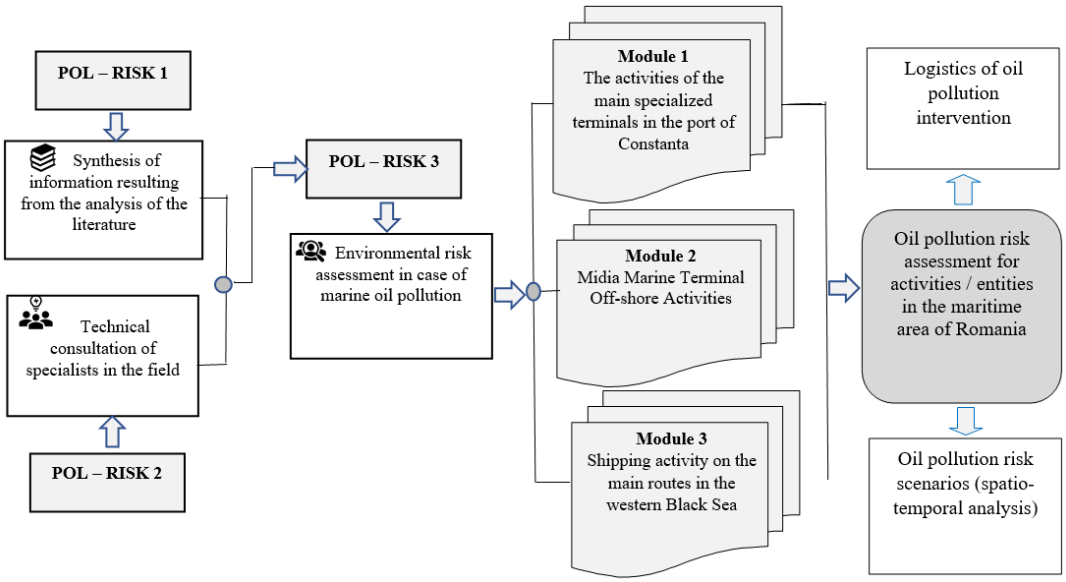


Figure 3. Assessment of the risk of oil pollution for the activities/entities in the maritime area of Romania.
Establishing risk scenarios (spatio-temporal analysis) and intervention logistics for oil pollution

Each round of discussions was made by an integrating expert, who organized and led the debates in the following directions: presentation of the purpose of the research; presentation of the synthesis obtained within the POL-RISK1 module. The results of the POL-RISK stage 2 were organized and centralized in classes / analysis groups, which would allow the clarification of the following topics: sources of pollution, causes of pollution accidents, frequency of a pollution accident, consequences / impact on the environment, etc. The results of step POL-RISK 2 were used in step POL-RISK 3.

POL-RISK 3. The purpose of this step was to assess the level of environmental risk for each of the activities / entities presented in Table 1. The results obtained during the POL-RISK stage 2 were organized in 3 modules: Module 1 - the activities of the main specialized terminals in the port of Constanța; Module 2 - Midia Marine Terminal & Off-shore Activities; Module 3 - Naval transport activity on the main routes in the western Black Sea. The experts who participated in the POL-RISK 3 stage were selected from among the seafarers (managerial and operational level), representatives of port operators, responsible in the field of risk and safety in maritime transport, specialists in offshore activities, etc. The experts were organized in teams of 4 members for each module (for the cohesion of the analysis only one expert was kept of those who participated in the POL-RISK stage 2).

For the activities / entities present in the 3 modules, 6 levels of risk have been established for marine oil pollution / hazardous substances classified as follows: 0 - No risk; 1: Insignificant risk; 2 - Poor risk; 3 - Significant risk; 4 - Heavy risk; 5 - Maximum risk.

After the detailed analysis, each expert gave a score based on which the risk of oil pollution assessment is performed for the activities / entities in the Romanian maritime area. The logic diagram corresponding to the concept plan (figure 3) provides the information to be used for establishing the risk scenarios (spatio-temporal analysis) and the intervention logistics in case of oil pollution.

### *4.2. Modeling and simulation of marine oil pollution accidents*

The references analyzed in section 2 highlight the importance of the process of managing emergencies /pollution in the maritime area of Romania. The emergence of new types of pollution risks (internationally recorded events but also the economic and military context in the Black Sea) generates

increasingly complex needs in the field of managing such events. In this context, the use of appropriate tools, through which risk scenarios can be developed (spatio-temporal analysis) and the establishment of the minimum logistical intervention for oil pollution, is a necessity.

A major oil pollution corresponds to a high-complexity physical-mathematical model, influenced by an important set of factors: the variable geometry of the area where the discharge takes place, especially when it includes the coastal area; a set of parameters that characterize the discharge of the pollutant (amount discharged, type and properties of the pollutant product, discharge rate, etc.); difficult delimitation of impact areas (from small areas to areas spread over for hundreds of kilometers); variability of hydro-meteorological conditions (temperature, wind direction and force, water currents, etc.). In most cases, the availability of this information as well as time and space management increase the complexity of oil pollution accident modeling.

A series of models that simulate the process of degradation and spatio-temporal evolution of the film of oil discharged into the marine environment or on a course of water have been developed [36-38]. The spatio-temporal evolution of the spilled film can be described by a two-dimensional mathematical model, the process being divided into three stages: stage 1 which takes place in the first minutes of the spill, under the action of gravity-inertial forces; stage 2 which takes place within a period of up to 20 hours after the spill, under the action of gravity-viscous forces; stage 3 characterized by the action of tension and viscous forces, the oil film is fragmented and then dispersed (tension-viscous stage).

The trajectory followed by the oil film can be described by means of the Euler model or the Lagrange model [39]. The Euler model is based on the equations of conservation of mass and momentum, applied to an oil slick, and on the convection-diffusion equations, which model the process of natural spread of oil and its horizontal displacement under the action of currents and wind. The Lagrange model is the representation of oil spills by the movement of a large number of particles under the combined effect of wind, currents and diffusion process.

Practice has shown that both methods are limited, in the case of simulating the pollution response, the results obtained in modeling the interaction between the pollutant film and the anti-pollution barrier systems being inconclusive [40]. In these conditions, for the management of the risk of oil pollution, in an area such as the maritime and fluvial area of Romania, it is necessary to use specialized solutions, such as Oil Spill (OS) Simulation Module, to ensure the modeling and simulation of pollution processes, figure 4.

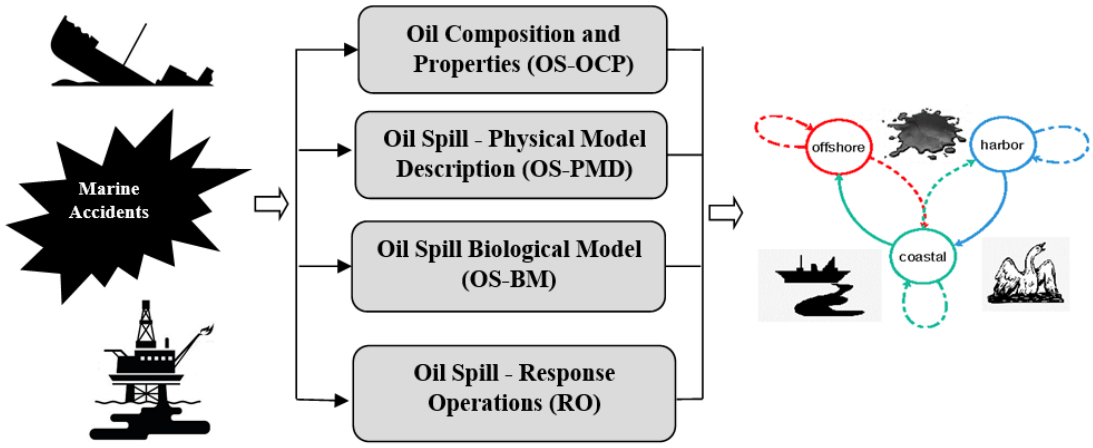


Figure 4. Oil Spill Simulation Module

*4.3. Identifying the requirements for the specialized model for modeling and simulating the risk of oil pollution*

An Oil Spill Simulation Module tool must be flexible and efficient, allowing not only the generation of possible scenarios, made after the investigation / research, which is strongly multidisciplinary but also training / preparation for interventions. From this perspective, disaster risk management in the Romanian

maritime area, on the Danube, on inland waterways or in the Danube Delta is a major objective of the national maritime and river policy. These areas are perceived as areas with biodiversity and precious natural values, which require the implementation of high standards of environmental management. From this perspective, adequate protection must be provided for these areas against disasters caused by pollution, such as spillage of pollutants from ships or other fixed sources at sea or on land.

The analysis of the relevant references but also of the real situations existing in the field shows that there is room for improvements regarding the coordination and collaboration between the government agencies that have attributions of intervention in the emergency situations generated by pollution. Emergency agencies are the main coordinating structure for marine pollution with oil / hazardous substances, and the agencies that take over the management of operations are different depending on the location and severity of the pollution.

Affected maritime areas and inland waterways are often difficult to monitor and access, and responsible agencies need to continuously improve their preparedness and response capacity, given the growing risks of water pollution. On the other hand, intervention units do not have sufficient means of intervention, adequately equipped to be able to manage incidents of water pollution in the areas of interest. Starting from the real situation, which characterizes the current state of the problems reported in the mentioned areas, a module for researching and preparing emergency situations associated with oil pollution / dangerous substances is a solution that could solve the reported problems.

Starting from the main objective of disaster risk management in the maritime area of Romania, a synthesis of the main requirements imposed to Oil Spill (OS) Simulation Module was made.

*4.3.1. Research, preparation and training facilities*

By customizing emergency situations, to the one corresponding to marine oil pollution, such a module must ensure both the research stage and the preparation and training stage. The module should provide participants with an interactive environment, by generating relevant information based on mathematical modeling of the environment, hydrometeorological conditions (wind, current, etc.) and the amount of oil reached in the water. The module should be a powerful research tool, mainly aimed at dynamically simulating the pollution of the marine environment with oil and supporting (planning) response operations.

It is necessary that the elements of the mathematical model, which are the basis of the specialized module, to provide information about: the nature of the film of spilled oil, hydrometeorological conditions, evaporation processes, emulsification, dispersion, viscosity variation, distance from the coast, including suggestions for intervention equipment.

*4.3.2. Flexible and efficient structure adapted to the requirements*

The main requirements that the module must meet are:

- to integrate the information provided both in real time as a result of an ongoing event and in the modeling developed for research or exercises;
- to include the provisions of international conventions (Marpol 73/78, Oil Pollution Act 1990, OPA 90);
- the simulation medium must facilitate the precise modeling of the pollutant film trajectory and allow the determination of the area in which it will reach the coastal zone;
- to facilitate the process of establishing forecasts regarding the behavior of the pollutant under the effect of hydrometeorological factors, including the problem of dispersal of pollutants;
- to offer the possibility to establish a real working interface with GPS and AIS modules.

*4.3.3. Generation and development of pollution intervention scenarios*

In performing the simulations, the module must ensure the selection of systems and equipment for intervention in case of oil pollution: vehicles, ships, aircraft, skimmers, dispersant spreading equipment, firefighting equipment, technique used in Search And Rescue operations, personal. Thus, the system must offer the possibility of using a real database, specific to each simulated accident, with the

possibility of generating new scenarios for research or training. Also, the system can be used to organize the response in real situations or for training. For the data used by the simulation module it must be possible to change the data in real time, depending on the existing / collected information in the affected area, weather conditions, including air temperature, wind speed and direction, wave height, current profile. The module must offer the possibility to use both maps previously developed by the manufacturer and electronic maps and references from other sources, such as topographic maps, aerial photographs, satellite images, electronic maps developed according to the S-57 standard. Based on these requirements, a series of programs / modules for simulation of pollution with dangerous substances / oil have been identified, table 2.

**Table 2.** Synthesis of modules for simulation, control and assessment of situations of marine pollution with oil / hazardous substances

| **Simulation module** | **Simulation module facilities** |
|---|---|
| Environmental Sensitivity Index (ESI) Maps | ESI performs in-depth analysis of the effects associated with oil pollution. |
| GNOME | GNOME is a modeling and simulation software that predicts the evolution of the oil film due to a spill on the surface of the water. |
| Trajectory Analysis Planner (TAP) | TAP is a useful tool in developing contingency plans. Provides solutions to protect areas from likely oil spills. |
| Spill Tools | Spill Tools is a free set of programs that allow to simulate the effects associated with a oil spill. |
| Dispersant Mission Planner (DMP2) | DMP2 is a useful tool for sizing the ability to respond to oil pollution through the use of dispersants. |
| Selection Guide for Oil Spill Response Countermeasures | The online guide develops a set of measures applicable in the event of a oil spill. It allows rapid impact assessment and facilitates the determination of minimum response measures. |
| ADIOS | ADIOS is a tool used to determine the response to pollution, adapted to the type of oil spilled and the specific conditions of the environment in which the spill took place. |
| GOODS | GOODS is an online tool that completes the GNOME package. Converts the necessary information to the GNOME format in the decision-making process (data on ocean currents, wind distribution, etc.). |
| CAFE | The CAFÉ database completes pollution response facilities, assesses the impact on the environment and on biological species subject to the impact of oil and chemicals. |
| Unit Converter for Spill Responders (NUCOS) | The simulation unit allows the assessment of the impact associated with a spill of oil / other pollutants. |
| Electronic IncidentCommand System (ICS) Forms | The ICS package is used to develop the capacity to respond to pollution or other emergencies. |
| PISCES II | A powerful tool for planning and decision-making in support of pollution prevention or real-time action. |

## 5. Results

The complex simulation program PISCES II (Potential Incident Simulation Control and Evaluation System) was identified as a possible tool that could be used for disaster risk management in the Romanian maritime area. The PISCES II module provides facilities for both research and training, Figure 5. Also, PISCES II develops accident scenarios, through which national authorities, with

responsibilities for the safety of shipping and the prevention of environmental pollution, can develop training programs for the responsible human resource. At the same time, the module provides the necessary support in the pollution decision-making process, contributes to the development of the capacity to identify and assess the consequences of pollution of water and land areas (coastline, inland waterways, wetlands, etc.); environmental impact assessment (flora and fauna), economic impact assessment (costs associated with the intervention).

The module proposes an extension of the Lagrange model, based on the interaction between oil particles, which initiates the physicochemical processes that take place in the oil slick: spreading, evaporation, dispersion, emulsification, dissolution, oxidation, sedimentation and immersion, biodegradation.

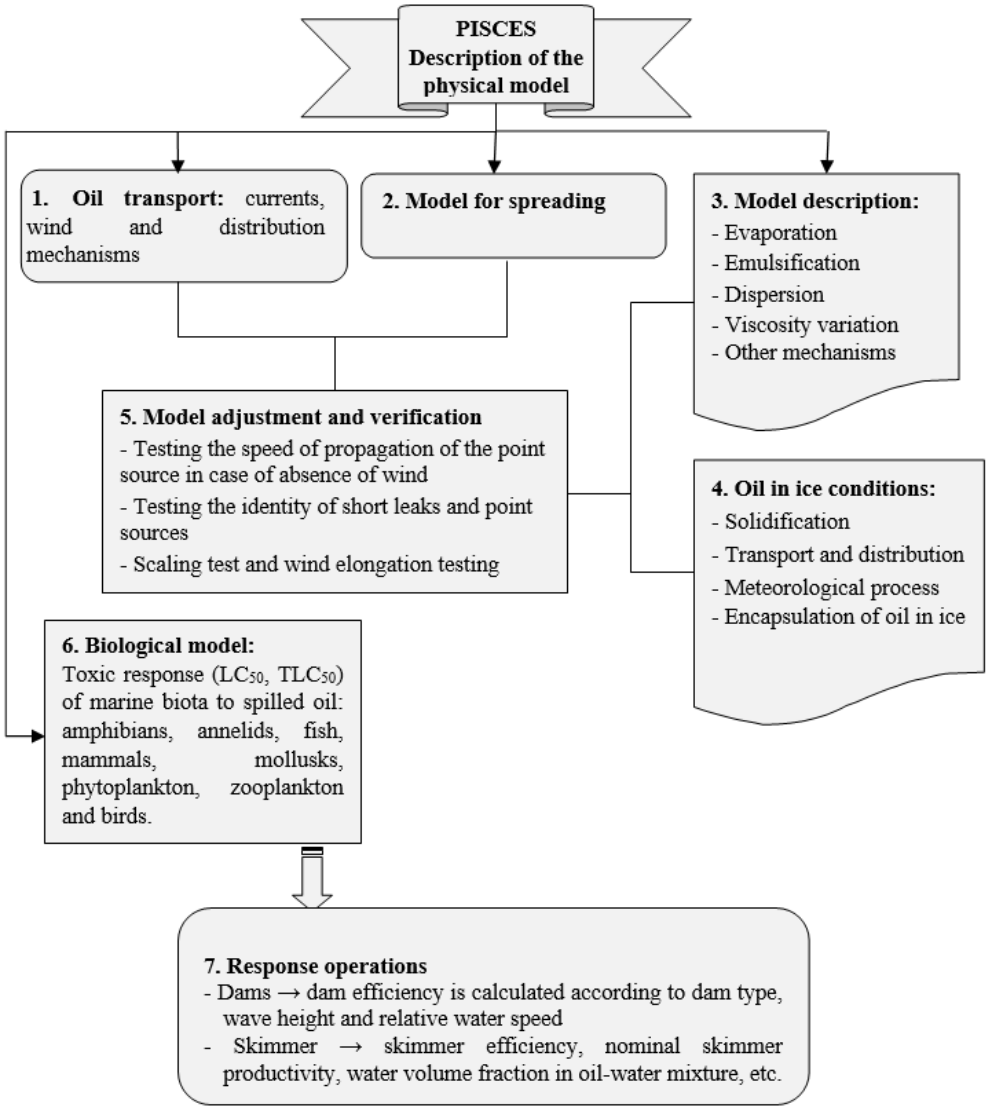


Figure 5. PISCES II model [42]

## 6. Conclusions

The analysis of the existing situation in the maritime area of Romania allowed the identification of oil pollution sources. Starting from the general and particular aspects resulting from the analysis of the main

modeling and simulation tools in the field of oil pollution risk, the PISCES II module was identified as a specialized tool of the type Oil Spill Simulation Module.

The PISCES II module offers the possibility to identify appropriate solutions for pollution interventions, multi-criterial and effective in relation to pollution limitation, response time, and quick access to the site of the pollution incident. The results of the research can be used to develop plans to prevent and limit pollution, in the case of simulating complex pollution accidents (offshore and onshore) caused by various stationary or fixed pollution sources.

The results can also be used in the process of preparation and training based on scenarios and improvement of human resources in the field of intervention in case of pollution incidents, including in the field of continuous training through programs specific to crisis management (marine pollution, inland waterway pollution, etc.).

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**Author Contributions:** Conceptualization, F.N. and M.B.; methodology, A.P. and A.C.; formal analysis, F.N.; resources, A.P., A.C. and M.R.A.; writing - original draft preparation, F.N.; writing - review and editing, A.P., A.C., D.S. and M.B.; visualization, D.S.; supervision, F.N.; project administration, M.R.A. All authors have read and agreed to the published version of the manuscript.

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