



From Gases and Evaporators risk assessment towards an Integrated management of sea and land pollution incidents

MANIFESTS is a project co-funded by the European Union Civil Protection - DG-ECHO, developed in cooperation with RBINS, CETMAR, IMT Mines Alés, INTECMAR, IST, the UK Security Agency as associated partner and coordinated by Cedre.



Co-funded by
the European Union



D3.2 – Report on desktop exercise: Definition of accident scenario (underwater & surface)

31/03/2026



Co-funded by
the European Union

Work Package 3:	Cross-border/Land-Sea preparedness and response to incidents involving Ammonia / LNG / Lithium ion batteries
Task 3.3	Desktop exercises: scenario 1 (underwater)
Date	31/03/2026
Version	V4
Author/s	LAURA COTTE, LAURENT APRIN
Partners	CEDRE, IMT MINES ALES, RBINS
Task 3.3	Desktop exercises: scenario 2 (surface)
Date	31/03/2026
Version	V3
Author/s	INTECMAR
Partners	INTECMAR, IST, CETMAR

ACKNOWLEDGEMENT

The work described in this report was supported by the Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG-ECHO) of the European Union through the Grant Agreement number No AMD-101140390-3 corresponding to the Call objective “Enhancing prevention and protection from the effects of maritime disasters” under priority 1: “Developing response capacity for marine pollution”.

DISCLAIMER

The content of this document represents the views of the author only and is his/her sole responsibility; it cannot be considered to reflect the views of the European Commission and/or the Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG-ECHO) or any other body of the European Union. The European Commission and the DG-ECHO is not responsible for any use that may be made of the information it contains.



Co-funded by
the European Union

Content

Introduction	4
1. PART I_Introduction	5
2. Scenarios	5
2.1. Fire model.....	5
2.1.1. Incident scenario 1	6
2.1.2. Model outputs	6
2.2. Explosion model	7
2.2.1. Incident scenario 2	7
2.2.2. Model outputs	8
2.3. Main conclusions regarding the fire and explosion models.....	8
2.4. Underwater gas release model.....	9
2.4.1. Incident scenario 3	9
2.4.2. Sea conditions and leak information	10
2.4.3. Outputs from the underwater gas release model.....	10
3. PART II_Introduction	12
4. Exercises in port areas	12
4.1. IRA-MAR – MANIFESTS Genius projects collaboration	12
4.2. INTECMAR-GALICIA COASTGUARDS exercise AROUSA.....	15
4.3. INTECMAR-GALICIA COASTGUARDS exercise MARIN.....	17
4.4. INTECMAR-REPSOL-PORT OF CORUÑA exercise	17
5. Exercise in coastal installation (WOFECO/FANDICOSTA Drill)	19
5.1. Preliminary Considerations.....	19
5.2. INTECMAR Resources	19
5.2.1. Human Resources	19
5.2.2. Technical Resources.....	19
5.3. INTECMAR’s Participation in the Drill	20
5.4. Technical Description of Scenario E20251029FANDICOSTA.....	20
5.5. Conclusions.....	26



Introduction

The MANIFESTS genius project has been primarily aimed at enhancing preparedness and response capabilities in both land-sea and cross-border contexts. To achieve this objective, the project focuses on the development of accessible, practical solutions and the provision of relevant information to effectively address the challenges associated with toxic gas cloud incidents.

Within the framework of Work Package 3 (WP3), efforts have been directed towards the recreation of scenarios closely resembling real-life accidents involving the release of hazardous gas clouds. In this context, a comprehensive review of the most probable incidents leading to toxic gas cloud formation was conducted during the project. This analysis served as the basis for the design of experimental and simulation exercises, which were approached from two distinct perspectives: (i) releases originating from underwater sources, such as pipeline leaks or discharges from vessels, and (ii) releases originating from industrial facilities or ships, directly affecting the atmosphere and, in some cases, the surrounding marine environment.

The first approach is addressed in **Part I** of this report and includes three scenarios. The first scenario focuses on assessing the consequences of a maritime accident in a port involving a fire on board a chemical-carrying vessel. The second scenario evaluates the impact of an explosion resulting from a leak in an underwater gas pipeline in the port of Dunkirk. The third scenario examines the behaviour and dispersion patterns associated with an underwater gas release model.

The second approach is presented in **Part II** of this document and is based on case studies developed in port environments in Galicia, in collaboration with the IRA-MAR project, Galician Coastguards, Repsol and the Ports of Marin and A Coruña. Additionally, it includes an industrial scenario involving a fish processing facility that uses ammonia in its refrigeration system. This facility experienced a major accident in 2009 that led to the destruction of its installations. Following reconstruction, the site was used as a test case to improve preparedness and response strategies for similar incidents.

Across all scenarios, particular emphasis has been placed on identifying and evaluating the critical information required for effective incident management. Furthermore, the project promotes the integration and sharing of such information among all responding agencies through dedicated information management tools, thereby supporting informed decision-making processes.



1.PART I_Introduction

A release of LNG from an old or damaged underwater pipeline can result in a serious environmental disaster. Therefore, it is crucial to identify and understand potential incident scenarios in order to improve response strategies and mitigate impacts. The Nord Stream 2 pipeline incident in September 2022 is a case in point: the sabotage of a pipeline in the Baltic Sea caused significant gas leaks and led to a navigation ban for all vessels within a 5-nautical-mile (9.26 km) around the site of the leak and advised aircraft to fly at least 1,000 m above the leak ¹. This work was carried out in Task 3.2, which was organized into three subtasks.

In Task 3.2.1, scenarios were first defined based on information collected in Task 3.1, including data from previous accidents involving releases into the water column, such as from a pipeline or a wreck. Building on these scenarios, Task 3.2.2 focussed on numerical simulations to replicate realistic accident situations. The simulations have taken into account critical factors such as spill volume, the physical and chemical properties of LNG, and the met-ocean conditions.

Finally, in Task 3.2.3, the underwater gas release module was showcased. Building on the accident scenarios developed in Task 3.2.1 and the simulation results from Task 3.2.2, a hands-on demonstration of the MANIFESTS *Genius* risk prediction models – including the fire, explosion, and underwater gas release modules developed in T2.3 – was conducted for the Ports of Marseille, Le Havre, and Saint-Nazaire. The objective was to present the project outcomes and to make port authorities aware of the existence and usefulness of the models. This included a presentation of the project and the Decision-Support System (DSS), followed by a practical demonstration using the accident scenarios defined in Task 3.2.1.

2.Scenarios

2.1. Fire model

The aim of the first scenario is to assess the consequences of a maritime accident in a port involving a fire on a ship carrying chemicals. This scenario seeks to evaluate the consequences in terms of heat flux and their impact on people and infrastructure, as well as the dispersion of toxic fumes that could affect the local population.

¹ Bueger, C., Tobias Liebetrau, T. (2023). Critical maritime infrastructure protection: What's the trouble?, Marine Policy, Volume 155, 105772, ISSN 0308-597X, <https://doi.org/10.1016/j.marpol.2023.105772>.



The aim of the simulations is ultimately to enable decision-makers to imagine solutions for the protection and evacuation of citizens

2.1.1. Incident scenario 1

On 4 July 2025, at 10:00 local time, an incident occurred at the Marseille Fos harbour – Liquid Bulk Terminal. This feature caused a fire involving 200 m³ of styrene over an area of approximately 100 m². The fire model was used to model the potential impacts of the fire, including thermal radiation, smoke dispersion, and associated safety hazards, providing insights for risk assessment and emergency response planning.

2.1.2. Model outputs

The model outputs and the graphical interface are presented in Figure 1. This figure presents the results of simulations for various heat flux thresholds (3, 5, 8, 16, 20, 200 kW/m²) in relation to the impacts on people and building structures. The simulation model also makes it possible to estimate the combustion rates and the duration of the fire (Figure 2).

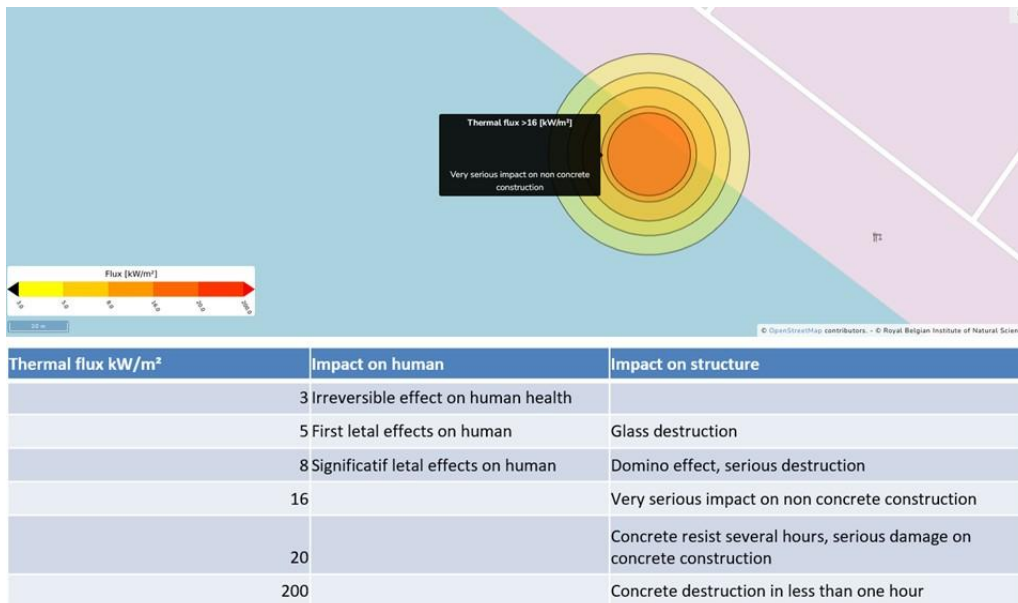


Figure 1. Fire model outputs for incident scenario 1. Thermal fluxes are presented together with specific indications of their potential impacts on the population and on buildings.

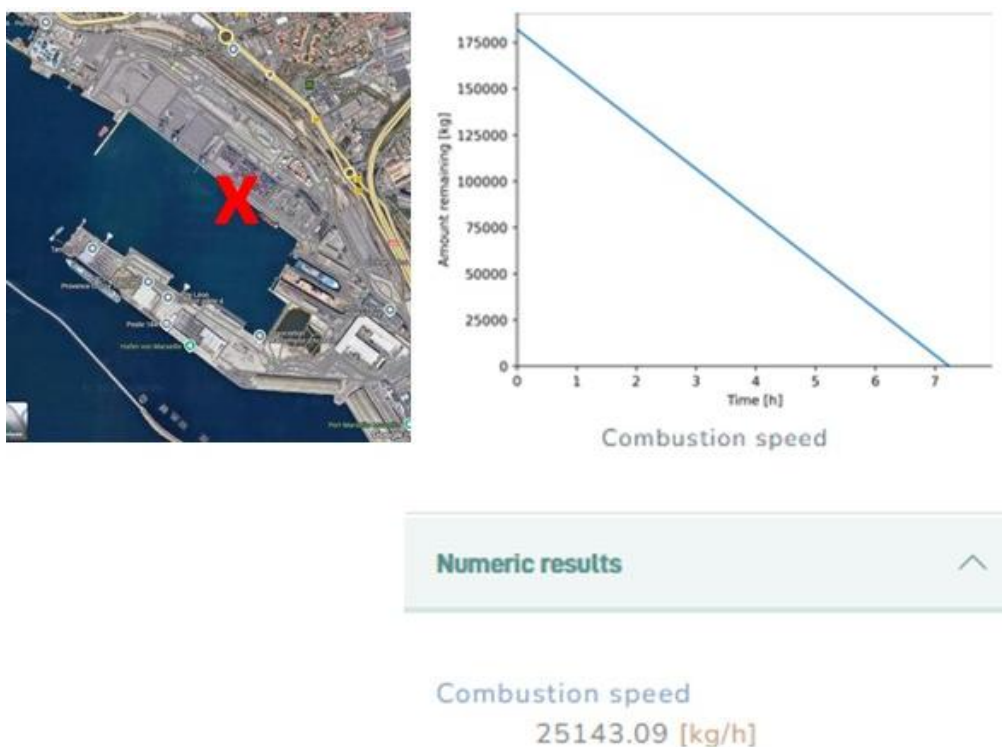


Figure 2. Location of the incident, combustion rate and duration of fire.

2.2. Explosion model

The second scenario aims to assess the consequences of an explosion caused by a leak of an underwater gas pipeline in the port of Dunkirk.

The aim is to assess the consequences in terms of overpressure (blast) that could lead to the total destruction of infrastructure in the vicinity of the explosion as observed in Beyrouth port in 2020. This type of result enables decision-makers to anticipate this type of accident and evaluate solutions to protect the population.

2.2.1. Incident scenario 2

On 4 July 2025, at 10:00 local time, a LNG leak at the Dunkirk LNG Terminal, France, leads to the formation of a flammable gas cloud, which may subsequently result in fire and explosion hazards. The simulated leak has a maximum flow rate of 14,000 m³/h and is assumed to last for 30 minutes. For modelling purposes, LNG is approximated as methane. The explosion model was used to simulate the impact of the overpressure of the shockwave caused by the combustion of methane.

2.2.2. Model outputs

The model outputs provide hazard zones associated with different levels of impact, ranging from minor injuries to fatalities on populations and building (Figure 3).

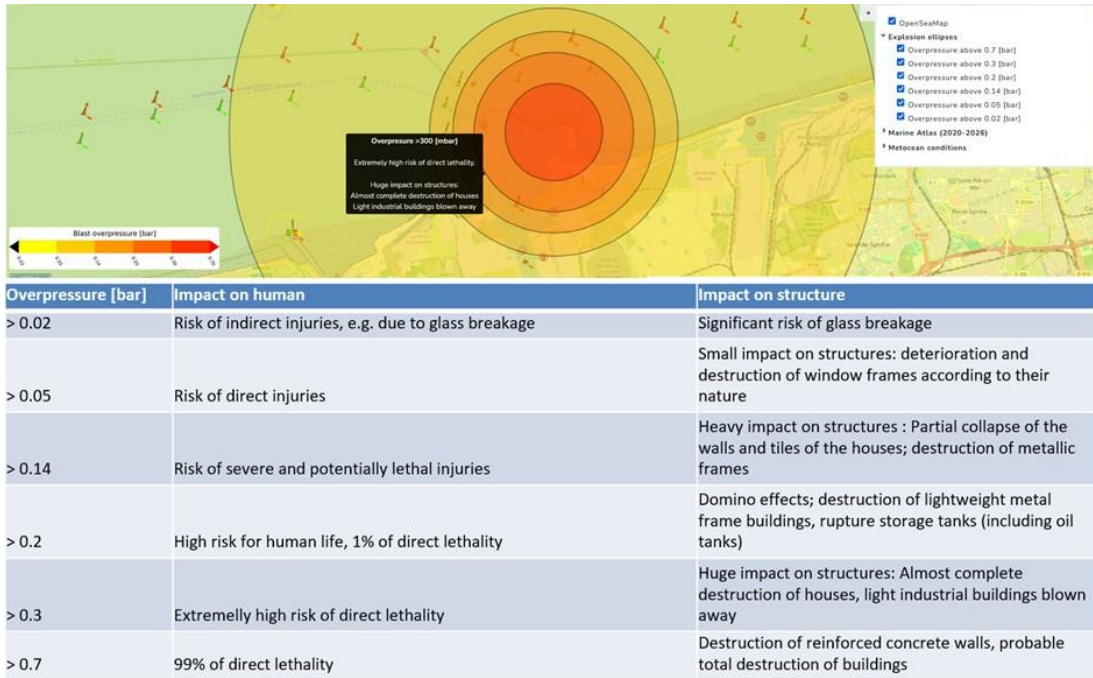


Figure 3. Explosion model outputs for incident scenario 2. The overpressure generated by the shockwave are presented together with specific indications of their potential impacts on the population and on buildings.

2.3. Main conclusions regarding the fire and explosion models

Explosion and fire models are accessible through a user-friendly application that allows simulations to be performed at any location. However, users must always consider the limitations of the models, especially the explosion model. The simulations assume unconfined conditions (outdoor environments without obstacles), which may lead to an overestimation of the total volume involved in an explosion. In addition, domino effects and secondary explosions are not taken into account. The upgrades to the explosion model performed in Task 2.4 were carried out to address this issue.

The model outputs for fire and explosion scenarios allow the definition of protective areas for people based on heat-flux thresholds for fires and overpressure

2.4.2. Sea conditions and leak information

Sea conditions	Leak properties
<ul style="list-style-type: none">• Water density: 1024 kg/m³• Water temperature: 10°C• Current speed: 1 m/s to the East, 0.5 m/s to the North• Windspeed: 5 m/s	<ul style="list-style-type: none">• Hole diameter in the pipeline: 40 cm• Hole area in the pipeline: 0.126 m²• Pressure: 155 bars• Depth: 50 m• Flow rate: 7.7 kg/s

Less than 2 minutes after the pipeline was struck, a gas pool formed on the sea surface.

2.4.3. Outputs from the underwater gas release model

The outputs of the underwater gas release model are presented below. These include, the methane concentration as a function of depth (Figure 6), the dissolved mass as a function of depth(Figure 7) and the mass repartition as a function of time (Figure 8).

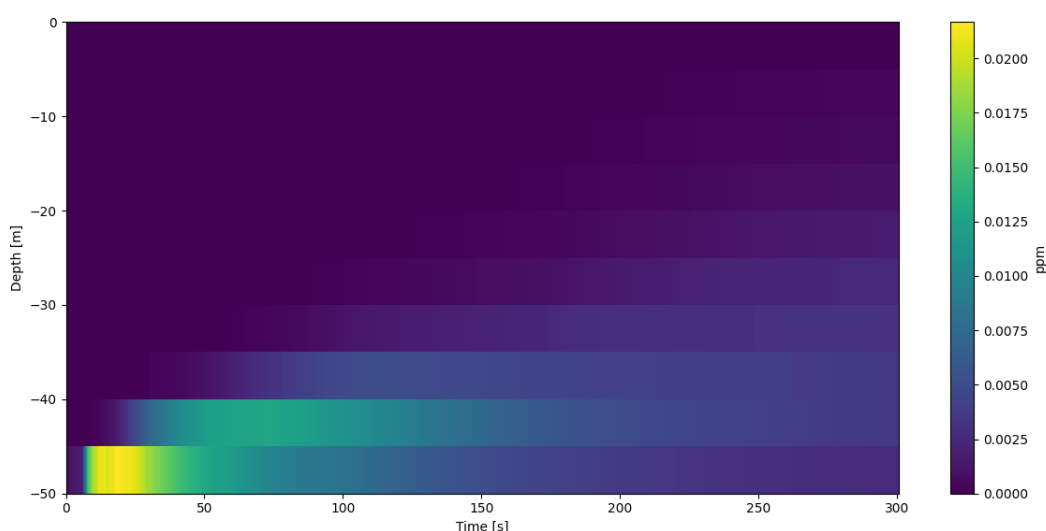


Figure 6. Concentration of methane as a function of depth.

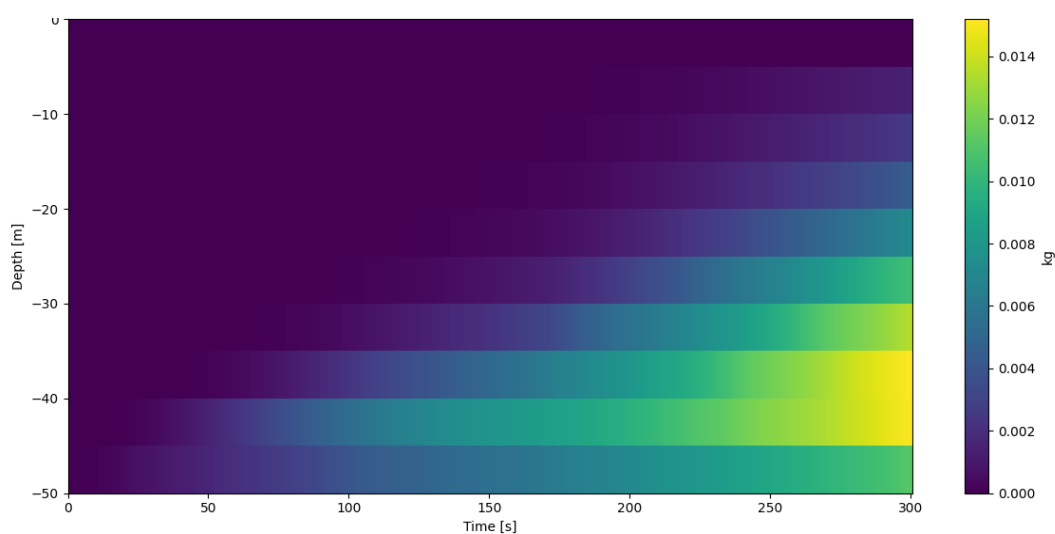


Figure 7. Dissolved mass as a function of depth.

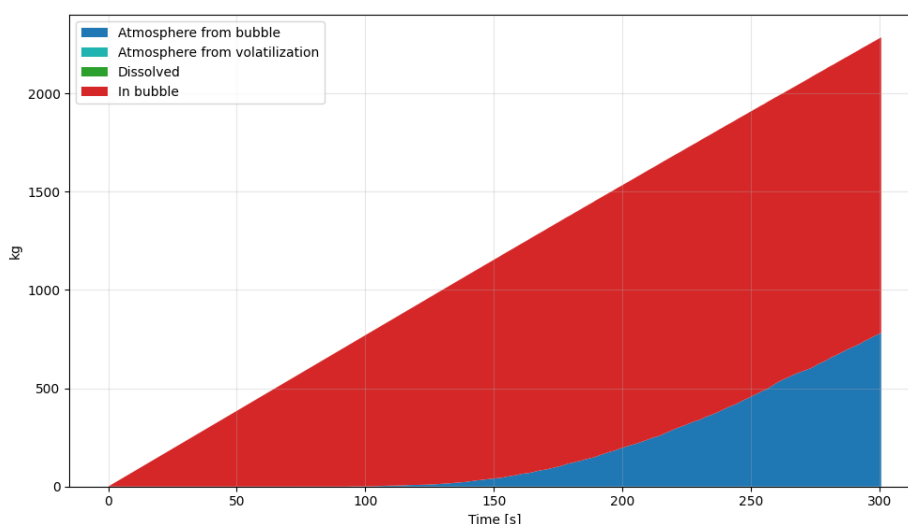


Figure 8. Mass repartition as a function of time.

The simulation of the gas release provides a clear timeline of methane behaviour, with the first bubble reaching the surface after approximately 100 seconds and a steady state achieved around 150 seconds, beyond which results remain unchanged. Over the total simulation duration of 30 minutes, all released methane migrates to the atmosphere. The model effectively illustrates the dynamics of the release and is a valuable tool for planning and preparing experimental phases.

3.PART II_Introduction

Anhydrous ammonia is widely used as a refrigerant gas in many industrial plants, especially by industries in charge of the preservation of sea products (fishing, aquaculture...) which are generally located on the coast. Also, freezer vessels use this substance as refrigerant. Facilities located on the coast with ammonia-based industrial refrigeration systems have the potential to release toxic ammonia gas during an incident and many examples of this can be found in reported literature (e.g. accident in Galician facility 2021). Similar events can also arise from vessels using ammonia as refrigerant or as a fuel and related port storage facilities. Such a release can put not only the workers at risk but can also impact the wider local population. Therefore, it is important to know the areas that could be affected by the toxic cloud and its impacts on human health and the aquatic environment.

These facilities (industries/storage tanks/vessels) may be subjected to accidents resulting in the release of this highly toxic gas with potential to impact workers and surrounding communities including transboundary. Response to those accidents must be deployed in a very efficient manner, particularly for the exchange of information that needs to be quickly and accurately.

Based upon the success of MANIFESTS, the **MANIFESTS-Genius** (From **G**ases and **E**vaporators risk assessment towards an **I**ntegrated management of sea and land pollution incident^S) project aims to strengthen preparedness and response capabilities for integrated management of coastal marine pollution by gases or evaporators, both at sea and on the shoreline. Specifically, WP3 aims to improve information sharing among marine pollution authorities and response groups from different agencies/organisms with responsibilities during an incident near the shoreline to enhance efficient coordination of the land and sea response.

4.Exercises in port areas

4.1. IRA-MAR - MANIFESTS Genius projects collaboration

The Integrated Response to pollution Accident at sea and chemical risk in port (IRA-MAR) project, financed by the DG ECHO, aimed to improve marine pollution preparedness in Spain, France, Italy, Malta, Morocco, Portugal and Tunisia. More specifically, the objective 1.4 of this project was to improve preparedness for accidental release of HNS in ports by reviewing and identifying areas for



Co-funded by
the European Union

improvement in order to step up the capacity of responders. In this sense, several activities were carried out during the period 2021-2023 as it is the case of 13 tabletop exercises along the Spanish coast developed by the Spanish maritime authority (Dirección General de la Marina Mercante), one of the exercises was carried out in Coruña port (Galicia).

These exercises attempted to assess all the factors that influence the response to an incident of contamination by SNPP products with the consequence of the development of a toxic cloud. In collaboration with involved stakeholders they try to identify the gaps or bad practices that make the response ineffective, whether due to a lack of resources, trained personnel, coordination, etc.

Taking into account the success of those exercises, the maritime authority decided to continue carrying out exercises after the IRA-MAR project lifetime and planned new exercises with the same objectives in new locations. Four of them were performed in Galicia along April and May.

As part of the regional contingency plan of Galicia INTECMAR and CETMAR were invited to participate in the exercises. Taking into account that the desktop exercises planned in the proposal of MANIFESTS_Genius pursued objectives completely aligned and complement each other, the exercises were used as perfect scenarios to achieve MANIFESTS Genius WP3 objectives.

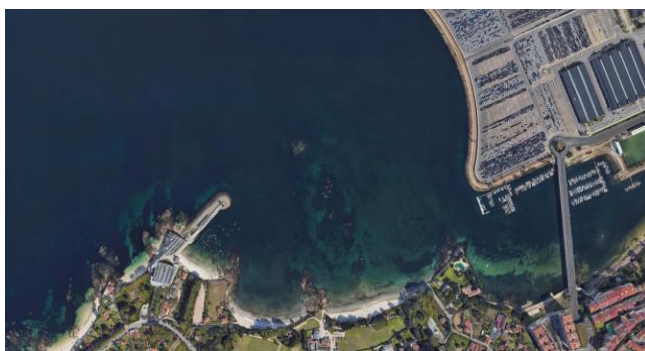
INTECMAR in collaboration with IST and CETMAR has participated in 4 desktop exercises. The scenarios simulated the generation of a toxic cloud in ports due to an atmospheric release of methanol, methane, and ammonia:

- 1/ Release of 60 m³ (gas) AMMONIA ANHIDROUS (Vigo, April/22-23/2024)
- 2/ Release of 1000 m³ METHANE (Ferrol, April/24-25/2024)
- 3/ Release of 60 m³ (gas) AMMONIA ANHIDROUS (San Cibrao, May/27-28/2024)
- 4/ Release of 800 m³ METHANOL (Vilagarcía de Arousa, May/29-30/2024)

MANIFESTS Genius contribution for each exercise:

- 1/** Toxic cloud modelling (Aloha model, Mohid model, Calpuff model)
- 2/** Water spill drift modelling (Mohid model)
- 3/** XesCamgal (Coptool) integrating model outputs with relevant environmental and response information to share information with involved stakeholder from different authorities
- 4/** Knowledge tool





Vigo scenario



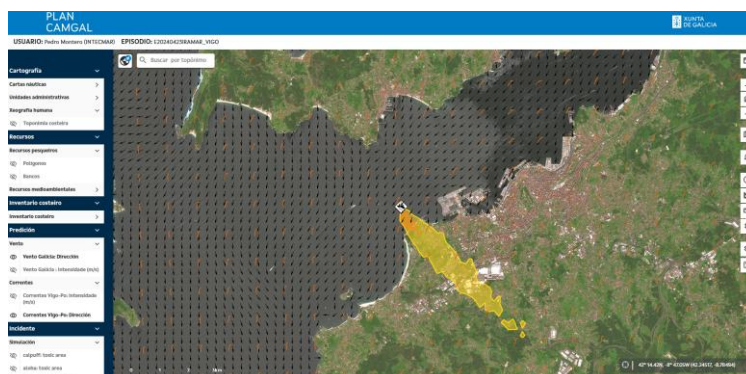
Ferrol scenario



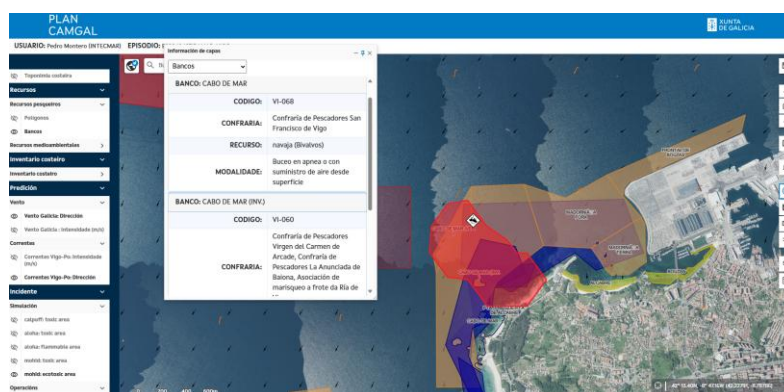
San Cibrao scenario



Vilagarcía scenario



Glas cloud simulation integrated into the COptool (sharing information tool)



Water spill simulation integrated into the COptool (sharing information tool)

4.2. INTECMAR-GALICIA COASTGUARDS exercise AROUSA

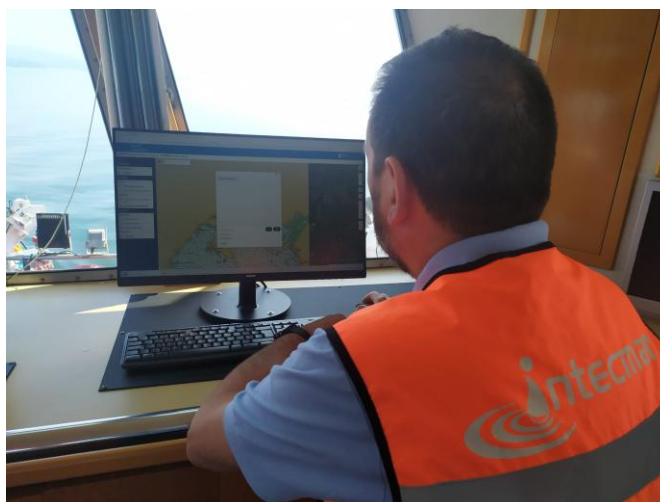
INTECMAR has participated in an outdoor exercise in collaboration with Galician Coastguards. The scenario simulated the generation of a toxic cloud in the coastal area due to an atmospheric release of ammonia from a fish processor facility:

Scenario: AMMONIA Release from a fish processing industry

MANIFESTS Genius objective: To share information with Galician Coastguards through XesCamgal (Coptool) about toxic cloud in order to facilitate water sampling by NRBQ equipped team.

Report on desktop exercise

31/03/2026



Using COptool on board



Coastguards during the exercise



Video of the exercise



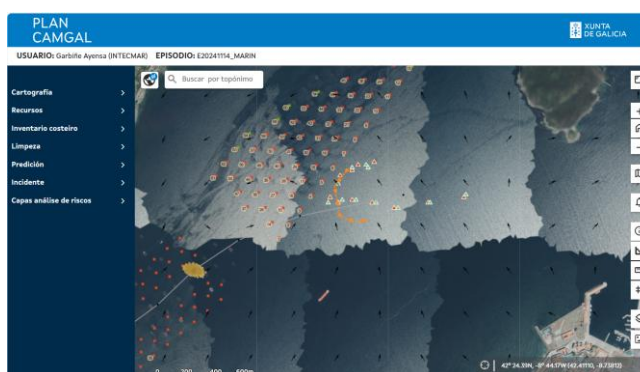
Co-funded by
the European Union

4.3. INTECMAR-GALICIA COASTGUARDS exercise MARIN

INTECMAR has participated in an outdoor exercise in collaboration with Galician Coastguards. The scenario simulated the collision with fire onboard and small fuel release in the coastal area of Marin Port.



Using COptool on board



Detail of the COptool on board

4.4. INTECMAR-REPSOL-PORT OF CORUÑA exercise

INTECMAR has participated in an outdoor exercise in collaboration with REPSOL and the Porto of Coruña. The scenario simulated the release of maya crude from a tanker during port operations. The objective was to share information with Port authorities and REPSOL responders trough XesCamgal (Coptool) about ocean meteorological conditions and spill drift.



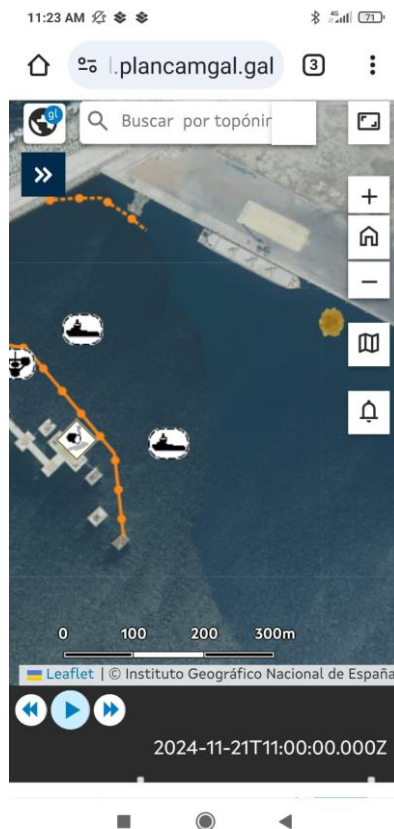
Co-funded by
the European Union

Report on desktop exercise

31/03/2026



Using COptool on port office



Detail of the COptool on a smartphone



Co-funded by
the European Union

5. Exercise in coastal installation (WOFCO/FANDICOSTA Drill)

5.1. Preliminary Considerations

The participation of INTECMAR during the drill falls within the support provided by its Oceanographic Modelling Unit and Scientific Documentation and Support Unit (UMO/UDAC) to the Regional Contingency Plan for Accidental Marine Pollution (Plan CAMGAL).

In this drill, INTECMAR's contribution was based on the use of tools developed under the MANIFESTS and MANIFESTS GENIUS projects (<https://manifests-project.eu/>).

5.2. INTECMAR Resources

5.2.1. Human Resources

On the day of the drill, two INTECMAR technicians were deployed with the following roles:

- One technician participated from the Advanced Command Post (PMA) located at the company's facilities.
- Another technician provided support at the Operational Coordination Centre (CECOP), located at the Port Authority of Vigo.

Additionally, two technicians provided remote support from INTECMAR's headquarters.

5.2.2. Technical Resources

The technical resources deployed included:

- MSi Drifting Buoys: Three drifting buoys were deployed, in collaboration with the Galician Coast Guard Service, to simulate the trajectory of a potential spill.
- Knowledge Tool (<https://knowledgetool.mariner-project.eu/>): Developed by the Technological Centre of the Sea (CETMAR), this tool allows access to safety data sheets and information on the behaviour and toxicity of substances in marine environments, such as ammonia.
- XesCamgal Tool: Information management system based on COPTool (<https://github.com/MANIFESTS-DSS/>) and adapted to the requirements of Plan CAMGAL.
- AQUASAFE Platform: Integrates real-time data from local and remote sensors, executes scheduled numerical models, and generates automatic



Co-funded by
the European Union

reports for comparative analysis between observations and simulation results.

- MOHID Drift Model: Used to simulate the marine dispersion of the potential spill resulting from firefighting operations.
- ALOHA Atmospheric Dispersion Model (<https://www.epa.gov/comeo/aloha-software>): Used to model the dispersion of toxic clouds.
- Dynamic Air and Water Dispersion Models (MOHID): Developed in collaboration with the Instituto Superior Técnico (IST) in Lisbon and MeteoGalicia, allowing joint simulation of atmospheric and marine dispersion.

5.3. INTECMAR's Participation in the Drill

The scenario simulated a fire in one of the WOFCO/FANDICOSTA company warehouses.

INTECMAR's technical support included:

- Deployment of three drifting buoys, simulating the position of a potential spill resulting from firefighting operations. Their position was monitored through the XesCamgal viewer.
- Simulation of the spill drift using numerical models, with real-time visualization in the XesCamgal platform.
- Simulation of a potential ammonia release scenario, in case the fire affected the company's ammonia storage tanks. This included:
 - Atmospheric dispersion modeling using the ALOHA and MOHID models.
 - Marine ammonia dispersion modeling, to assess potential impacts on fisheries and shellfish resources in the area.

5.4. Technical Description of Scenario E20251029FANDICOSTA

Overview of the XesCamgal Viewer

- Elements represented: CECOP in Vigo, HazMat_Release symbol, and vessel Ría de Vigo.
- Temporary barrier installed around the FANDICOSTA dock.



Co-funded by
the European Union

Report on desktop exercise

31/03/2026

- Meteorological conditions at 13:00 UTC: wind and currents represented.
- Simulated trajectories of three buoys.
- Predicted dispersion of an instantaneous release of 2 m³ of ammonia.

Models Used

- ALOHA: Simulation based on a constant NNW wind at 6.21 km/h (1.7 m/s), extracted from the MeteoGalicia WRF model.
- MOHID: Dynamic model with time-varying wind, based on hourly forecasts from the MeteoGalicia WRF model.

Simulation Results

- The lines represent AEGL levels 1, 2, and 3 for a 60-minute exposure.
- The MOHID model, being dynamic, allows the plume to adapt to the topography and shift according to the terrain and the predicted wind at each moment, which in this case is weak and variable.
- This dynamic behavior is not captured by the ALOHA model, which assumes a constant wind and flat topography, resulting in a more theoretical plume. MOHID modeling of marine ecotoxicity for a 2 m³ ammonia release at 09:00.
- Prediction of buoy trajectories and ecotoxicity analysis (LC50).

Model Comparison

- AEGL (60 min) simulated with ALOHA: Black line represents model uncertainty due to low wind intensity.
- AEGL (60 min) simulated with MOHID: Shows a more realistic and dynamic dispersion, sensitive to topography and wind changes.
- Visual comparison between models to evaluate differences in plume prediction.

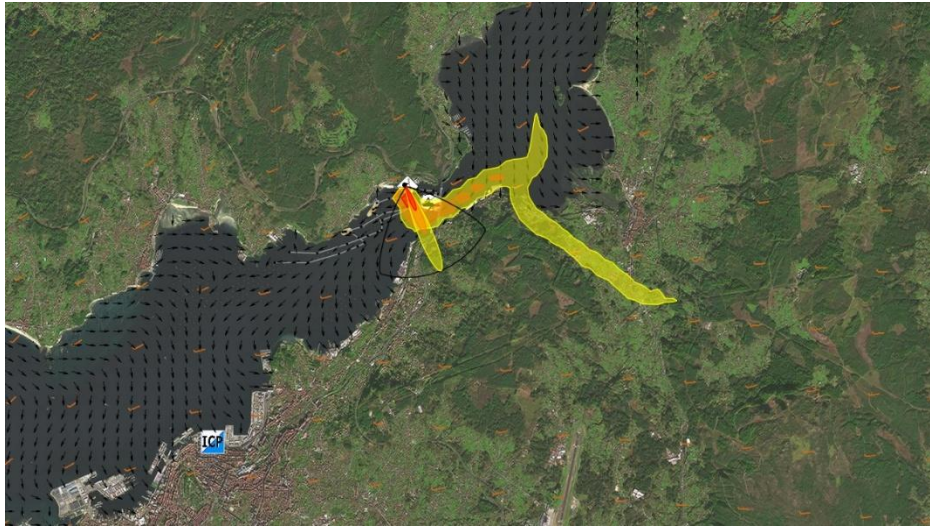
Overview:



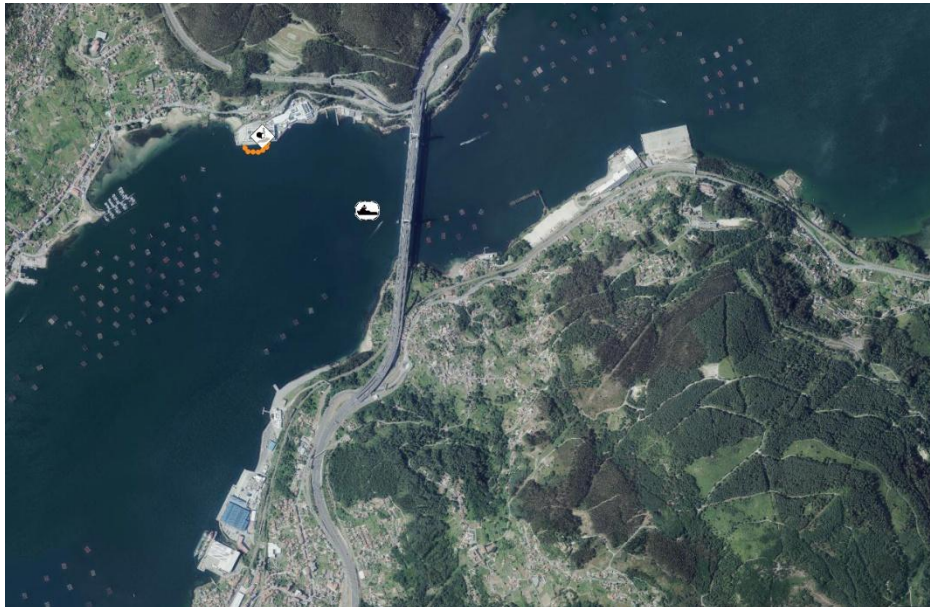
Co-funded by
the European Union

Report on desktop exercise

31/03/2026

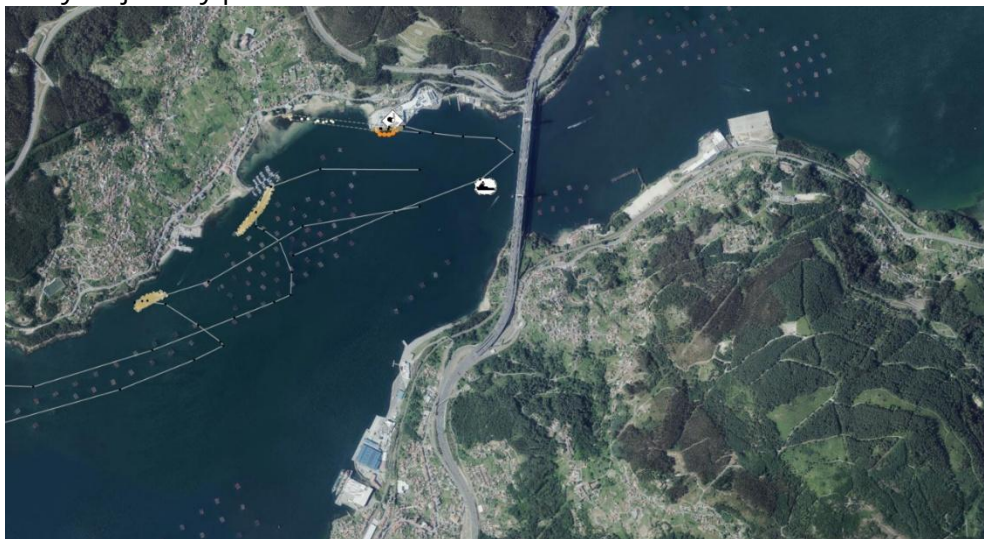


Media and barriers on stage:

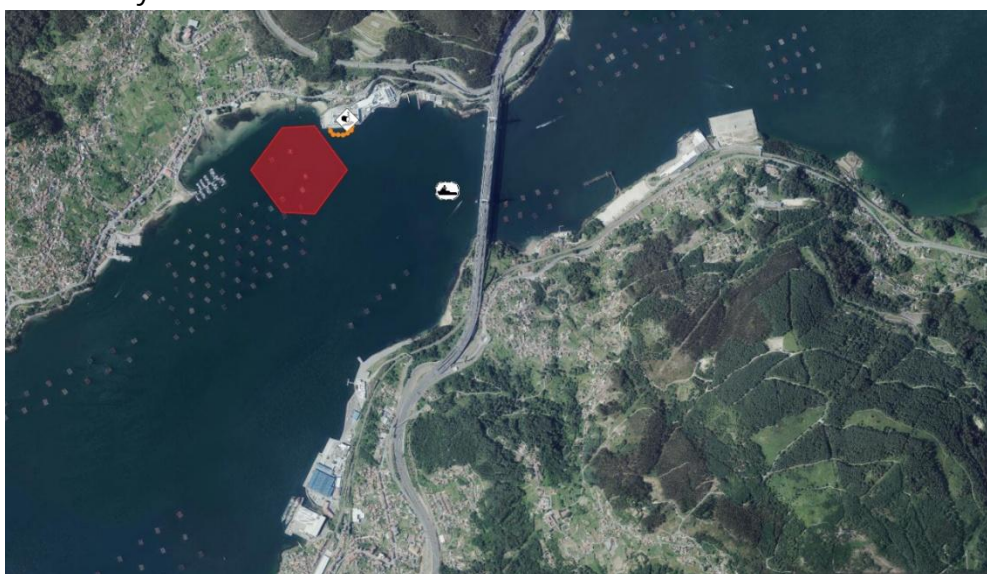


Co-funded by
the European Union

Buoy trajectory prediction:



Ecotoxicity LC50:



AEGL (60 min) simulated with ALOHA (the black line is the model uncertainty due to low wind):



AEGL (60 min) simulated with MOHID:

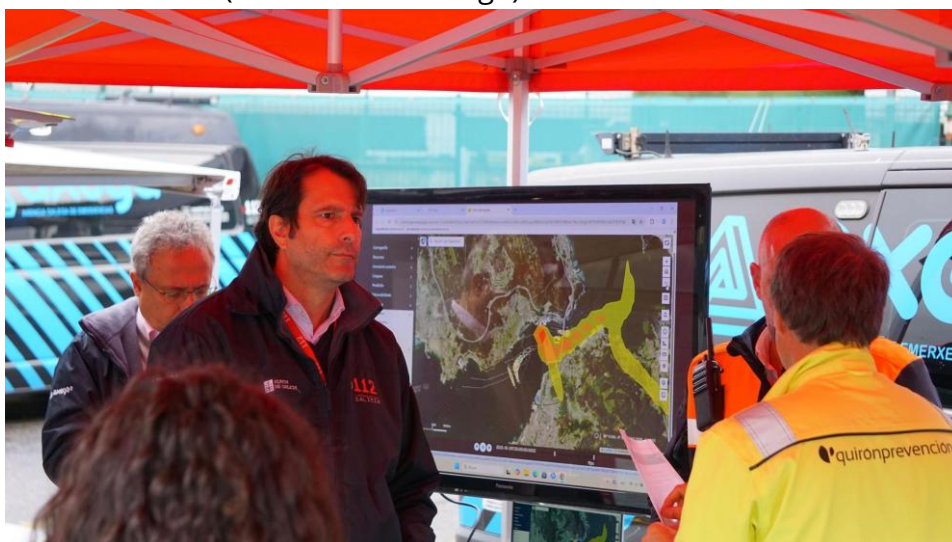


•

AEGL (60 min) simulated, comparison of the two models.



Information provided by INTECMAR through XesCamgal at the Advanced Command Post (Source: Faro de Vigo):



Information provided by INTECMAR through XesCamgal at the Operational Coordination Centre (Source: Vigo Port Authority):



5.5. Conclusions

- All tools deployed by INTECMAR functioned without incidents during the drill.
- The MOHID model, thanks to its dynamic nature, offered greater accuracy in simulating the dispersion of the toxic cloud, adapting to the topography and the predicted wind for each moment, an aspect that is not possible with the ALOHA model, which assumes a constant wind and a flat topography, and therefore presents a more theoretical plume.
- The computational time required by MOHID remains too long for operational emergency use, although improvements are being implemented at INTECMAR to expedite real-time execution.
- Given the rapid evolution of a toxic cloud, immediate modeling has limited use for acute-phase response, but it is highly valuable for risk scenario planning, identifying potentially affected areas, mobilizing resources, and issuing preventive alerts to the population.
- Marine ammonia dispersion simulation provides valuable information for assessing environmental and marine resource impacts, supporting decision-making regarding temporary extraction restrictions in affected areas.
- The XesCamgal tool proved to be an efficient and versatile platform for managing operational information. Its ability to adapt access and data visualization to user needs significantly improves coordination and efficiency during incident management.