MARINER

Enhancing HNS preparedness through training and exercising

Tools for modelling impact – Population modelling

Task C: HNS modelling and environmental impact

Action 2.4: Tools for modelling impact – population modelling

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1. Introduction

The general objective of MARINER is to improve regional cooperation in planning, preparedness and response to HNS spills by improving training and exercise, increasing awareness and information exchange, and by capitalization and translation of HNS relevant R & D projects' outcomes into operational products.

In order to achieve that aim, MARINER is organised around a range of coordinated technical tasks supported by two horizontal tasks, the project management and coordination (Task A) and project communication and dissemination (Task F). Among technical tasks, task C aims to:

- Improve the operational use of tools for modelling HNS transport, behaviour and biological impact;
- Define protocols and guidelines for environmental impact assessment of HNS spills.

This document is elaborated in the frame of action C2 "Tools for modelling impact", and it aims to model the effects of 4-nonyphenol on the structure of an amphipod population and to predict the recovery time of the referred population on different scenarios.

2. Tools for modelling impact – Population modelling

Model incorporating the effects of 4-nonylphenol on a marine macroinvertebrate (amphipod)

The present model describes the effects of the pollutant 4-nonylphenol (4-NP) on the growth of a marine amphipod, resulting from potential spills taking place at the North coast of Portugal. Besides being a HNS, 4-NP is considered a priority substance in the field of water policy (Annex II of Directive 2008/105/EC).

The model was developed with AQUATOX software release 3.1 plus (EPA, 2014), which accounts for the concentration of dissolved 4-NP, ammonia, nitrate, phosphate, carbon dioxide, oxygen, total suspended solids, detritus, salinity, temperature, pH, wind loading, light and water volume, as forcing functions acting on the growth of the amphipod population and, thus, on the variation of the amphipod biomass throughout time.

The variation of the amphipod biomass over time is described by the equation:

$$\frac{dBiomass}{dt} = Consumption - Defecation - Respiration - Excretion - Mortality - Predation - GameteLoss \pm Migration - Promotion + Recruit - Excretion \quad (1)$$

and the amphipod growth rate is described as:

$$Growth\ Rate = Consumption - Defecation - Respiration - Excretion \quad (2)$$

where,

Consumption - consumption of food (g/m^3.d);

Defecation - defecation of unassimilated food (g/m^3.d);

Respiration - respiration (g/m^3.d);

Excretion - excretion (g/m^3.d);

Mortality - non-predatory mortality (g/m^3.d);

Predation - mortality from being predated upon (g/m^3.d);

GameteLoss- Loss of gametes during spawning (g/m^3.d)

Migration - loss or gain due to vertical migration (g/m^3.d);

Promotion - promotion to next size class (g/m^3.d);

Recruit - recruitment from previous size class (g/m^3.d).

HNS spill of 4-NP

Using the interface of HNS dispersion model (MOHID model) developed in the frame of the MARINER project, a simulation of 100 m^3 4-NP spill was performed, at the North coast of Portugal. The simulation lasted for 1 day and 6 hours and Figure 1 presents the maximum time-integrated vertical concentration (mg/m^3) at the end of this period.

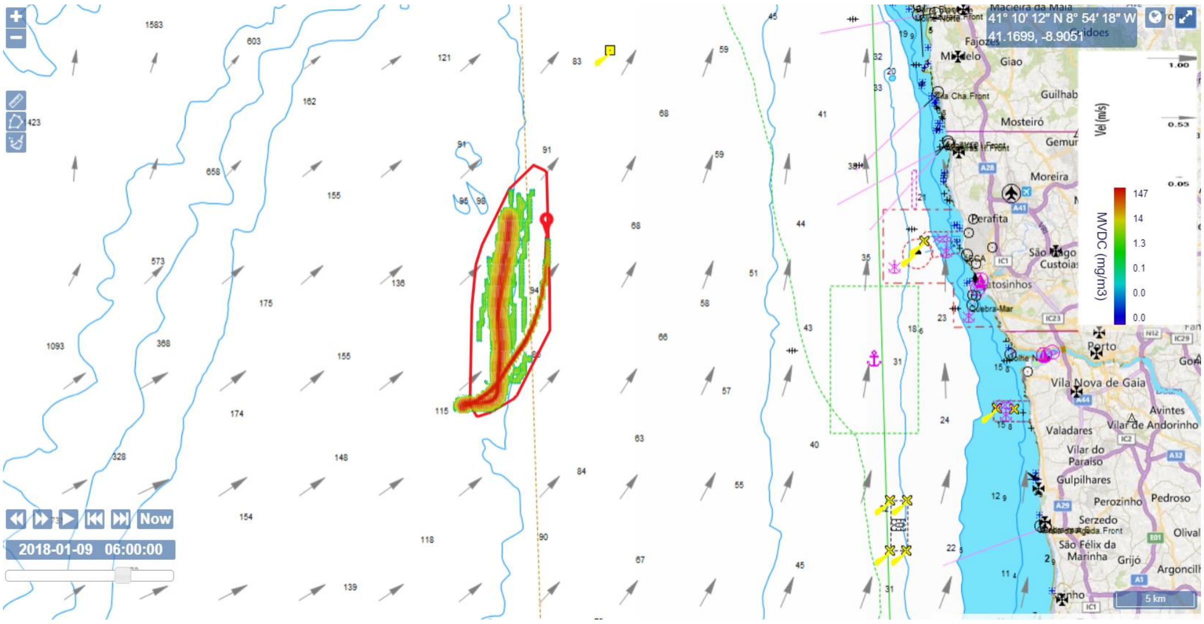

Figure 1. Maximum time-integrated vertical concentration (mg/m^3).

CIIMAR HNS database (https://www.ciimar.up.pt/hns/substances.php) feeds the interface of the dispersion model, providing the physico-chemical characteristics of the compounds, which will affect their behaviour in the water, and also HNS toxicity data. This allows not only to predict the distribution of the chemical during the spill but also to assess the environmental risk associated with its dispersion (Figure 2).

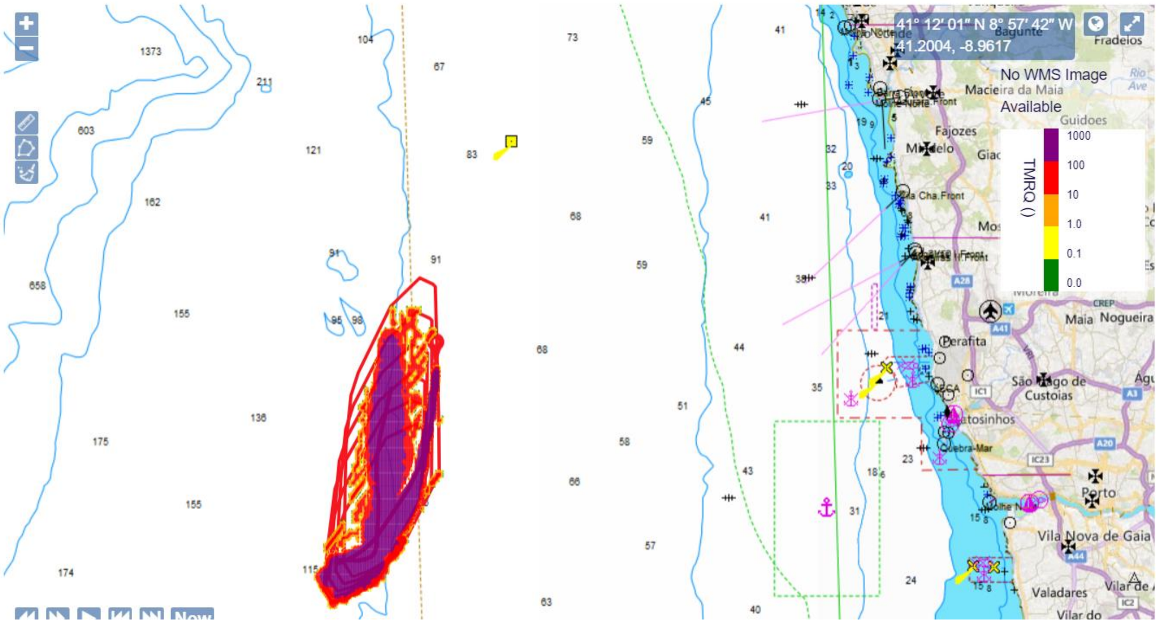

Figure 2. Maximum time-integrated Risk Quotient.

Linking of tools - Population model simulations

Aiming to reach a higher tier risk assessment approach, a population model was developed, to better project the effects at population levels and the time required to return to the pre-spill scenario.

At this point, 3-days simulations were implemented, linking with the HNS hydrodynamic dispersion model, with the aim to check for the effects of 4-NP on the amphipod population. According to figure 1, three range of concentration were selected according to 4-NP low (4.5 µg.l^{-1}), medium (43 µg.l^{-1}) and high (940 µg.l^{-1}) concentration levels.

Results suggest that the amphipod population is not sensitive to 4-NP concentrations ≤ 4.5 µg.l^{-1} (Figure 3).

For 4-NP concentrations within the range 23 - 940 µg.l^{-1}, the amphipod population shows increasing sensitivity, presenting very low biomass values during 1 to 2 weeks, in a direct relation with 4-NP concentrations, but still being able to recover through time, as the concentration of 4-NP fades away (Figure 4 and 5).

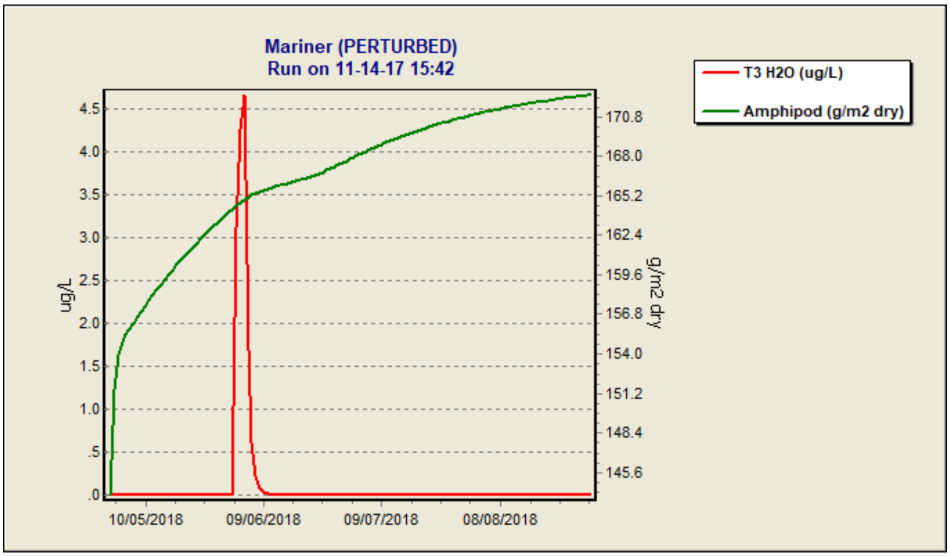

Figure 3. Effects of 4-NP (4.5 µg.l^{-1}) on amphipod biomass, during a 3-d simulation.

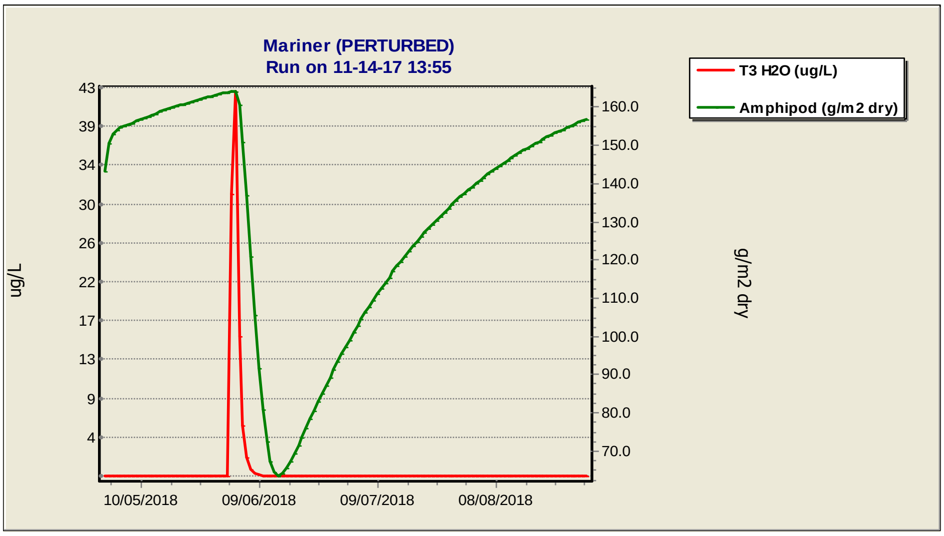

Figure 4. Effects of 4-NP (43 µg.l^{-1}) on amphipod biomass, during a 3-d simulation.

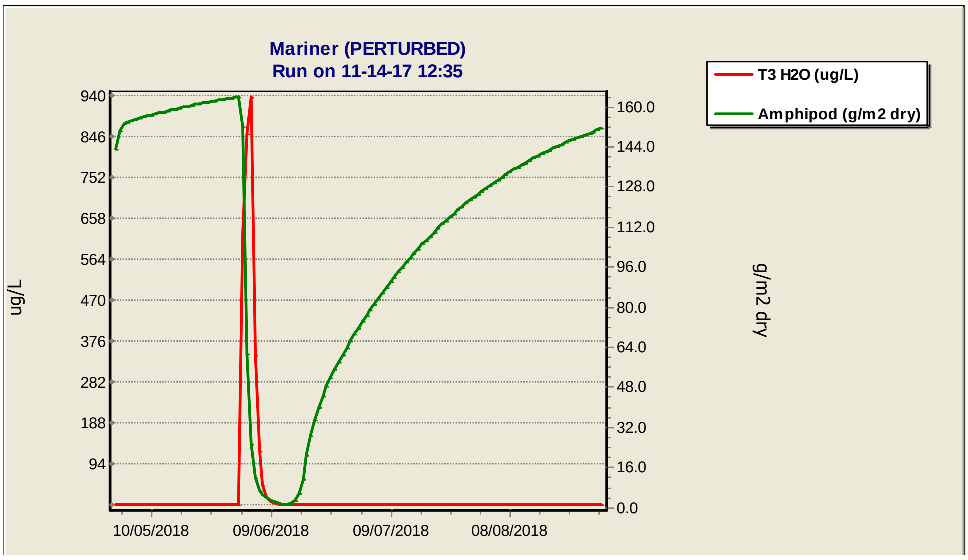

Figure 5. Effects of 4-NP (940 µg.l^{-1}) on amphipod biomass, during a 3-d simulation.

This systematized information is a useful tool to improve predictions on the behaviour and toxicity of priority HNS during accidental spills, supporting the competent authorities on spill preparedness and effective decision making. Therefore, we expect in the future to develop additional population models taking into account more species as well as several HNS.

3. References

Directive 2008/105/EC of The European Parliament and of The Council on environmental quality standards in the field of water policy. Official Journal of the European Union, 2008.