{HNS-MS}

Improving Member States preparedness
to face an HNS pollution of the Marine System

HNS-MS Layman's report

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Cedre

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HEALTH, FOOD CHAIN SAFETY AND ENVIRONMENT

HNS-MS is a project co-funded by DG-ECHO under agreement ECHO/SUB/2014/693705.
It runs from 1 January 2015 to 31 March 2017.

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Citation

Legrand S., F. Poncet, L. Aprin, V. Parthenay, E. Donnay, G. Carvalho, S. Chataing-Pariaud, G. Dusserre, V. Gouriou , S. Le Floch, P. Le Guerroue, Y.-H. Hellouvry, F. Heymes, F. Ovidio, S. Orsi, J.Ozer, K. Parmentier, R. Poisvert, E. Poupon, R. Ramel, R. Schallier, P. Slangen, A. Thomas, V. Tsigourakos, M. Van Cappellen and N. Youdjou (2017) "Improving Member States preparedness to face an HNS pollution of the Marine System - HNS-MS Layman's report", HNS-MS technical report, 38 pp.

About HNS-MS

The European project HNS-MS aimed at developing a decision-support system that national maritime authorities and coastguard stations can activate to forecast the drift, fate and behaviour of acute marine pollution by Harmful Noxious Substances (HNS) accidentally or deliberately released in the marine environment. Focussing on the Greater North Sea and Bay of Biscay, this 27 months project (01/01/2015-31/03/2017) had four specific objectives:

i. To develop a freely accessible data base documenting the most important HNS transported from or to the ports of Antwerp, Rotterdam, Hamburg, Nantes and Bordeaux;
ii. To conduct lab experiments in order to improve the understanding of the physico-chemical behaviour of HNS spilt at sea;
iii. To develop a 3D mathematical modelling system that can forecast the drift, fate and (SEBC) behaviours of HNS spilt at sea. Advanced processes such as chemical reactivity, explosions, fire or interaction with sediment were not considered in this first project;
iv. To produce environmental and socioeconomic vulnerability maps dedicated to HNS that will help end-users assessing the likely impacts of HNS pollution on the marine environment, human health, marine life, coastal or offshore amenities and other legitimate uses of the sea.

All these contributions have been integrated into a web application that will help coastguard stations to evaluate the risks for maritime safety, civil protection and marine environment in case of an acute pollution at sea. HNS-MS has been co-funded by the Directorate-General of European Commission for European Civil Protection and Humanitarian Aid Operations (ECHO).

About this report

This layman's report presents the objectives and the main results of the project "HNS-MS – Improving Member States preparedness to face an HNS pollution of the Marine System". It can be read as an introduction to a series of 4 technical sub-reports presenting in detail the outcome achieved by the HNS-MS consortium in the framework of this project:

- HNS-MS Layman's report
- Sub-report I : Understanding HNS behaviour in the marine environment
- Sub-report II : Modelling drift, behaviour and fate of HNS maritime pollution
- Sub-report III : Mapping HNS environmental and socioeconomic vulnerability to HNS maritime pollution
- Sub-report IV : HNS-MS Decision-Support System User's Guide

A copy of these reports can be obtained by downloading from the HNS-MS website https://www.hns-ms.eu/publications/.

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Motivation and objectives

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1 Introduction

1.1 General context

"Maritime services have benefited in recent years by considerable expansion fostered by globalization."[1] *"Around 90% of world trade is carried by the international shipping industry. Without shipping the import and export of goods on the scale necessary for the modern world would not be possible. Seaborne trade continues to expand, bringing benefits for consumers* across the world through competitive freight costs. Thanks to the growing efficiency of shipping *as a mode of transport and increased economic liberalisation, the prospects for the industry's further growth continue to be strong."* [2]

If maritime shipping is undoubtedly a key factor of the worldwide economic growth, the constantly growing fleet of tankers, bulk carriers and ever-increasing size container ships exacerbates the risk of maritime accidents, loss of cargoes and acute maritime pollution. In particular, more than 2,000 **harmful or noxious chemical substances** (**HNS**) are regularly shipped in bulk or package forms and can potentially give rise to significant environmental and/or public health impacts in case of spillage in the marine environment.

In recent years, huge efforts have been made by IMO, EMSA as well as other maritime authorities towards greater consideration of these risks. For instance, given the importance and complexity of the matter, the Bonn Agreement, HELCOM, Lisbon Convention, Barcelona Convention/REMPEC, Copenhagen Convention, DG ECHO and EMSA have jointly identified the urgent need of improving preparedness and response to HNS spills (10th Inter-Secretariat Meeting, Helsinki, 27.02.2014).

Until now, preparedness actions at various levels have primarily aimed at classifying the general environmental or public health hazard of an HNS (e.g. development of IBC and IMDG codes; GESAMP profiles), at developing operational datasheets collating detailed, substance-specific information for responders and covering information needs at the first stage of an incident. (MAR-CIS; MIDSIS-TROCS; CAMEO) or at performing a risk analysis of HNS transported in European marine regions (e.g. EU projects HASREP and BE-AWARE). However, contrary to oil pollution preparedness and response tools, only few decision-support systems currently used by Member States authorities (Coastguard agencies or other) integrate 3D models that are able to simulate the drift, fate and behaviour of HNS spills in the marine environment. When they do, they usually rely on black box commercial software or consider simplified or steady-state environmental conditions.

[1] World Trade Organization - https://www.wto.org/english/tratop_e/serv_e/transport_e/transport_maritime_e.htm
[2] International Chamber of Shipping - http://www.ics-shipping.org/shipping-facts/shipping-and-world-trade

HNS-MS aims at developing a 'one-stop shop' integrated decision-support system that is able to predict the drift, fate and behaviour of HNS spills under realistic environmental conditions and at providing key product information - drawing upon and in complement to existing studies and databases - to improve the understanding and evaluation of a HNS spill situation in the field and the environmental and safety-related issues at stake.

The key challenge in this project is to understand the physico-chemical processes that drive the numerous behaviours and fate of HNS spilt in the marine environment.

1.2 What are HNS precisely?

HNS-MS defines **hazardous and noxious substances** or **HNS** following the OPRC-HNS Protocol 2000:

> *"HNS are any substances other than oil which, if introduced into the marine environment, are likely to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea".*

This generic definition covers a wide range of chemicals with diverse intrinsic qualities (such as toxicity, flammability, corrosiveness, and reactivity with other substances or auto-reactivity). It includes:

- oil derivatives;
- liquid substances which are noxious or dangerous;
- liquefied gases;
- liquids with flashpoints not exceeding 60°C;
- packaged dangerous, harmful and hazardous materials; and
- solid bulk material with associated chemical hazards.

In the framework of HNS-MS, vegetal oils are also considered as HNS.

1.3 How does HNS behave when spilt in the marine environment?

The behaviour of a substance spilt at sea is the way in which it is altered during the first few hours after coming into contact with water. Predicting this behaviour is one of the most important stages in the development of a response strategy.

Since the early 1990's, the best HNS behaviours predictions were given by the Standard European Behaviour Classification (SEBC) [Bonn Agreement, 1991]. This classification determines the theoretical behaviour of a substance according to its density, vapour pressure and solubility. Five main behaviour classes are considered: **gas**, **evaporator**, **floater**, **dissolver** and

sinker. However, most of the time, a substance does not have one single behaviour but rather several behaviours due to its nature and the environmental conditions (wind, waves, current). This is the reason why the SEBC considers a total of 12 mixed behaviours classes (Figure 1). For example, ethyl acrylate is classified as FED as it floats, evaporates and dissolves.

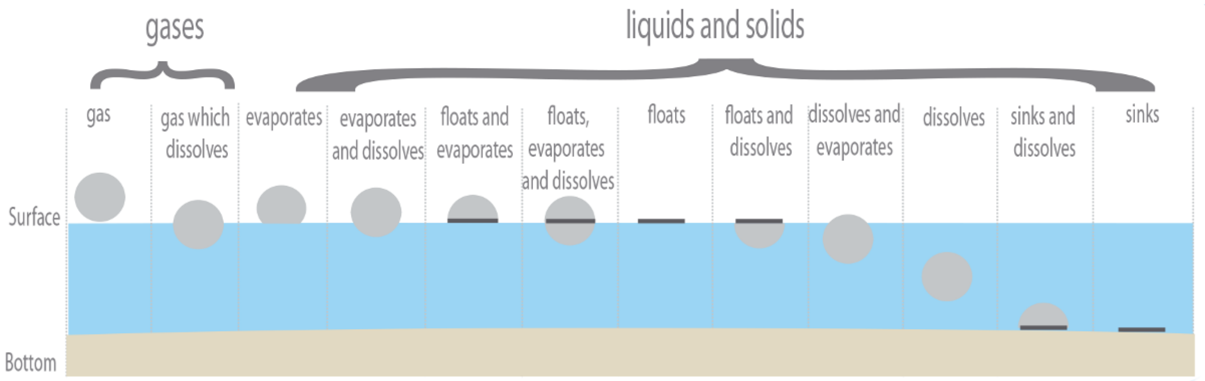

Figure 1: According the Standard European Behaviour Classification (SEBC), a substance spilt at sea will behave following one of these 12 theoretical behaviour classes.

The SEBC code has its limits. It is based on experiments conducted in the laboratory on pure products at a temperature of 20°C in fresh water. These controlled conditions are quite different from those encountered in case of a real incident at sea. In addition, the SEBC also fails to provide any information on the physico-chemical processes explaining the observed mixed behaviour, their kinetics and their eventual competitions. As a consequence, further experimental characterization of chemicals behaviour at different scales (ranging from laboratory to the field) is needed in order to gain a better understanding of the physico-chemical processes at stake, to develop more reliable mathematical models of these processes (taking into account the actual environmental conditions) and eventually to provide more accurate answers to decision makers when they plan response efforts and pollution control.

1.4 HNS-MS objectives

The project HNS-MS aimed at developing a decision-support system that national maritime authorities and coastguard stations can activate to forecast the drift, fate and behaviour of acute marine pollution by Harmful Noxious Substances (HNS) accidentally released in the marine environment.

Focussing on the Greater North Sea and Bay of Biscay, this 2 year project (01/01/2015-31/03/2016) had four specific objectives:

i. To develop a freely accessible data base documenting the most important HNS transported from or to the ports of Antwerp, Rotterdam, Hamburg, Nantes and Bordeaux;
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Results

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2 Improving HNS understanding

2.1 Facilitating access to HNS information: the HNS-MS data base

Despite recent initiatives such as MAR-ICE, MAR-CIS, MIDSIS-TROCS or CAMEO…, maritime authorities and responders often report that the easy and timely access to trustful HNS information is still a challenge in case of maritime pollution. To help solving this issue, one of the first achievements of the HNS-MS project is the development of a **HNS data-base**, specifically designed for marine environmental hazards.

A total of **123 relevant HNS** -760 HNS with all synonyms- have been selected taken into account criteria such as

- Frequency of appearance in existing HNS lists/databases[3],
- transported volumes from and to the Bonn Agreement area,
- toxicity,
- risk (threat for human lives),
- representation of different SEBC behaviour classes,
- product data availability and reliability.

Each of the 123 HNS is described by 90+ elements of information covering 6 main themes:

- Names and regulation information;
- Physical and chemical properties;
- Behaviour;
- Ecotoxicity;
- GESAMP profile;
- GHS/CLP hazard and safety profile.

Because the data base also aims at supporting the HNS-MS modelling activities, it contains the physical and chemical properties as reported in the literature for standard temperature (20°C) and salinity (0‰) condition but also for the non-standard temperature and salinity conditions (closer to the real field conditions). The latter were measured in the framework of the project (cf. section 2.2).

[3] Namely the BE-AWARE Top-100 products list, the ARCOPOL top-20, the HASREP top-100, the GESAMP top-100 lists; the MARCIS +200, CLARA's MAIA 70 products and Finland HNS list.

Freely accessible and searchable, the HNS-MS data base can be consulted from

- The HNS-MS public website (human readable): https://www.hns-ms.eu/hnsdb
- The HNS-MS private decision support system: https://www.hns-ms.eu/app
- The HNS-MS data base public API (machine readable):
    - HNS list : https://www.hns-ms.eu/api/hns/?limit=1000
    - HNS detail : https://www.hns-ms.eu/api/hns/?id=#id ,
      with #id, the id of the HNS as listed with the previous URL
      e.g. : https://www.hns-ms.eu/api/hns/?id=19

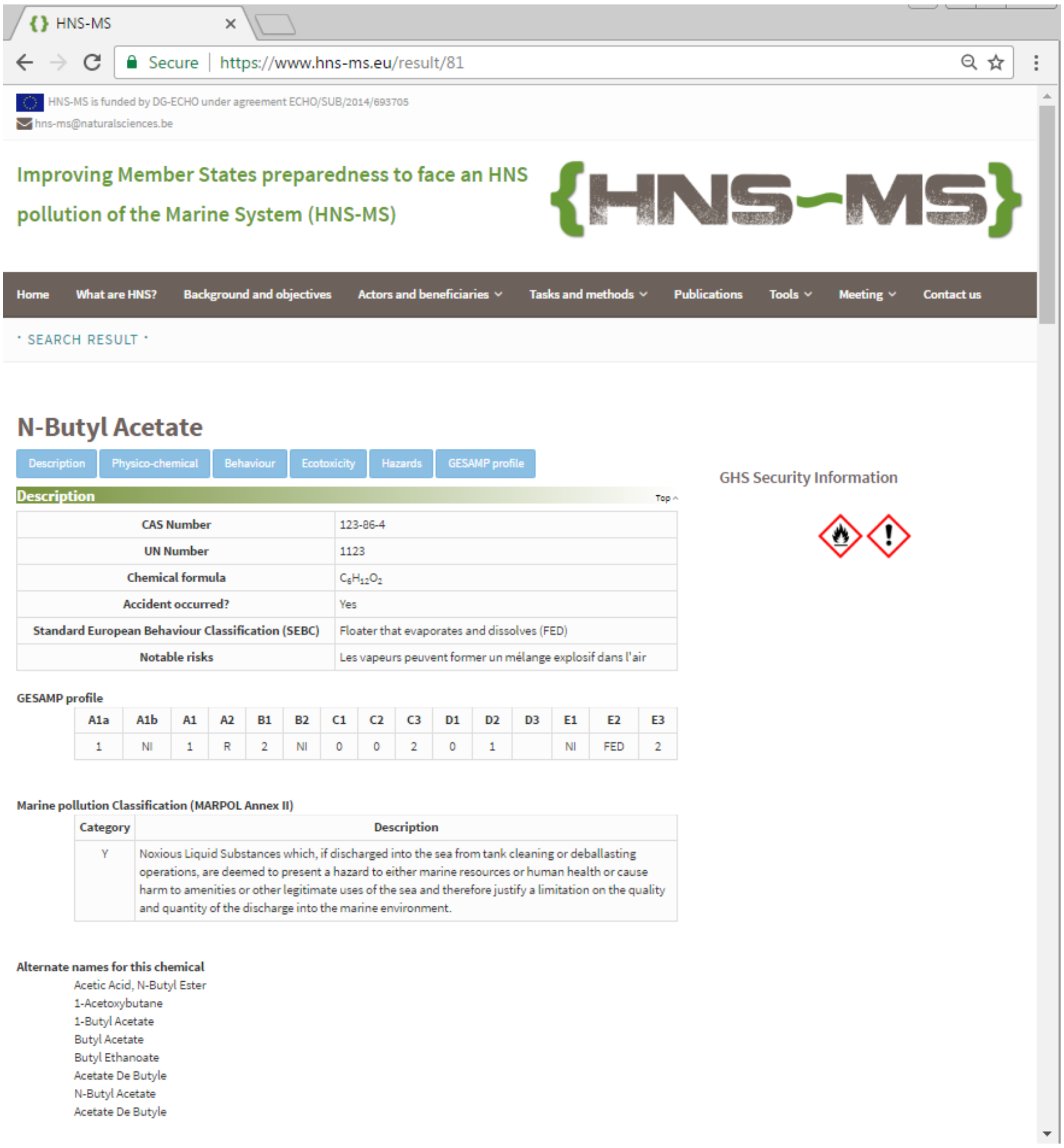


Figure 2: The HNS-MS data base is freely accessible and searchable from the HNS-MS public website : https://www.hns-ms.eu/hnsdb

More information on the HNS-MS data base: Sub-report I, Chapter 2

2.2 Further HNS lab characterisation

19 HNS from the HNS-MS database have been characterized in laboratory. Several parameters have been tested at 5°C, 10°C and 20°C: specific gravities, viscosities, surface tensions, evaporation and evaporation at the surface of seawater. In addition, Dissolution kinetics at three salinities (freshwater, 5‰ and 30‰) have been tested for 16 of the 19 HNS.

- Evaporation

The loss of mass by time was recorded for each HNS and an evaporation rate (%lost.h^{-1}) was calculated. This experiment was conducted for the HNS alone and the HNS and artificial sea water to simulate when they are spilled at the surface of seawater.

Most of the HNS alone have a linear evaporation. There is a positive correlation between the evaporation rate and their vapour pressure. Two behaviours have been observed when the HNS are spilled at the surface of seawater: for some HNS the evaporation rate is higher at the surface than alone and for the other the evaporation rate at the surface is lower than the evaporation alone.

- Specific gravities, viscosities, surface tension at 5, 10 and 20°C

Specific gravities, surface tensions and viscosities (except for low viscosities) results are globally in accordance with the literature data. A decrease of temperature results in an increase of viscosity and surface tension but there is no significant difference for specific gravities (gaps below 2%).

- Dissolution kinetics

HNS were spilled in glass bottles filled with water of different salinities. Water sample were analysed at several time intervals until the same concentration was found 4 times. This concentration was considered as the limit of solubility. The limits were then compared to the literature data with the different salinities (Figure 3).

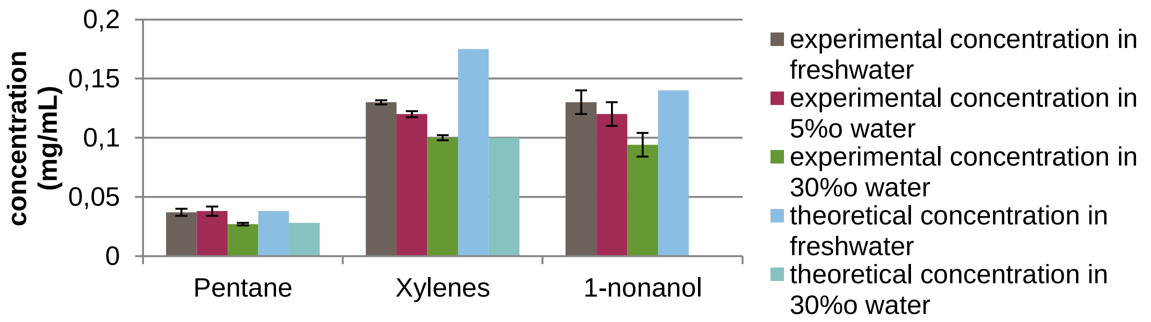


Figure 3: Effect of Salinity on the limit of solubility for Pentane, Xylene and 1-nonanol

The experimental solubilities are globally in accordance with the literature data. For all the tested HNS the solubility is higher in freshwater than in seawater. For most HNS the limits of solubility are slightly higher in freshwater than in 5‰ water. These results are in adequacy with the "salting out effect" establishing that for most of the chemicals, solubility is lower at high salt concentration.

More information on HNS lab characterization: Sub-report I, Chapter 3

2.3 Quantifying the competition between evaporation and dissolution kinetics

The overall fate of HNS at the seawater surface has been evaluated under controlled environmental conditions by using the "chemical test bench" (Figure 4). 10 HNS of the HNS-MS data base have been tested for three wind velocities (0, 3 and 7 $m.s^{-1}$) and two water temperatures (10°C and 20°C). The concentrations in the water column and in the air have been monitored during 8.5 hours and the persistence of the slick has been assessed at the end of the test.

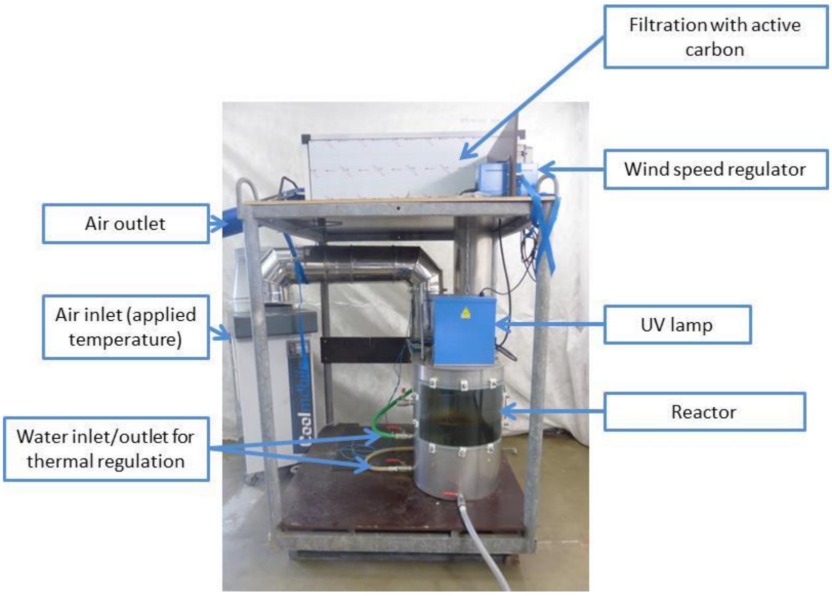


Figure 4: Cedre chemical test bench

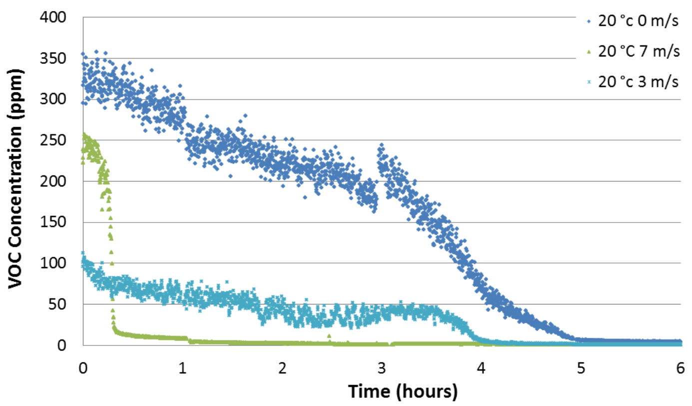


Figure 5: Examples of the time evolution of the evaporated fraction of the n-butyl measured above the slick for different wind speed

- <u>Evaporation process</u>

The concentration above the water surface is recorded all along the experiment. Except for the non-evaporating HNS, the evaporation is slower for the 'no wind' condition (Figure 5): the vapours remain above the slick increasing the concentration of VOC. With a 3 $m.s^{-1}$ wind velocity, the evaporation is a little faster: the vapours do not remain above the slick. With a 7 $m.s^{-1}$ wind velocity, the evaporation of the slick is much faster. The example of n-butyl acrylate is shown on the graph above. The influence of temperature is less important especially when there is wind. The evaporation kinetic is slightly slower at 10°C in comparison with 20°C.

- <u>Dissolution process</u>

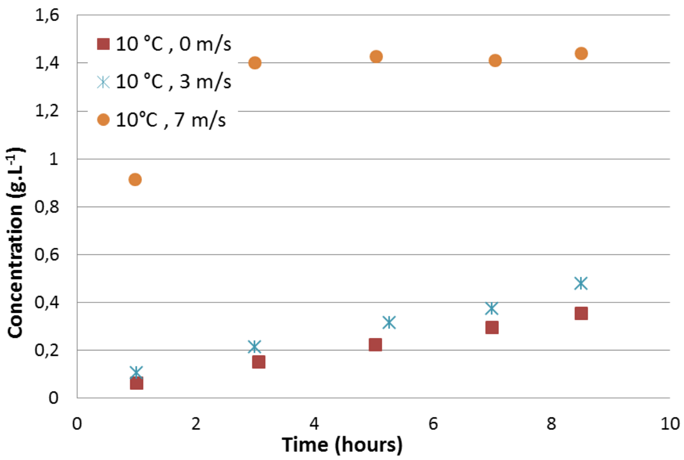


Figure 6: Example of time evolution of the dissolved concentration of 2-ethylexanoic acid for different wind speed and surface agitation

The concentration in the water is measured every two hours during the experiment. The wind velocity has a strong influence on the dissolution process (except for the HNS that evaporate quickly). Indeed the wind velocity directly impacts the surface agitation in the chemical bench. The concentrations in the water of 2-ethylhexanoic acid at 10°C and for the three wind velocities are shown on Figure 6. There is not a significant difference between the two lower wind velocities. The concentration with a wind velocity of 3 $m.s^{-1}$ is slightly higher than without wind. On the other hand, the concentration of HNS dissolved in water is much higher with a 7 $m.s^{-1}$. It reaches 80% of the product spilled for 2-ethylhexanoic acid. A stronger wind implies a much more agitated surface and so more contact between the water and the HNS. The dissolution is favoured by an increase in wind velocity.

There are two kinds of influence of the water temperature on the dissolution process. Usually the solubility is higher at higher temperature. This direct influence occurs for the HNS that do not have an evaporating behaviour. However, for the HNS with an evaporator and dissolver behaviour, the concentrations in water are higher for the 10°C condition. When the HNS has an evaporating behaviour, the temperature has an indirect influence: the evaporation of the slick is slower with a decrease of temperature. The slick remains longer at the surface of water and then it has more time to dissolve into water.

- <u>Overall fate and critical analysis of the SEBC classification</u>

The overall fate of an HNS can be represented by normalized mass balance expressed versus time. This graphic representation is given for butyl acrylate in the figure above for two environmental conditions (Figure 7 --- 7 m.s^{-1} and 20°C on the right and 0 m.s^{-1} and 20°C on the left). Butyl acrylate has a FED behaviour (floater, evaporator, and dissolver) according to the SEBC classification. The three behaviours are observed without wind and at 20°C even though the dissolution process is rather minor compared to the other behaviours. With a 7 m.s^{-1} wind, the slick disappears much faster and the evaporation becomes the main behaviour. The concentration in water is higher at the beginning of the test but then decreases. This can be explained by the evaporation of butyl acrylate from the water. With no wind and at 20°C, the SEBC behaviour is in accordance with the results from the chemical bench for most HNS. In deteriorated weather conditions, SEBC categorization cannot be used in a straightforward way.

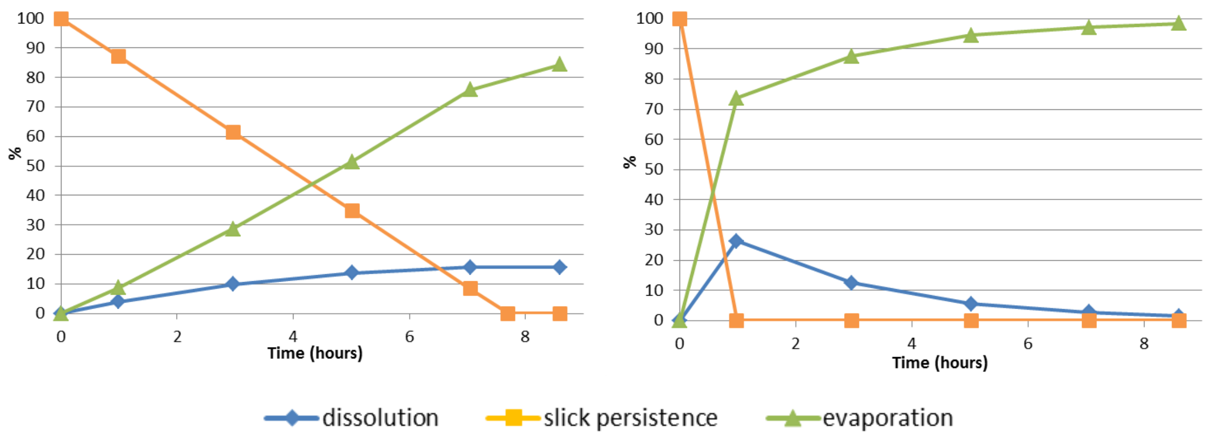


Figure 7 : Example of the measured mass balance of the evaporated, dissolved and persistent fractions of butyl acrylate at 20°C for speed wind of 0 ms^{-1} (left) and 7 ms^{-1} (right).

More information on the competition between evaporation and dissolution:

Sub-report I, Chapter 4

2.4 Understanding HNS dissolution and resurfacing behaviours in the water column

HNS behaviours in the water column were experimentally tested in the Cedre Experimental Column (Figure 8). The objective focuses on the characterization of the mass transfer process of five chemicals: n-butanol, ethyl acetate, methyl ter butyl ether, methyl methacrylate and methyl isobutyl ketone. Tests were designed to analyse the hydrodynamic behaviour and solubilisation processes of chemical droplets in seawater column of 4m of height. The shadowgraphy technique (Figure 9) was used and clearly shows the relevance of this technique to highlight the solubilisation cloud and the recirculation cells in the droplet wake (Figure 11). From a global scale, HNS droplet diameters were measured during their rise to the surface and clearly show a decrease for the majority of the tested fluids (Figure 10). The comparison of measurements with Clift's correlation for droplet rising velocity shows a good agreement for average data. Assuming the Clift's droplet rising velocity model, an estimation of average mass variation with time was calculated for the tested fluids. These results have been used to validate the resurfacing and dissolution processes simulated in the models developed.

Figure 8: Illustration of the Cedre Experimental Column

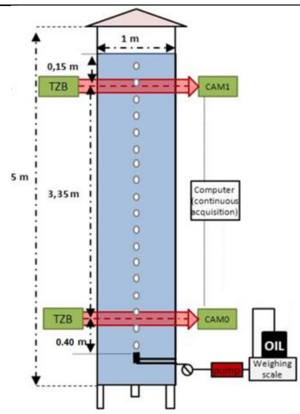


Figure 9: Illustration of Direct Shadowgraphy Imaging

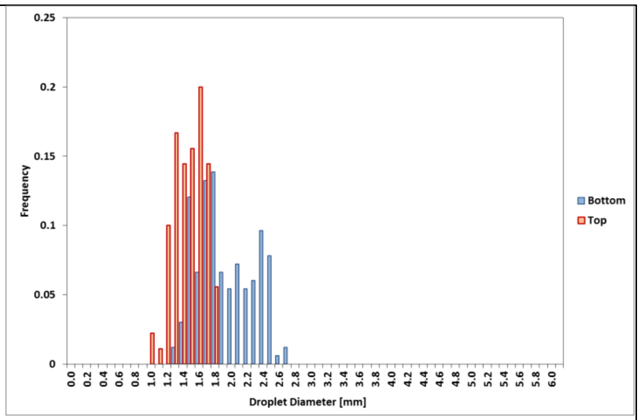


Figure 10: Histogram of distribution of equivalent droplet diameter for n-butanol between bottom and top of the water column

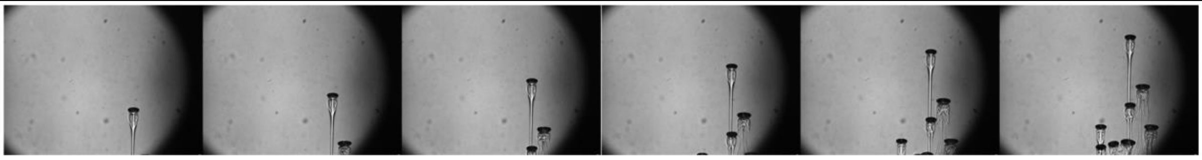


Figure 11: Illustration of n-butanol rising droplets in seawater at 3.85m of depth obtained with the shadowgraphy technique. Dissolution plumes can be observed in the droplets wake.

More information on HNS dissolution and resurfacing: Sub-report I, Chapter 5

3 Modelling drift, behaviour and fate of HNS maritime pollution

3.1 Introduction

The third objective of the HNS-MS project is the development of a fully documented state-of-the-art modelling suitable for simulating drift, fate and behaviour of HNS pollution *once spilt in the marine environment*. With respect to oil pollution, simulating HNS pollution drift, fate and behaviour has many challenges so that the development of fully suitable models will surely remain a long lasting research topic for the coming decade(s).

In this first 2-year project, our development mainly focuses on modelling the drift, fate and behaviour of **pure HNS** spilt in the greater North Sea (also known as the Bonn Agreement area), its Atlantic margin and the Bay of Biscay. We deliberately kept out of our scope modelling complex processes as weathering of HNS mixtures; chemical and physical reactivity; fire and explosion; interaction between HNS and sediments or suspended particulate matter…

To be useful, the developed model had to be able to simulate a wide variety of predefined release scenarios including

- orphan pollution observed at the sea surface, in the water column or at the sea bed

as well as pollution from a known source such as:

- Spillage from a moving vessel
- Subsurface spillage from a sunk vessel or submerged tank
- Subsurface spillage from a broken pipeline
- Spillage from a land source
- Direct gas release in the atmosphere
- Spillage from leaking containers adrift.

In order to better simulate all these release scenarios with the largest possible panel of HNS, three different models have been developed:

1. ChemSPELL, as a near-field model, mainly aiming at modelling processes occurring at small time and space scales, from a few seconds to an hour and from a few meters to a few kilometres away from the source.
2. ChemDRIFT, as a far-field model, mainly aiming at modelling processes occurring at larger time and space scales, from hours to a week and from a few hundreds of meters to tens or hundreds of kilometres away from the source
3. ChemADEL, as a Gaussian puff atmospheric dispersion model.

3.2 ChemSPELL, the HNS-MS near-field model

During an underwater spill, the crucial issues for authorities and operating people are to know how much, where and when the pollutant reaches the surface, in order to evaluate the potential risk for human health and the environmental impact on fauna and flora. In the HNS-MS project, the decision support tool covers a wide range of scenarios, including specific releases such as leakage from a sunken vessel or a pipeline break. In these cases, predictions are done by the near field model ChemSPELL (Chemical Subsea Plume modEL for Leakage).

ChemSPELL is an advanced tool that simulates the **fate and behaviour in the water column** of the five SEBC categories of chemicals i.e. **floaters, sinkers, dissolvers, evaporators, gases, and combinations of them**.

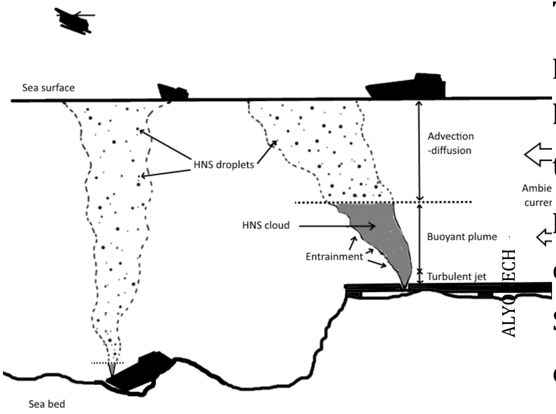


Figure 12: Illustration of HNS leaks in the water column

The near field model is based on 3D jet/buoyant plume and advection-diffusion stages with a lagrangian approach. Ambient currents, salinity and temperature are taken into account (Figure 12). The pollutant physical-chemical properties are used to evaluate droplet slip velocity and dissolution.

Shared by ChemSPELL and ChemDRIFT, the dissolution module is validated against CEDRE and ARMINES/EMA experimental results on some HNS dissolvers.

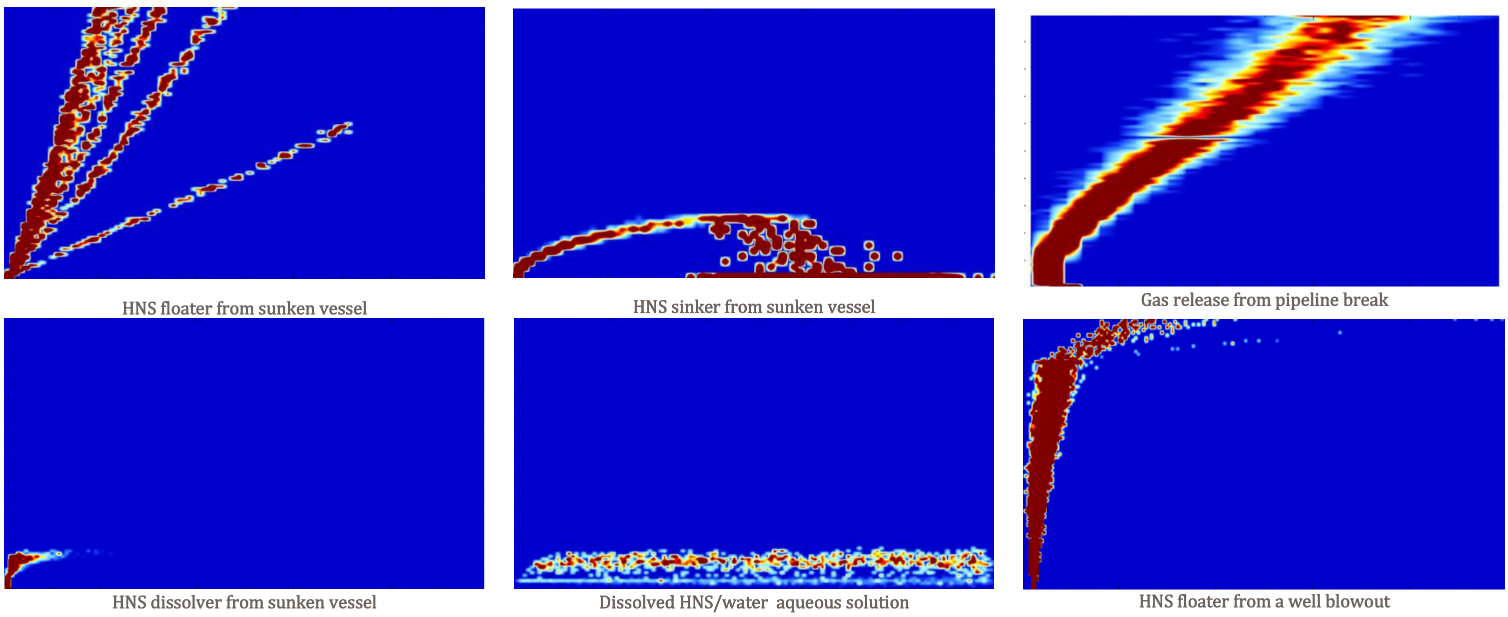


Figure 13: Examples of concentration profile in the water column from ChemSPELL output file (NASA GISS Panoply).

ChemSPELL simulation results are exported to a netCDF file containing concentration, droplet size distribution, dissolved mass and vertical velocity values in function of time, latitude, longitude and depth.

Figure 13 is an illustration of the evolution of the concentration values in the water column for different scenarios and for chemicals from different SEBC categories, using the NASA GISS Panoply data viewer.

More information on ChemSPELL: Sub-report II, Chapter 3

3.3 ChemDRIFT, the HNS-MS far-field model

The model ChemDRIFT aims at modelling HNS drift, fate and behaviour for the first five days after the release. Being an in-depth evolution of the oil spill drift and fate model OSERIT, ChemDRIFT represents HNS pollution as a cloud of tens of thousands of Lagrangian particles to which are associated a fraction of the total mass of the released pollutant.

Taking into account HNS initial physical state (solid, liquid, gas), HNS physico-chemical properties (density, viscosity, interfacial tension, solubility…), HNS phase (slicks, droplets/bubbles, dissolved fraction in sea water, evaporated fraction…) and the met-ocean conditions forecasted by CMEMS and ECMWF for the greater North Sea and the Bay of Biscay, ChemDRIFT computes at each time step and for each particle (Figure 14)

- The drift due to the combined effect of wind, waves, currents;
- The dispersion or dilution due to turbulent mixing;
- The resurfacing/sinking processes due to buoyancy;
- The entrainment in the water column due to waves agitation;
- Slick spreading (computed from a random walk method);
- The mass fraction exchanges between the different HNS phases (slicks, droplets/bubbles, dissolved fraction in sea water, evaporated fraction…).

ChemDRIFT simulation results are exported to a netCDF file containing time evolution of the Lagrangian particles trajectory and the associated HNS mass fractions per phase. These basic information are then further processed to compute useful elements of information for maritime authorities and responders such as

- Trajectory maps of the particles cloud

- Concentration maps of the different HNS phase fractions at different times steps and different vertical levels of the water column
- Maps of the impacted area
- Map of exposure time above given threshold concentrations
- Beaching risk

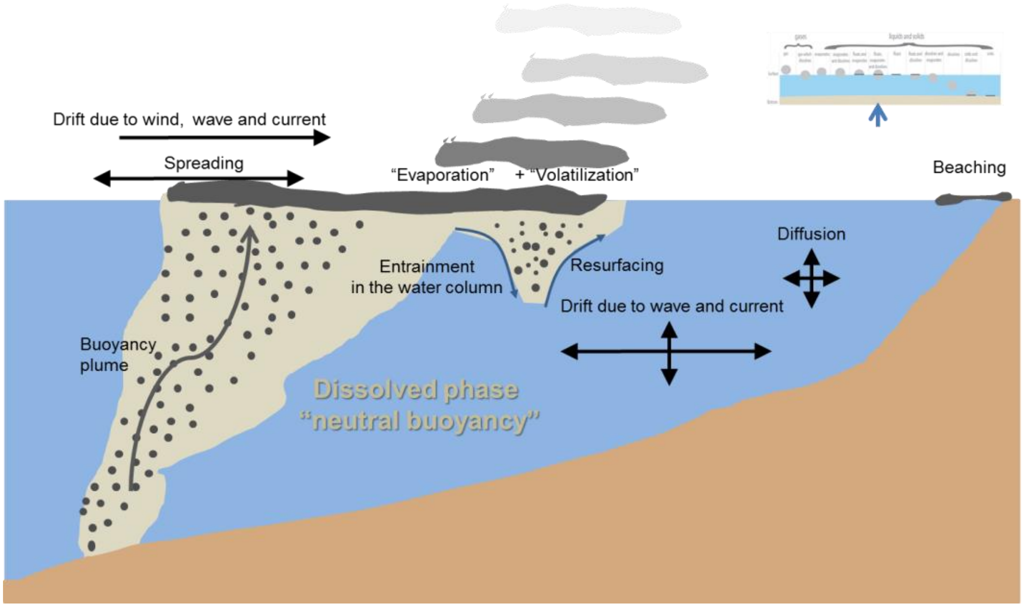


Figure 14: Basic processes simulated by ChemDRIFT to compute the drift, fate and behaviour of HNS pollution. Example of a Floater-Evaporator-Dissolver HNS for a subsurface release.

More information on ChemDRIFT: Sub-report II, Chapter 4

3.4 ChemADEL, the HNS-MS atmospheric dispersion model

In the context of a spill, some HNS evaporates when they are released at sea. A fraction or the totality of the pollutant goes into the atmosphere. Depending on its nature, there is a risk of fire, explosion or inhalation hazards for personnel intervening or operating in the field, or, in case of a nearshore risk, for coastal communities. Hence it is crucial to know how much and where the gas goes, to evaluate and prevent health issues. The model ChemADEL (Chemical Atmospheric Dispersion modEL) has been developed to answer the latter questions.

ChemADEL is a simple, fast and efficient tool to evaluate gas concentration over space and time from a release point, and provides a first line information on potential risks, necessary for all concerned authorities.

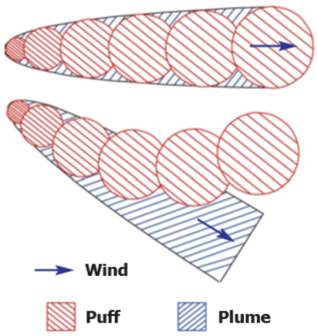


Figure 15: Schematic representation of Gaussian plume and puff models

The atmospheric dispersion model is based on the classical and proven puff model. Several puffs are released along time as a continuous plume following a Gaussian dispersion, but with the advantage of taking into account local wind speed and temperature variations (Figure 15).

ChemADEL simulation results are exported to a netCDF file, containing concentration values in function of time, latitude, longitude and for three different heights (1m, 10m, 50m). Figure 16 is an illustration of the evolution of the concentration values in the atmosphere at two different times in a lat/lon coordinates system, using the NASA GISS Panoply data viewer.

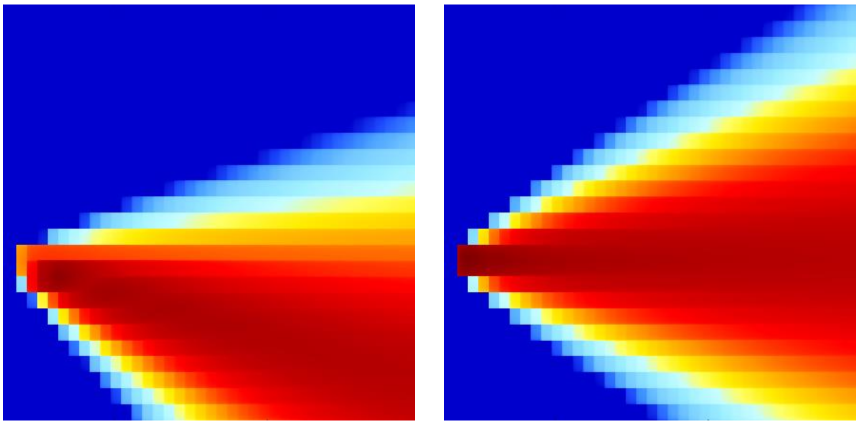


Figure 16: Example of concentration evolution in a lat/lon coordinates system from ChemADEL output file (NASA GISS Panoply)

More information on ChemADEL: Sub-report II, Chapter 5

4 Vulnerability mapping

The fourth specific objective of the HNS-MS project is the production of environmental and socioeconomic vulnerability maps dedicated to HNS. The motivation is to help HNS-MS end-users assessing the likely impacts of HNS pollution on the most HNS sensitive marine habitats, human health, marine species, coastal or offshore amenities and other legitimate uses of the sea. To this purpose, the methodology developed in the framework of the BE-AWARE projects for oil spill vulnerability mapping was adapted and extended to HNS spill scenarios.

HNS covers a wide range of chemical substances that have diverse behaviours in the marine environment, acting as evaporators, sinkers, floaters or dissolvers (SEBC classification), and intrinsic qualities (such as toxicity, flammability, corrosiveness, and reactivity with other substances or auto-reactivity).

A feature (environmental or socio-economic resource) is defined as vulnerable if it is likely that it could be directly exposed to an HNS spill in relation to the behaviour of the chemical involved:

- vapours in the air
- slicks on sea surface or stranded on intertidal zone at low tide
- high concentrations dissolved in the water column
- slicks or high concentrations of HNS sinking on the sea bed

Most of the time, a substance has several behaviours. For necessary simplification, to evaluate sensitivity of environmental and socio-economic features, we have considered the main behaviour for each category of chemical.

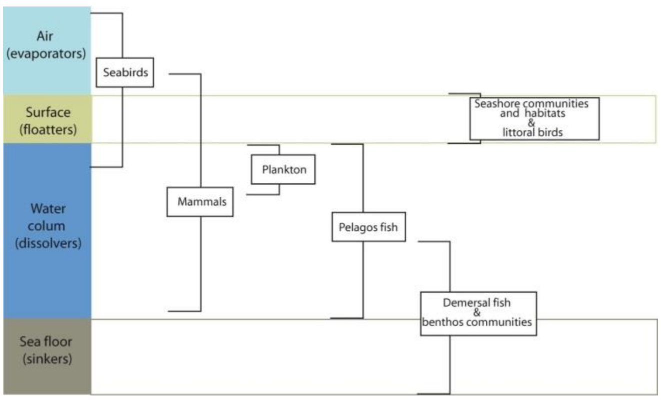


Figure 17: Marine life compartments and marine communities potentially affected by chemical pollution according to the vertical distribution of organisms

18 shoreline habitats, 8 open sea habitats, 4 types of environmental protections, 12 species and 16 socio-economic features were selected for assessment and attribution of vulnerability ranking score (5 levels of vulnerability ranking scores were defined).

The vulnerability analysis was conducted at two levels:

- At the regional scale of the Bonn Agreement area;
- At a local operational scale the waters and coastline of Belgium, chosen as a test area.

A total of 72 maps were produced:

- 39 vulnerability maps at regional scale for the Bonn Agreement area
- 3 thematic maps at local operational scale for Belgium
- 32 vulnerability maps at local operational scale for Belgium

The vulnerability maps catalogue with viewing and downloading facilities is available on the HNS-MS public website: https://www.hns-ms.eu/tools/sensitivity_maps

More information on the methodology developed for the vulnerability mapping:
Sub-report III

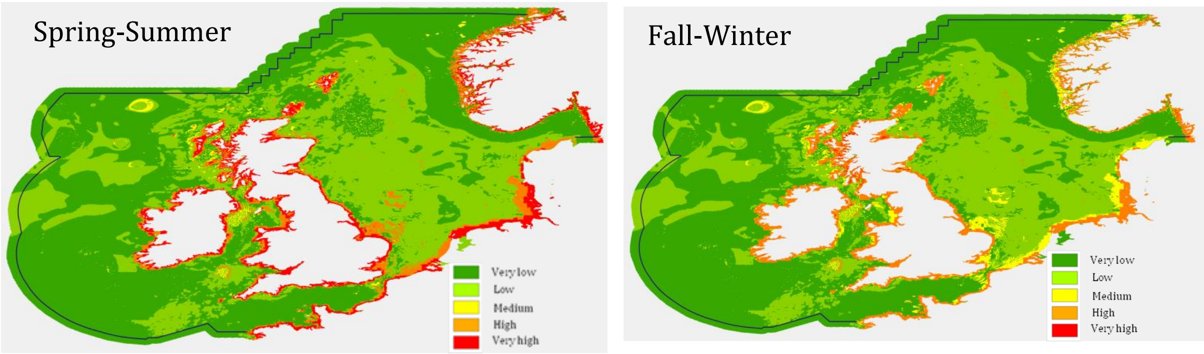


Figure 18: Example of seasonal vulnerability of habitats to pollutant at the sea surface (same score respectively for spring/summer and fall/winter)

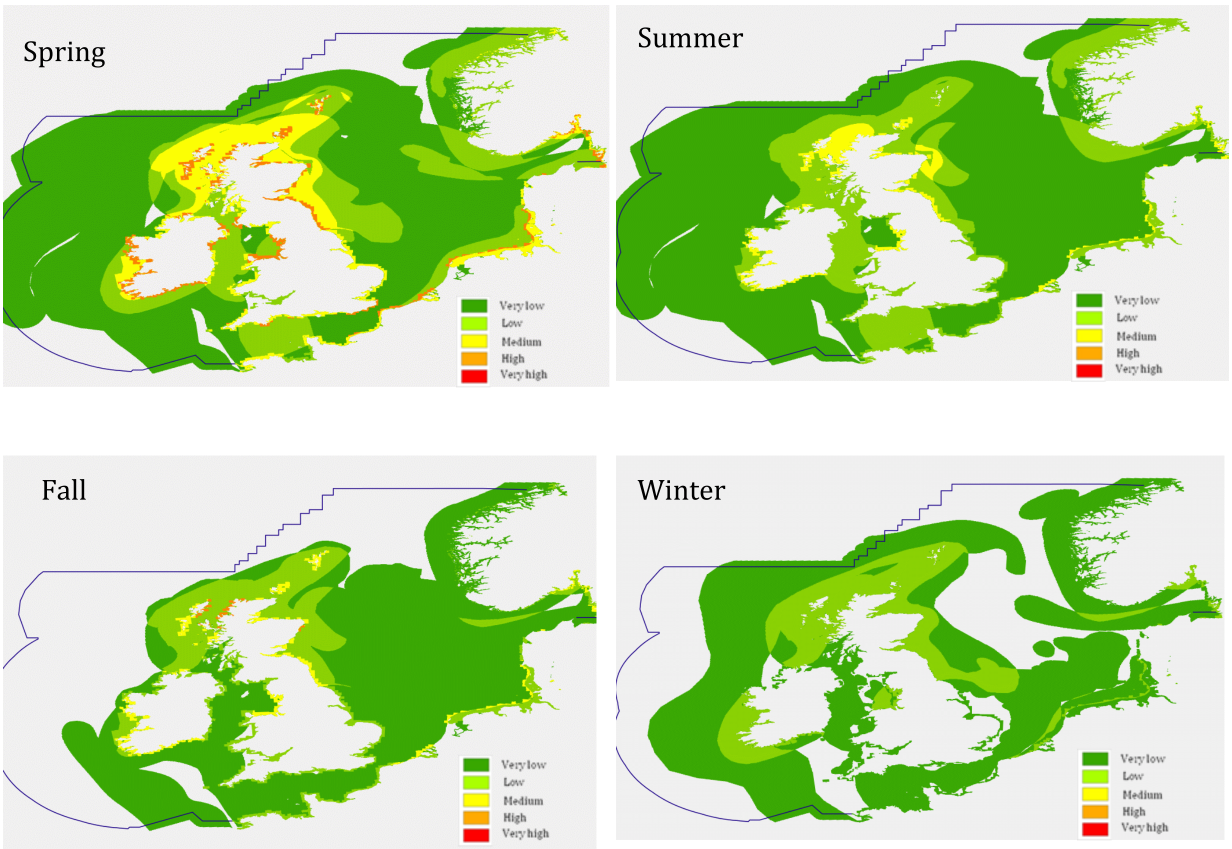


Figure 19: Example of seasonal vulnerability of Species to pollutant on the air

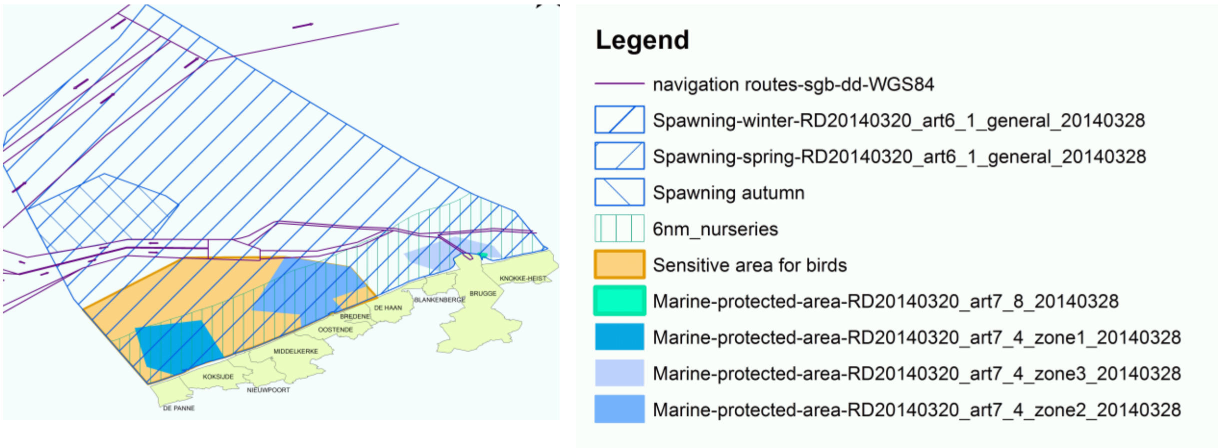
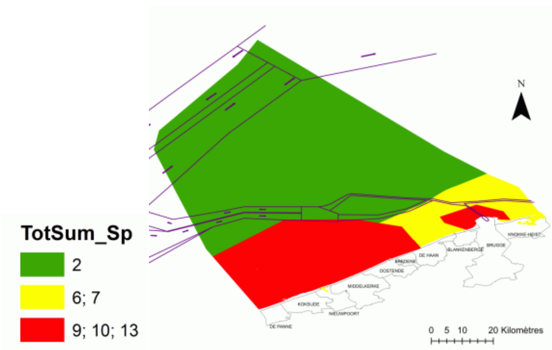
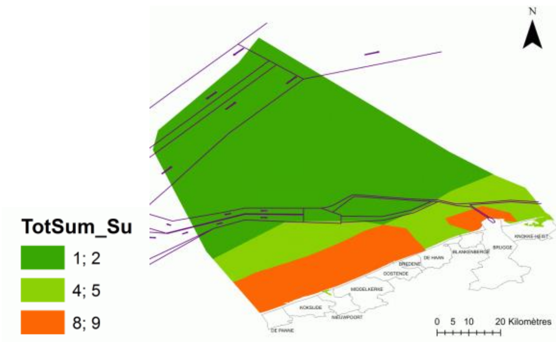


Figure 20: Example of thematic operational maps for sensitive species and protected areas

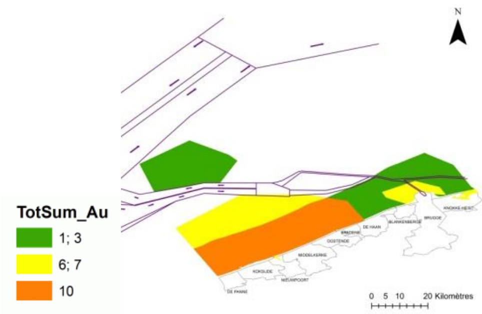
Spring



Summer



Autumn



Winter

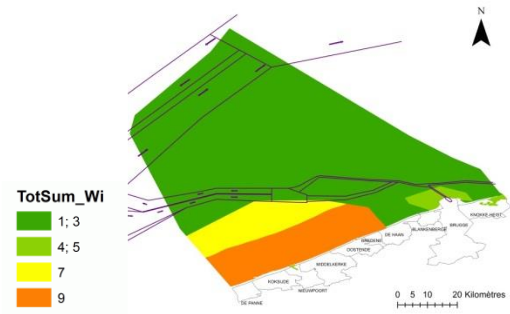


Figure 21: Example of seasonal operational vulnerability map of species to pollutant on the seabed

5 The HNS-MS Decision Support System

The last achievement of the HNS-MS project is the integration of all the previously presented results into a unique decision support system that will help maritime authorities and coastguard operators to evaluate the risks for maritime safety, civil protection and marine environment in case of HNS pollution at sea.

This decision support system is designed around five main functionalities:

1. Providing information on 123 different HNS (760 if synonyms included) listed in the HNS-MS database;
2. Requesting on-demand realistic simulations based on 9 predefined released scenarios;
3. Visualizing the simulations results and the associated met-ocean forcing;
4. Assessing the likely impacts of HNS-pollution with use of regional and local seasonal vulnerability maps;
5. Providing efficient management tools for existing simulations, including their sharing with the HNS-MS user community.

The decision support system is scheduled to be ready for operational use by end 2017. Once stamped as operational, our users will be able to request the creation of their account at https://www.hns-ms.eu/app.

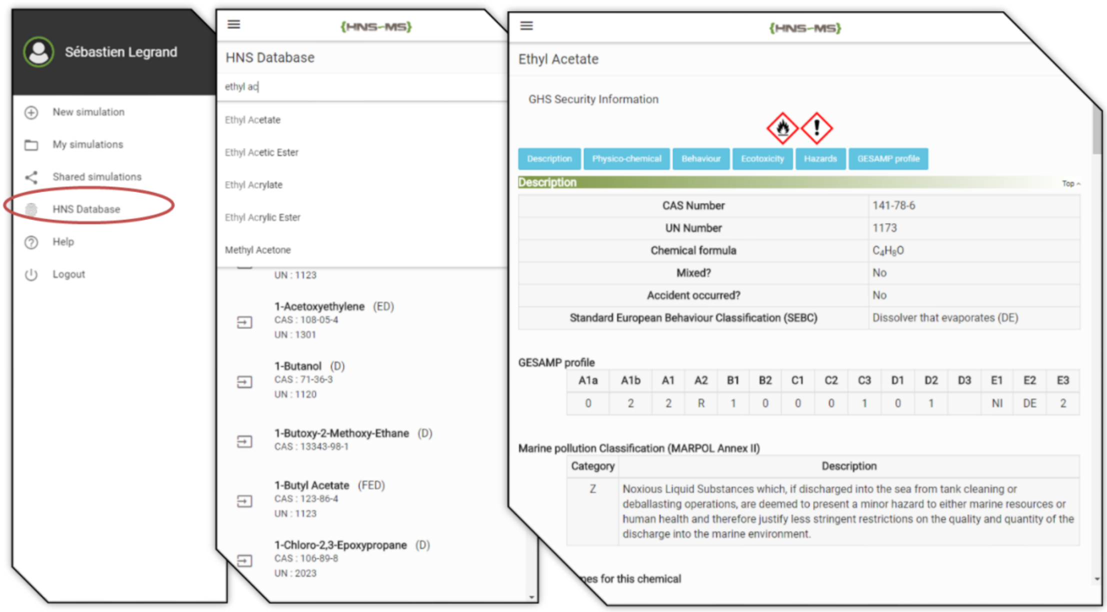


Figure 22: The HNS-MS decision support system allows an easy consultation of the HNS-MS database, offering a direct access to 123 different HNS and their 760 synonyms.

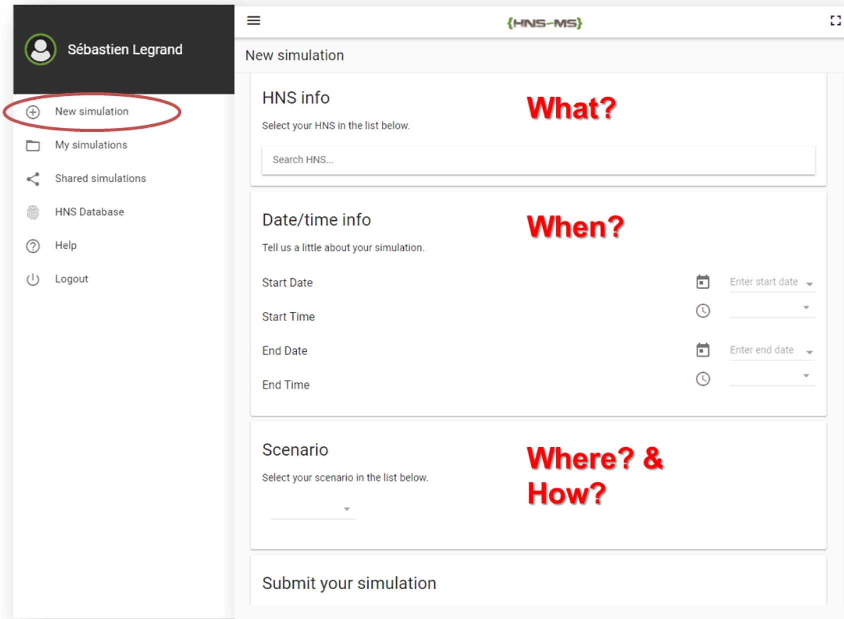


Figure 23: Owing to its interactive simulation set-up form, HNS-MS end-users can request new on-demand simulations for 9 predefined release scenarios. The set-up form helps them answering the 4 basic questions: What? When? Where? and How?

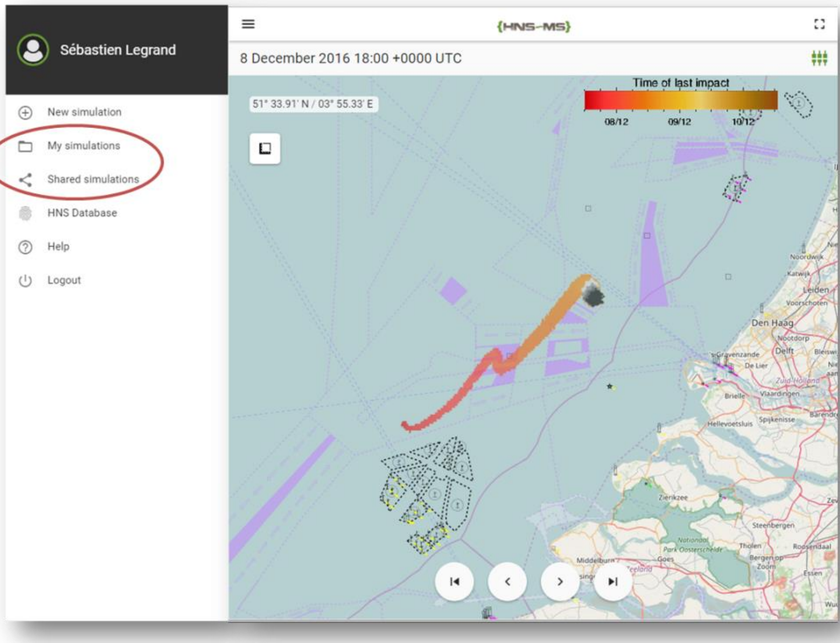


Figure 24: The HNS-MS decision support system allows visualizing results of simulations own by the logged-in user or shared by the HNS-MS community. The latter functionality greatly improves the communication between the different responder teams that are involved for real pollution events.

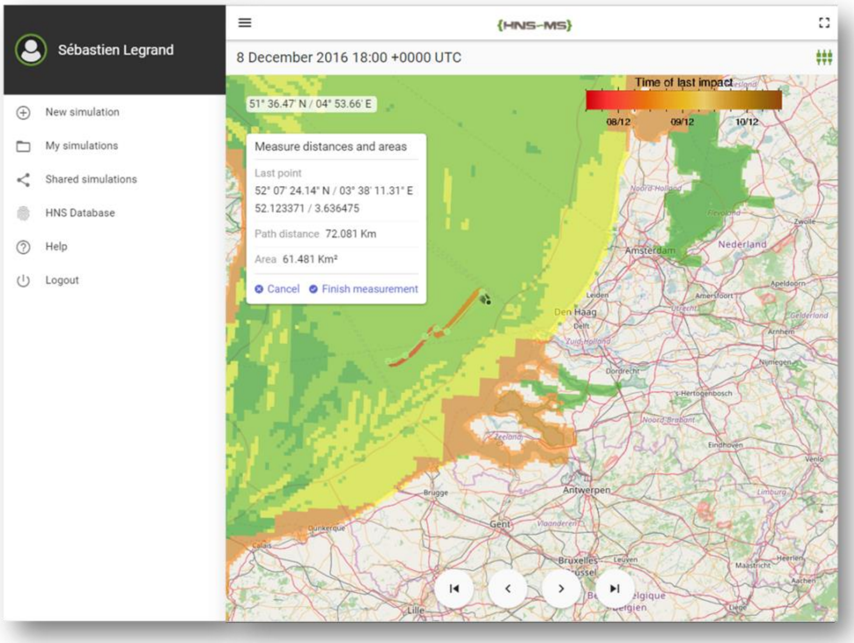


Figure 25: The HNS-MS decision support system allows the superposition of simulations results and vulnerability maps in order to better assess the likely impacts of the pollution event on the most HNS sensitive marine environment, the human health, the marine life, the coastal or offshore amenities and other legitimate uses of the sea.

More information on the HNS-MS decision support system:

Sub-report IV

6 Outreach activities and the stakeholders meeting

At many occasions[4], HNS-MS objectives and results have been presented in order to reach the wider possible community of potential stakeholders and end-users.

Two highlights:

1 The conclusion of a co-operation agreement between the projects consortia MARINER, MARPOCS and HNS-MS.
2 The organization of a 2 days stakeholders meeting at the premises of "FPS Health, food chain safety and environment", Brussels, on the 13th and 14th of December 2016.

This latter activity gathered 34 experts and delegates from the European Maritime Safety Agency, the Bonn Agreement, the International Maritime Organization, as well as from national maritime authorities, coast guards services from Belgium, Finland, France, Germany, Norway, the Netherlands, Portugal, Sweden and the United Kingdom.

More information and presentations : https://www.hns-ms.eu/meeting/programme/

Figure 26: 34 experts attended the HNS-MS stakeholders meeting on 13th and 14th of December 2016.

[4] Among others OTSOPA meetings 2015, 2016 & 2017, EGU general assembly 2016 & 2017, ITAC 2015, Cedre Information Day 2016, various Belgian coastguard meetings…

Conclusion

The project "HNS-MS – Improving Member States Preparedness to face HNS pollution of the Marine System" was a 27 months project (01/01/2015-31/03/2017) co-funded by the Directorate-General of European Commission for European Civil Protection and Humanitarian Aid Operations (ECHO).

Focussing on the Greater North Sea and Bay of Biscay, the HSN-MS consortium

i. Developed a freely accessible database documenting 123 relevant HNS transported from or to the ports of Antwerp, Rotterdam, Hamburg, Nantes and Bordeaux;
ii. Conducted lab experiments in order to improve the understanding of the physico-chemical behaviour of HNS spilt at sea;
iii. Developed the HNS-MS modelling system made of a near-field model ChemSPELL, a far-field model ChemDRIFT and an atmospheric dispersion model ChemADEL. Together, these models can simulate the drift, fate and (SEBC) behaviours of HNS spilt at sea.
iv. Produced environmental and socioeconomic vulnerability maps dedicated to HNS that will help end-users assessing of the likely impacts of HNS pollution on the marine environment, the human health, the marine life, the coastal or offshore amenities and other legitimate uses of the sea.

All these contributions have been integrated into a Decision Support System that, once stamped as operational, will help maritime authorities, coastguard stations and responders to evaluate the risks for maritime safety, civil protection and marine environment in case of acute HNS maritime pollution.

HNS-MS achievements meet real needs. For instance, the HNS-MS database is already used in the framework of MARPOCS and MARINER projects. These achievements also open new perspectives and opportunities. During the numerous interactions with our stakeholders and potential end-users, we have discussed the perspective to use HNS-MS achievements to support a regional HNS risk analysis for the Bonn Agreement area. Similarly, the opportunity to implement the HNS-MS decision support system for the Nordic and Baltic Seas has been mentioned during the HNS-MS stakeholders meeting the consortium organised in December 2016.

Owing HNS-MS achievements, the HNS-MS consortium has solid basis to tackle the many remaining challenges, issues and knowledge gaps that shall be addressed for the coming years and decade(s). Depending on funding opportunities, our priority short-term follow-up actions are:

- The realisation of an extended validation of the HNS-MS model against field data and/or the realisation of inter-comparison studies with similar tools;
- The long term maintenance and extension of the HNS-MS database, maybe in concertation with EMSA and OSINet;
- The systematic laboratory characterisation of HNS for non-standard temperature and salinity conditions.
- Further development of models to include advanced processes such as weathering of HNS mixtures , chemical reactivity or interaction with sediments;
- Production of the operational vulnerability maps for the whole Bonn Agreement area and the other seas were the decision support system will be implemented.

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Improving Member States preparedness
to face an HNS pollution of the Marine System