This project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 953152

Project Acronym: DIAGONAL

Deliverable 6.1

Definition and characterisation of risk management approaches

Due date of Deliverable: 30th April 2024 (M36)

Actual submission date: 26th April 2024 (M36)

Lead beneficiary for this Deliverable: ITENE

Level of Dissemination: Public

Authors: Blanca María Pozuelo Rollón, Verónica Vela Vela, Arantxa Ballesteros

Document Control

Version	Date	Author	Modifications
v0	27.02.2024	Blanca María Pozuelo Rollón & Verónica Vela Vela (ITENE), Andreas Tsoumanis (NOVAM)	Initial version
v1	29.02.2024	Arantxa Ballesteros Riaza (ITENE)	Review
v2	26.04.2024	Laura Gómez-Cuadrado (ICCRAM-UBU)	Review & Submission

Acknowledgement

This project has received funding from the European Union's Horizon2020 research and innovation programme under grant agreement No 953152

The statements made herein do not necessarily have the consent or agreement of the DIAGONAL consortium.

Abbreviations

CPE	...	Collective protective equipment
FF	...	Far Field
HARN	...	High Aspect Ratio Nanoparticles
MCNM	...	Multi-Component Nanomaterials
NEAT	...	Nanoparticles Emission Assessment Technique
NF	...	Near Field
NIOSH	...	National Institute for Occupational Safety and Health
OEB	...	Occupational Exposure Benchmark
PPE	...	Personal protective equipment
RMT	...	Risk Management Tool
SbPD	...	Safe by Process Design
SMEs	...	Small and Medium-sized Enterprises
UI	...	User Interface
WPMN	...	Working Party on Manufactured Nanomaterials

Model parameters abbreviations

BE	...	Band for exposure
BH	...	Band for hazard
Cbg	...	Background concentration
CPE	...	Collective protective equipment
DFF	...	Environmental dilution when the source is in the far field
DNF	...	Environmental dilution when the source is in the near field
E_1	...	Material functionalization score
E_2	...	Nanometric percentage score
E_3	...	Shape score

E_4	...	Dustiness score
E_5	...	Relative humidity score
E_6	...	Percentage of product in dilution score
E_7	...	Viscosity score
f	...	Task frequency score
Fbg	...	Working surface contamination score
F_s	...	Other exposure sources presence score
h	...	Manipulation energy score
M	...	Material score
P_h	...	H-phrases score
PPE	...	Personal protective equipment
PPEm	...	Potential process emission
PPEx	...	Process potential exposure
PPE_1	...	Respiratory protective equipment score
PPE_2	...	Protective gloves score
PPE_3	...	Protective clothing score
PPE_4	...	Eye protection score
PPE_5	...	Protective footwear score
PSEm	...	Potential substance emission
q	...	Quantity of material used in the process score
S	...	Working area surface score
s	...	Nanoparticle size score
SPEx	...	Substance potential exposure
t	...	Task duration score
w	...	Number of involved workers score
wp	...	Existence of work procedure score

Contents

1 Scope

This deliverable presents the work carried out within Work Package 6 "Risk Management and Governance" and refers to Task 6.1 of the project, which aims to define effective risk management approaches for Multi-Component Nanomaterials (MCNMs) and High Aspect Ratio Nanoparticles (HARNs), considering their unique toxicological properties and various exposure scenarios in nanotechnology.

Using the STOP principle, priority is given to strategic, technical, organizational, and personal protection measures. An interactive Risk Management Tool (RMT) has been developed to support regulators, industries, and other stakeholders on the selection of the best available approaches to reduce risk at source and mitigate the exposure at all stages of MCNMs and HARNs life cycle.

Existing guidelines will be adapted, and data from various sources will be analysed. Hazard avoidance or reduction will be explored, followed by recommendations for product, process, and workplace control. Engineering controls and good work practices will be evaluated, along with individual protective equipment to mitigate risks.

Additionally, the document also includes a user manual generated to explain the operation of the RMT with the aim of guiding the user.

2 Introduction

Within the realm of nanotechnology, Multi-Component Nanomaterials (MCNMs) and High Aspect Ratio Nanoparticles (HARNs) have become increasingly prevalent, presenting unique challenges in terms of safety and risk management. Recognizing the importance of addressing these challenges, a comprehensive effort is underway to define and characterize effective risk management approaches tailored specifically to MCNMs and HARNs.

This document aims to compile a thorough list of proven risk management strategies designed to mitigate the potential hazards associated with these materials. Grounded in the STOP principle —Strategic measures for elimination and substitution, Technical measures for ventilation and containment, Organizational and administrative measures, and Personal Protection— the aim is to provide a comprehensive framework for risk reduction across various exposure scenarios, using as a basis the scenarios defined for the industrial cases targeted in DIAGONAL (as well as the experimental results obtained in the monitoring campaigns performed at those facilities), within the nanotechnology value chain.

Central to this initiative is the development of an interactive RMT, intended to provide guidance and assistance to regulators, industries, and stakeholders in navigating the complexities of risk mitigation. Drawing upon a diverse array of sources, including existing guidelines, databases, and research projects, the goal is to ensure that decision-makers have access to the most up-to-date and relevant information available.

Throughout this document, the methodologies, principles, and recommendations underlying the risk management approach for MCNMs and HARNs will be elucidated. From product modifications to workplace protocols, each aspect of risk reduction will be examined with the best care and attention to detail.

In summary, this document serves as a comprehensive guide for understanding and implementing effective risk management strategies tailored to the unique characteristics of MCNMs and HARNs. By fostering collaboration and knowledge-sharing across various sectors, this document intents to promote a safer and more sustainable approach to nanotechnology innovation.

3 Risk Management Tool

3.1 Introduction

During the last few years, significant progresses have been made in developing qualitative methodologies for evaluating exposure risks related to nanomaterials, particularly concerning MCNMs and HARNs. These methodologies enable the estimation of initial risk and the identification of concerning scenarios. Since MCNMs and HARNs could pose risks to human and environmental health due to their very unique characteristics (high aspect-ratio, small size), which may be even higher to those compared to the risks associated with conventional nanomaterials, scientific efforts have been directed towards the development of qualitative methods, primarily mathematical approaches, to aid in evaluating and preventing exposure risks associated with MCNMs and HARNs.

The use of MCNMs and HARNs has expanded across various sectors including healthcare, pharmaceuticals, and defence, with further anticipated growth in the years ahead. Despite their advantageous properties, research on toxicity has underscored potential adverse health effects. Given the limited understanding of these risks, adherence to the precautionary principle is recommended, advocating for minimizing exposure these materials whenever feasible.

However, quantitative assessment of exposure to MCNMs and HARNs arise difficulties due to lack of adequate equipment for personal sampling, and the scarcity of toxicological and epidemiological studies to set limit values. Despite these limitations, there are other options to monitor the exposure as Control Banding tools, the establishment of internal limit values based on appropriate toxicological studies, or the use of toxicological information of similar substances.

Control Banding tools offer a qualitative approach to assessing exposure to MCNMs and HARNs, facilitating decision-making regarding necessary control measures or the requirement for further risk investigation. These methods categorize situations into different bands, reflecting the likelihood of exposure and potential risks.

Qualitative methods play a crucial role in implementing safe design practices, enabling predictions of exposure based on material characteristics and usage scenarios.

The risk assessment model developed within this framework aims to broaden the application of such tools beyond research settings to technical personnel in small and medium-sized enterprises (SMEs), assisting employers and employees in accurately assessing risks associated with exposure to MCNMs and HARNs. This facilitates the implementation of risk mitigation measures based on the priority determined by the risk bands.

3.2 Applicability

The tool is used for conducting qualitative risk assessment of MCNMs and HARNs, with MCNMs defined as materials comprising multiple components at the nanoscale with a size range lower than 100 nm and HARNs as nanoparticles with a high aspect ratio, typically greater than 3:1. This tool is intended to examine the following types of processes:

- Production processes where MCNMs or HARNs are directly used as raw materials.
- Processes where the resulting material intentionally falls within the nanoscale range or exhibits a high aspect ratio.
- Processes where nanoscale particulate material or high aspect ratio nanoparticles are obtained as by-products at various stages of the production line.

Exposure calculations are carried out based on in-situ data measured by industrial hygiene technicians through continuous monitoring equipment or based on concentration estimation from ITENE's own database, obtained from all nanoparticle exposure monitoring campaigns conducted by the technical staff of the environmental monitoring and safety department under various European projects.

3.3 The model

The RMT estimates two different bands for hazard and exposure which result on five possible bands for risk when they are combined.

These bands classification is the outcome of the study of several commercial methods functionality and the experience of ITENE's technical workers, identifying the better characteristics to give the user the best service.

Hazard bands scheme relies on the COSHH Essentials model widely known on the chemicals risk prevention area, while the exposure bands scheme is based on the combination of several models' functionalities, such as Cherrie & Schneider model (1999) and other already available platforms, for instance Stoffenmanager nano 1.0 and Nanosafer.

In the following sections, an explanation on the data used by the model to estimate each band and the needed factors to its classification is given.

For the calculation of risk bands, the RMT organizes the data in a way that is more understandable for the user, but internally carries out the appropriate parameter association for band classification as seen in Figure 1 and Figure 2. In this manner, the RMT organizes the data into three sections. The first section gathers information about the workplace to characterize the environment where the exposure scenario occurs (volume, cleanliness, area maintenance, etc.), the second section collects information related to the process (frequency and duration of the task, exposed workers, personal protective equipment (PPE), etc.), and finally, the material used is characterized (quantity, form, dustiness, moisture, etc.).

3.3.1 Exposure band

Exposure bands are influenced by the following factors:

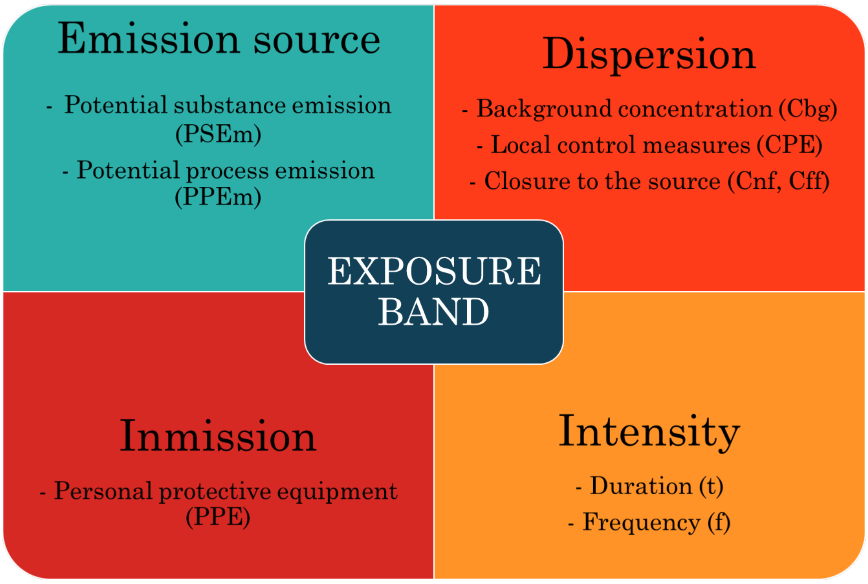

Figure 1. Factors which influence the exposure band estimation

3.3.1.1 Emission source

Potential substance emission (PSEm)

There are different factors which influence the emission of a substance. The main factor is the substance's shape since it is directly related to the way it is released to the environment. In this model, 4 different shapes are taken into account: dust, granules or scales, paste and liquid.

Table 1. Shape scores (E_3)

Shape (E_3)	Score
Dust	1
Granules/scales	0.75
Paste	0,3
Liquid	0.01
Unknown	1

The release of each of these shapes will be influenced as follows:

In the case of dust and granules/scales, the most influential factors will be the nanometre percentage of the material, the dustiness, and the relative humidity, while in the case of paste and liquids the factors influencing the emission will be the nanometre percentage of the material, the percentage of product in the dilution and the viscosity. In the event that any of the above factors are not known exactly, the precautionary principle will be applied, and the highest score will be assigned.

The scores for the factors influencing the emission are shown below:

Table 2. Nanometric percentage scores (E_2)

Nanometric percentage of the material (E_2)	Score
Pure product (100%)	1
Main compound (50-99%)	0.75
Substantial (10-50%)	0.3
Traces (1-10%)	0.01
Unknown	1

Table 3. Dustiness scores (E_4)

Dustiness (mg/kg) (E_4)	Score
Very high (> 500)	1
High (150 – 500)	0.75
Medium (50-150)	0.3
Unknown	1

Table 4. Relative humidity scores (E_5)

Relative humidity (E_5)	Score
> 50%	0.3
10 – 50%	0.75
< 10%	1
Unknown	1

Table 5. Percentage of product in the dilution scores (E_6)

Percentage of product in the dilution (E_6)	Scores
No diluted	1
50 – 99%	0.75
10 – 50%	0.3
1 – 10%	0.2
0.001 – 1%	0.01
Unknown	1

Table 6. Viscosity scores (E_7)

Viscosity (E_7)	Score
High	1
Medium	0.5
Low	0.1
Unknown	1

With this information, the multiplier factor dependent on the physical shape of the material (η) can be calculated as follows:

$$\eta_{dust,granules,scales} = E_2 \times E_4 \times E_5$$

$$\eta_{liquid,paste} = E_2 \times E_6 \times E_7$$

$$\eta = \begin{cases} E_2 \times E_4 \times E_5, & if\ E_3\ in\ \{dust, granules, scales\} \\ E_2 \times E_6 \times E_7, & if\ E_3\ in\ \{liquid, paste\} \end{cases}$$

Potential process emission (PPEm)

To estimate the potential emission of the process, the model uses *in situ* measured data coming from exposure campaigns. To provide these data, a specific excel document with the information should be filled and uploaded. The structure of this document is shown below (see section 6.1 in the Appendix) and it is provided to the user as a template they can download to complete.

The measurements conducted by the Industrial hygiene technicians must follow the Nanoparticles Emission Assessment Technique (NEAT), developed by the National Institute for Occupational Safety and Health (NIOSH, USA) and the guidelines of OECD Working Party on Manufactured Nanomaterials (WPMN)[1], which involves the implementation of real-time measurement equipment for calculating the average concentration of particles in the range from 10 nm to 10 microns. This methodology is deeply discussed within Deliverable 4.2.

With these measured data, the platform scores the risk of that process based on the 4 reference levels of occupational exposure defined by ITENE under the framework of the NANOEXPLORE[2] project, where 1 corresponds to a high-risk level and 4 to a low-risk level based on the concentration of particles released in the process. In this way, it uses these levels as reference but adds more steps in the scoring classification, going from being 4 as shown in Table 7 to being 8 as shown in Table 8.

[1] OECD, "Harmonized tiered approach to measure and assess the potential exposure to airborne emissions of engineered nano-objects and their agglomerates and aggregates at workplaces - Series on the Safety of Manufactured Nanomaterials No. 55 JT03378848," Jun. 2015

[2] https://www.lifenanoexplore.eu/about/overview

Table 7. Occupational exposure benchmark level of the NANOEXPLORE project

Occupational exposure benchmark (OEB) level of NANOEXPLORE project	Concentration	
	mg/m³	part/cm³
Level 1	1 - 10	> 100000
Level 2	0.1 - 1	40000 – 99999
Level 3	0.01 – 0.1	20000 – 39999
Level 4	< 0.01	< 20000

Table 8. Measured process concentration scores.

part/cm³	Scores
> 100000	1
75000 – 99999	0.9
60000 – 74999	0.8
30000 – 59999	0.7
10000 - 29999	0.6
6000 – 9999	0.5
1000 – 5999	0.3
< 999	0.1

It should be mentioned that the PPEm is directly related to the type of process performed and the energy released by the process during the time it is carried out. This released energy is here named manipulation energy (h) and its different options and scores are provided in Table 9.

Table 9. Manipulation energy scores (h)

Manipulation energy (h)	Scores
Very high (high energy impact, trituration, aerosols, evaporation, etc)	1
High (break-fall from 0.5 to 2m, bubbles through liquid)	0.3
Moderate (less than 0.5m drop, splashing spill)	0.1
Low (lifting, stacking, pouring)	0.03
Very low (careful lifting, etc)	0.01
None (no manipulation nor processing)	0.00001

3.3.1.2 Dispersion

Having the Cherrie and Schneider model (1992)[3] as reference, two different areas can be differentiated depending on the distance between the worker and the emission source. It is defined to be close to the source (Near Field – NF) if the head of the worker is located less than 1 meter away of the emission source; while it is considered far from the source (Far Field – FF) when the distance is greater than 1 meter.

This differentiation is important knowing that the emission impact increases the worker exposure as the emission source is closer. Thus, ventilation conditions, whether it is natural or mechanical, as well as the working area volume will influence the contaminant dilution depending on the location of the emission source, if it is placed on the near field or in the far field. Exposure risk will be directly proportional to the number of workers involved in the performed task.

Table 10. Environmental dilution having the source on the near field (DNF)

Environmental dilution (DNF)	Working area ventilation				
Volume	No general ventilation	Natural ventilation	Mechanic ventilation (< 30 m^3/h per person)	Mechanic ventilation (> 30 m^3/h per person)	Exterior
< $100m^3$	1	0.8	0.5	0.01	-
100 – $1000m^3$	0.8	0.5	0.3	0.01	-
> $1000m^3$	0.5	0.3	0.01	0.01	-
Exterior	-	0.01	-	-	0.01

3 CHERRIE JW, SCHNEIDER T (1999) "Validation of a new method for structured, subjective assessment of past concentrations" Ann Occup Hyg 1999; 43: 235-245

Table 11. Environmental dilution having the source on the far field (DFF)

Environmental dilution (DFF)	**Working area ventilation**				
Volume	**No general ventilation**	**Natural ventilation**	**Mechanic ventilation (< 30 m³/h per person)**	**Mechanic ventilation (> 30 m³/h per person)**	**Exterior**
< 100m³	0.9	0.7	0.3	0.01	-
100 – 1000m³	0.5	0.3	0.1	0.001	-
> 1000m³	0.3	0.01	0.001	0.001	-
Exterior	-	0.01	-	-	0.001

Table 12. Number of involved workers scores (w)

Number of involved workers (w)	**Score**
1	0.03
2 – 3	0.06
4 – 10	0.25
11 – 30	0.5
> 30	1

To estimate background concentration, PSEm should be known as well as the working place, the contamination of the surface and the presence of other sources should be characterized.

Table 13. Working area surface scores (S)

Working area surface (S)	**Score**
Closed premises	1
Open floor plan	0.5
Outdoor works	0.001

In every working place there are contaminants that deposit on the surfaces and that can be adhered to workers clothing. This contamination which covers equipments, machinery, etc. is known as “background emission” and it is assumed to be related to the intrinsic emission of the contaminants. Working surfaces pollution (Fbg) is defined by two key factors characterisation, the cleanliness frequency of the area and the maintenance and inspection of the machinery.

Table 14. Working surface contamination scores (Fbg)

The maintenance/inspection of the machinery/equipment takes place monthly	Cleanliness frequency			
	Daily	**> twice a week**	**Each two weeks**	**Monthly**
Yes	0.001	0.3	0.5	1
No	0.3	0.5	1	1

Last, to estimate the background concentration, the presence of other emission sources should be kept in mind.

Table 15. Other exposure sources presence scores (Fs)

Other exposure sources (Fs)	Score
Yes	1
No	0

To reduce workers exposure to contaminants, some control measures can be applied, such as collective protective equipment (CPE). These measures are implemented close to the emission source, and they aim to clear the working environment and avoid its dispersion.

Following are shown the different collective protective equipment that can be selected in the model, which are the most recommended for risk mitigation to nanoparticles according to the study developed within the NANOREG European project to evaluate nanomaterials safety[4].

It is also considered whether the process has a specific work procedure, since it becomes a work safety standard, i.e., instructions or correct guidelines to perform a certain task in a safe way, instructions, or correct guidelines to develop a certain task in a safe way, in such a way that it becomes a tool to help promote health in the company and how to prevent accidents.

[4] doi:10.2760/245972

Table 16. Collective protective equipment scores (CPE)

Collective protective equipment (CPE)	Score
Local exhaust	0.01
Local exhaust enclosure (Glove Box)	0.01
Nanoparticle hood	0.01
HEPA filtered down flow booth	0.01
HEPA filtered down flow room	0.01
Custom-fabricated enclosures	0.01
Ventilated laboratory hood + built-in water wash down systems (sprays)	0.01
Negative pressure hood/room	0.01
Vacuum systems with HEPA filter or wet sweep systems	0.01
Ventilated laboratory hood (partial enclosure)	0.3
Biological safety cabinet (small amounts of nanomaterials)	0.3
Walk-in hoods	0.3
Ventilated collar-type exhaust hoods	0.3
Movable LEV systems with HEPA filter (extendable arms)	0.3
Receiving hood (hot process)	0.3
None	1

Table 17. Existence of a work procedure scores (wp)

Existence of work procedure	Scores
Yes	0
No	1

3.3.1.3 Inmission

As mentioned in the previous section, the model takes into account the distance between the worker and the emission source. Thus, the concentration to which the worker is exposed to is conditioned by his separation from the source, but in addition, the personal protective equipment (PPE) used has a direct influence on the reduction of the perceived concentration. According to the hierarchy of application of preventive measures, PPE will be used as a preventive measure whenever all the previous means (elimination of the emission source, substitution of the emission source, CPEs and administrative controls such as work procedures) are not sufficient to ensure the health and safety of workers.

The following are the most recommended PPE for protection against nanomaterials according to the study carried out within the framework of the European project NANoREG for the safety assessment of nanomaterials[4].

Table 18. Respiratory protective equipment scores (PPE1)

Respiratory protective equipment (PPE1)	Score
Self-contained breathing apparatus	0.001
Filtering full mask with inhalation valves (P3)	0.1
Filtering half mask with inhalation valves (P3)	0.5
Half-face particulate respirators (P2)	0.8
None	1

Table 19. Protective gloves scores (PPE2)

Protective gloves (PPE2)	Score
Nitrile gloves – Double glove for large exposure periods	0.5
Neoprene gloves / Butyl gloves	0.8
None	1

Table 20. Protective clothing scores (PPE3)

Protective clothing (PPE3)	Score
Full body protective coverall (EN type 4-6) made of PE laminated with built-in hood	0.001
Full body protective coverall (EN type 4-6) made of polypropylene with or without built-in hood	0.1
Laboratory coats (Non-woven)	0.9
None	1

Table 21. Eye protection scores (PPE4)

Eye protection (PPE4)	Score
Tight-fitting dustproof (i.e. non-vented) safety goggles	0.01
Safety glasses	0.8
None	1

Table 22. Protective footwear scores (PPE5)

Protective footwear (PPE5)	Score
Boot covers	0.2
Safety shoes	0.8
None	1

3.3.1.4 Intensity

Exposure to nanoparticles is closely linked to the time the worker spends in contact with the contaminant, which is defined by the duration of the task performed during the workday and its frequency.

Table 23. Task duration scores (t)

Task duration (t)	Score
< 0.5 hours/day	0.06
0.5 – 2 hours/day	0.25
2 – 4 hours/day	0.5
4 – 8 hours/day	1

Table 24. Task frequency scores (f)

Task frequency (f)	Score
4 – 5 days/week	1
2 – 3 days/week	0.6
Once a week	0.2
1 day each two weeks	0.1
Once a month	0.05
Once a year	0.01

3.3.1.5 Exposure band

As detailed in Figure 1, the exposure band is the result of the interaction of four important factors such as the emission source, the inmission, the dispersion of the pollutant and the intensity with which the pollutant is perceived by a worker. The multiplicative function to obtain the exposure band (BE) is shown step by step below.

First process potential exposure (PPEx) and substance potential exposure (SPEx):

$$PPEx = P + h$$

$$SPEx = E_3 * \eta$$

With this information, the background concentration is estimated:

$$C_{bg} = \left(SPEx * F_{bg} * S\right) + F_s$$

Then, the concentration perceived by the worker is computed depending on the proximity of the worker to the emission source.

$$C = \begin{cases} SPEx * PPEx * (CPE + wp) * DNF * w, & emission\ source\ on\ NF \\ SPEx * PPEx * (CPE + wp) * DFF * w, & emission\ source\ on\ FF \end{cases}$$

Finally, the exposure band is estimated as follows:

$$BE = (C_{bg} + C) * \left(\sum EPI_i\right) * t * f$$

As a result of the application of the above equations, where all the factors influencing exposure are included, a total of 4 exposure bands are obtained, where 1 corresponds to low exposure, 2 to medium exposure, 3 to moderate exposure and 4 to high exposure.

Table 25. Exposure bands

BE value ranges	Exposure band
< 1	1
1 – 5	2
6 – 30	3
> 30	4

3.3.2 Hazard band

The figure below shows the interaction of both interaction factors involved on hazard bands classification.

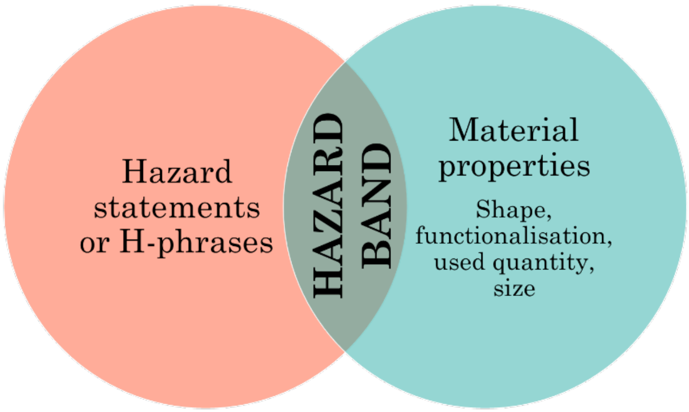

Figure 2. Factors involved in hazard bands estimation.

Regarding the H phrases, they have been classified according to the hazard they indicate and have been assigned a score from A to E, where A are those phrases referring to a low hazard and E are those of high hazard. A description of each of the H phrases can be found in the Appendix in section 6.2.

Table 26. H-phrases scores

<table>
<tr><th colspan="5">H-phrase</th><th>Score (P_H)</th></tr>
<tr><td colspan="5">There are h-phrases, but none of them appears in this table</td><td>A</td></tr>
<tr><td>H335</td><td>H336</td><td colspan="3"></td><td>B</td></tr>
<tr><td>H304</td><td>H332</td><td>H361</td><td>H361d</td><td>H361f</td><td rowspan="2">C</td></tr>
<tr><td>H361fd</td><td>H362</td><td>H371</td><td>H373</td><td>EUH071</td></tr>
<tr><td>H331</td><td>H334</td><td>H341</td><td>H351</td><td>H360</td><td rowspan="3">D</td></tr>
<tr><td>H360F</td><td>H360FD</td><td>H360D</td><td>H360Df</td><td>H360Fd</td></tr>
<tr><td>H370</td><td>H372</td><td>EUH032</td><td>EUH070</td><td></td></tr>
<tr><td>H330</td><td>H340</td><td>H350</td><td>H350i</td><td>EUH029</td><td rowspan="2">E</td></tr>
<tr><td>EUH070</td><td colspan="4"></td></tr>
<tr><td colspan="5">Unknown</td><td>E</td></tr>
</table>

In the event that a material has phrases corresponding to different categories, the material shall be classified in the most hazardous category. Likewise, if information on these H-phrases is not known, the highest score (E) shall be assigned to comply with the precautionary principle.

The calculation of the hazard is based on the properties of the material, its toxicity, and physicochemical characteristics. This model takes the H hazard phrases as a reference, however, due to the fact that obtaining this data is more complex when dealing with nanomaterials whose safety data sheets do not usually exist, it is necessary to use other parameters such as the functionalization given to the material to reduce its toxicity (E1), the physical form of the material (E3), the amount of material used in the process (q) and the size of the nanoparticle (s).

Table 27. Existence of material functionalization scores (E1)

Existence of material functionalisation (E1)	**Score**
Yes	0.01
No	1
Unknown	1

Table 28. Quantity of material used in the process scores (q)

Quantity of material used in the process	Score
100 – 500 g	0.01
500 – 1000 g	0.1
1000 – 5000 g	0.5
5000 – 10000 g	0.75
> 10000 g	1

Table 29. Nanoparticle size scores (s)

Nanoparticle size (s)	Score
<= 50 nm	1
50 – 100 nm	0.5
> 100 nm	0.03

With the following equation to estimate the hazard of the used material (M), which will be used to get the material score from Table 30 ranges.

$$M = E_1 * E_3 * q * s$$

Table 30. M parameter about used hazard material scores

M parameter value	Material score
<0.2	A_M
0.2-0.4	B_M
0.4-0.6	C_M
0.6-0.8	D_M
<0.8	E_M

3.3.2.1 Hazard band

By combining the hazard derived from the H-phrases (P_H) and the estimated parameter M score, Table 31 is used to obtain the hazard band (BH). In the case that no H-phrases are selected, the final hazard band will correspond to the material computed score.

Table 31. Hazard bands

Hazard band		H-phrases score (P_H)				
		A	**B**	**C**	**D**	**E**
Material score (M)	**A_M**	A	A	A	B	C
	B_M	A	A	B	C	D
	C_M	A	B	C	D	E
	D_M	B	C	D	E	E
	E_M	C	D	E	E	E

3.3.3 Risk estimation

The risk bands offer a relative classification of the risks associated with the worker's activities. It is important to consider that the result of the risk bands is interpreted as control bands because each one has associated prevention measures (see section 3.3.4) as a recommendation to implement them in the process and thus mitigate the risk. These resulting control measures are not binding and shall be used as a guide, i.e., the prevention technician, at his discretion, shall choose those that he considers applicable to the case in question.

This allows the user to both mitigate their risk as a result of the obtained result and to redesign the exposure scenario by guiding towards the control measures that are anticipated to achieve the best possible reduction. In addition, a significant advantage is the possibility to evaluate the effect that the implementation of a specific control measure would have on the risk priority. Thus, from the combination of the five hazard bands and the four exposure bands, five risk bands emerge Table 32, where band 1 represents the lowest risk and thus a lower priority for action, while band 5 indicates the highest risk or highest priority for action.

Table 32. Risk bands

Risk band		Hazard band				
		A	**B**	**C**	**D**	**E**
Exposure band	**1**	1	1	2	3	4
	2	1	2	3	4	5
	3	2	3	4	5	5
	4	3	4	5	5	5

3.3.4 Risk mitigation measurements implementation

The following nanomaterial risk mitigation measures are mainly based on the results of years of experience in nanomaterial exposure monitoring campaigns carried out by ITENE's technical team, which have been based on the verification of the effectiveness of these mitigation measures. These mitigation measures are supported by the aforementioned study carried out in the framework of the European project NANoREG for the safety assessment of nanomaterials[4].

Table 33. Local exposure control measures depending on the risk level/band.

Risk level	Local exposure control measures
1	The risk of exposure is negligible. It is recommended to continue with the measures already implemented, to maintain the equipment correctly, to maintain order and cleanliness in the workplace.
2	The risk of exposure is low. The following order of action is recommended: 1. Assess the possibility of replacing the material with one that involves less risk. 2. Assess the possibility of modifying the process so that there is less exposure to the material used. 3. Implement mobile LEV systems with HEPA filter (extendable arms) at the main emission sources or carry out the process causing the emission inside a receiving hood. If none of the measures 1,2 or 3 can be implemented, the worker should use the following PPE. - Partial face mask type P3 - Safety goggles - Nitrile gloves - Non-woven lab coat - Safety boots 4. It is recommended that a specific work procedure be created for this process and material, in addition to keeping worker training up to date. 5. It is recommended that procedures be established to address nanomaterial spill clean-up and surface decontamination to minimize worker exposure. For example, prohibit dry sweeping or the use of compressed air for cleaning up dust containing nanomaterials, use wet cleaning and HEPA filter-equipped vacuum cleaners.
3	The risk of exposure is moderate. The following order of action is recommended: 1. Assess the possibility of replacing the material with one that poses less risk. 2. Assess the possibility of modifying the process so that there is less exposure to the material used. 3. Assess the total or partial isolation of the process: custom-made sealed enclosure that prevents contact with the worker, specific work area with negative pressure, workplace with HEPA filtering systems. 4. Implement an LEV mechanism at major emission sources. If none of the measures 1, 2, 3 or 4 can be implemented, the worker should use the following PPE - Partial face mask type P3 - Tight fitting dust-proof safety glasses (i.e. non-ventilated)

	- Double nitrile gloves - Full body protective coverall (EN type 4-6) made of polypropylene with or without integrated hood or alternatively a lab coat made of non-woven material - Safety boots 5. It is recommended that a specific work procedure be created for this process and material, in addition to keeping worker training for this type of high-moderate tasks up to date. 6. It is recommended that procedures be established to address nanomaterial spill clean-up and surface decontamination to minimize worker exposure. For example, prohibit dry sweeping or the use of compressed air for cleaning up dust containing nanomaterials, use wet cleaning and vacuum cleaners equipped with HEPA filters.
4	The risk of exposure is high. The following order of action is recommended: 1. Assess the possibility of replacing the material with one that involves less risk. 2. Evaluate the possibility of modifying the process so that there is less exposure to the material used. 3. Evaluate the total or partial isolation of the process: custom-built sealed enclosure to prevent contact with the material used. to avoid contact with the worker, specific working area with negative pressure, workplace with negative pressure, workplace with HEPA filtering systems. 4. If none of the measures 1,2 or 3 can be implemented, the worker shall wear the following PPE worker should use the following PPE. - Full or partial face mask type P3, if it is partial coverage, it must be completed with safety goggles completed with dust-proof safety goggles (i.e. without ventilation) - Double nitrile gloves - Full body protective coverall (EN type 4-6) made of PE laminate with integrated hood - Safety boots plus shoe covers 5. It is recommended that a specific work procedure be created for this process and material, in addition to keeping worker training for this type of high-risk tasks up to date. 6. It is recommended that procedures be established to address clean-up of nanomaterial spills and decontamination of surfaces to minimize exposure of workers. For example, prohibit dry sweeping or the use of compressed air for cleaning up dust containing nanomaterials, use wet cleaning and vacuum cleaners equipped with HEPA filters.
5	Exposure risk is very high. Requires specific consultation with an occupational health and safety technician specializing in industrial hygiene and a mandatory quantitative risk assessment to evaluate specific risk mitigation measures.

4 Decision Support System Development

4.1 Risk Assessment Model implementation

Once the model described above was defined, ITENE focused on its implementation. To this purpose, a script was developed using python as programming language. This python script receives as input parameters the id of the options selected by the user as well as the list of H-phrases they select. In section 6.3 from the Appendix, the different options for each parameter and its indexes are shown. As output, the script provides the estimated risk band with the recommendations assigned to it and some information about the calculations carried out.

In addition to the development of this python script, ITENE has worked on the design of the user interface for the integration on the cloud platform. The designed user interface (UI) consists of a form, as seen in Figure 3, in which a dropdown or a radio button for each parameter is shown except for the data file, for which a section to upload the users file is displayed. As stated previously, the input parameters in the platform are sorted in a more suitable way to users' understanding, organizing the information in three different sections: working area, task, and material. The working area section compiles information about environment where the task is carried out, while the task section collects facts about the work that is carried out in the studied process, and the material section aims to characterize the substance that is used in the process.

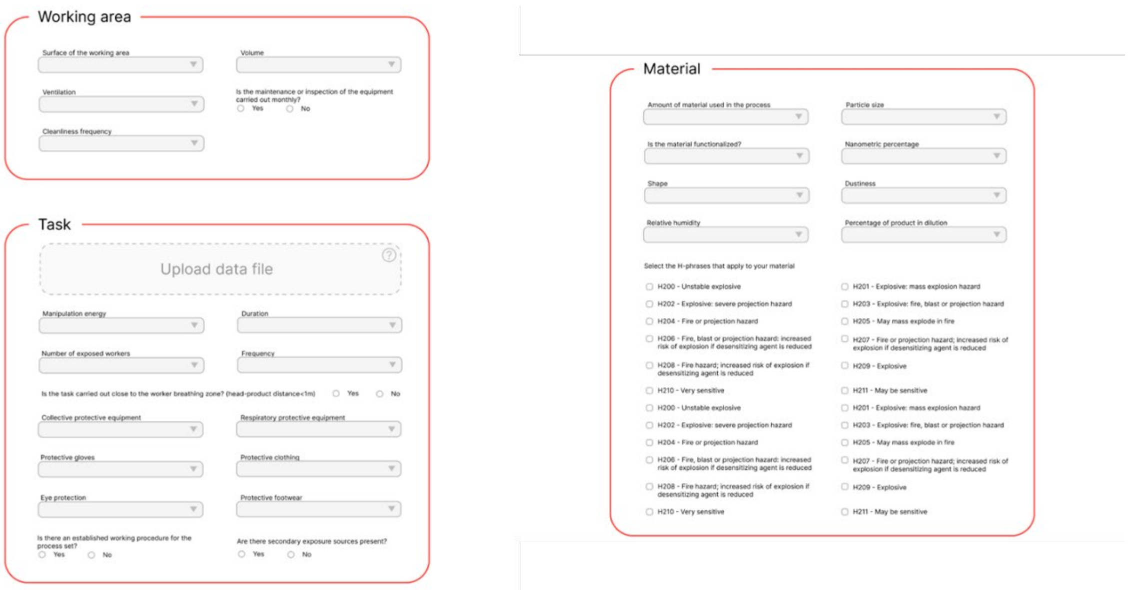

Figure 3. Proposed user interface

Once the users have selected one option for each parameter, the estimated risk band will be displayed. As it was already mentioned, the risk level will be displayed along with more information about the calculations carried out and the recommendations associated to the risk level that has been computed. To show all this information, ITENE has also been working on a design to represent the results, as shown in Figure 4. In this design, the risk level can be firstly seen, showing not just the estimated number, but also in a gradient graph within its range. Just below it, a text with the corresponding recommendations will be displayed. Next to this information, the following calculations information will be placed: hazard and exposure bands, as well as the table used to estimate the risk band with the information provided (Table 32). In the exposure section, the exposure band is shown together with a graph which plots the data of the uploaded file and shows information about it such as the average, maximum and minimum values for both near and far fields. Moreover, the hazard section includes the hazard band along with the two scores that influence its estimation: H-phrases and material scores.

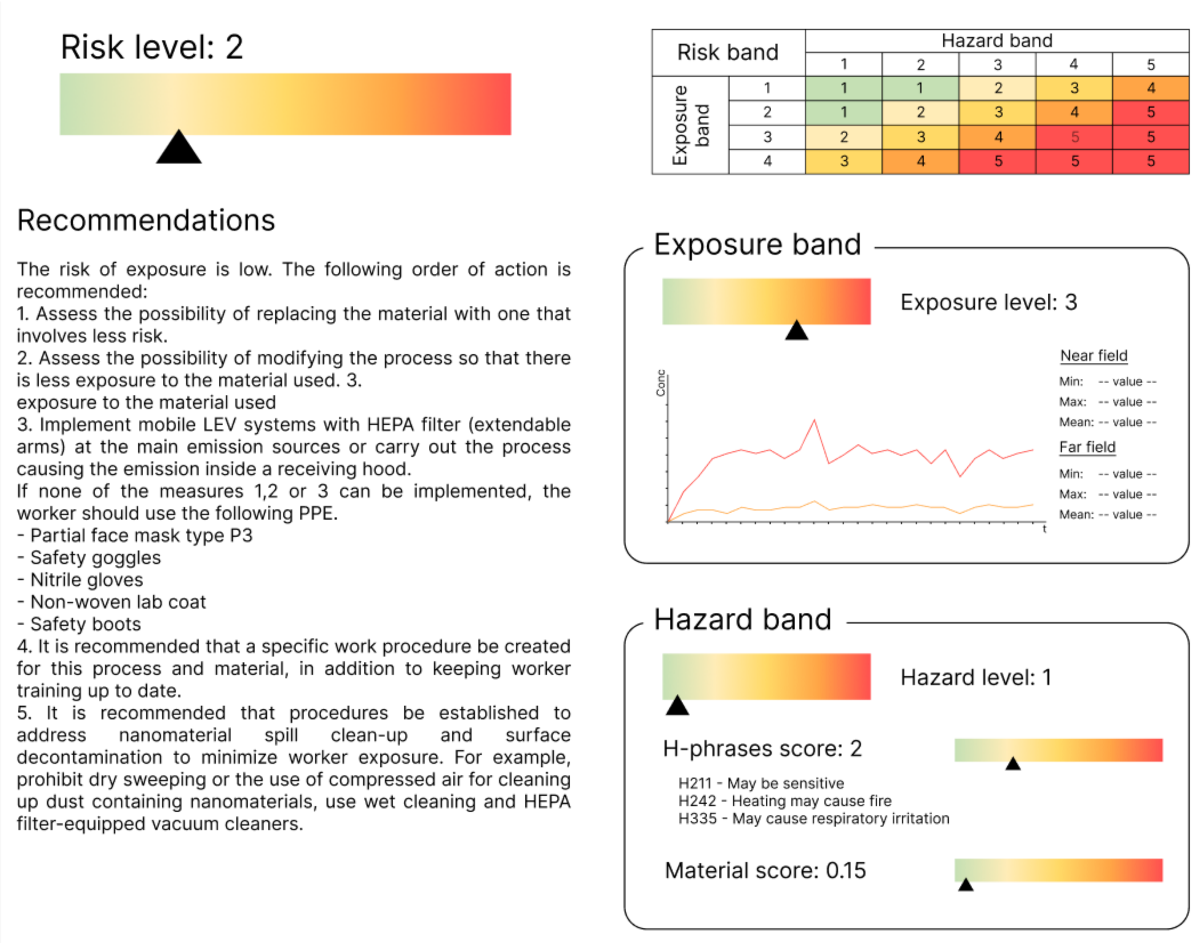

Figure 4. Results design

4.2 Integration within the DIAGONAL Cloud Platform

NovaMechanics has been actively working on developing the user interface for the Risk Management Tool. Using the ZK framework, the team has designed a graphical user interface (GUI) that is user-friendly and meets the specific functional needs of the Decision Support System (DSS). The specific GUI is crucial for providing a smooth and efficient experience for users interacting with the tool. In the area of backend development, NovaMechanics uses a containerization software. This setup is key for executing the Python code essential to the DSS, enabling it to process results based on a range of user inputs. By adopting Docker for containerization, they have added a level of adaptability and portability, making it easier to deploy the tool in different computing environments. An important development in the project has been converting the DSS execution into a microservice. This was achieved by developing a custom server. The server doesn't just support the DSS' s functionality but also heightens the security of communications between the GUI and the DSS. To secure data transmission, especially important due to the sensitive nature of risk management information, the team has implemented both asymmetric and symmetric encryption techniques. Continuing with the technical aspects, NovaMechanics' custom server for the Risk Management Tool is further enhanced through its support by the Enalos Cloud Platform. This robust platform underpins the server, ensuring reliable and scalable cloud-based operations. Additionally, the Risk

Management Tool is hosted on the DIAGONAL instance of the Enalos Cloud Platform, providing a stable and secure environment for the tool's deployment and accessibility.

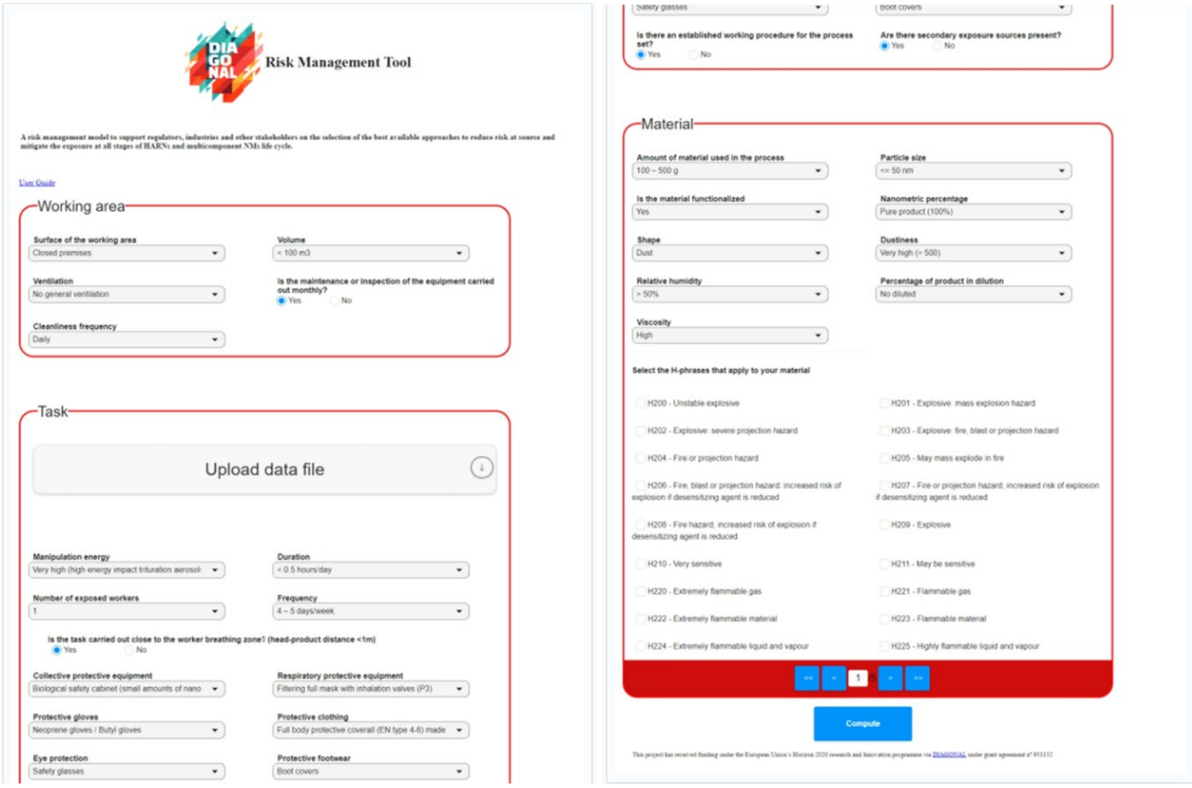

Figure 5. Risk Management Tool UI integrated on the Cloud Platform

4.3 User guide

The RMT is already available in the cloud platform under the following link: https://www.enaloscloud.novamechanics.com/diagonal/dss/.

The tool has been designed to be as easy to use as possible. The user only needs to complete the form with the information they have for each section about the process they want to evaluate.

- Every dropdown or radio button element is compulsory to fill in. They all have a default option selected, but this doesn't mean is the most suitable for the evaluated case. **Note:** Make sure to go through every element to update the value if needed.
- In the task section, where the data file is requested, the user should first download the template, then fill it in and finally upload it.
- Regarding the H-phrases, multiple of them or none can be selected depending on what better fits the material that is being evaluated. The H-phrases are distributed in five pages, so use the blue arrow buttons below to make sure you go through all the possible hazard phrases available.

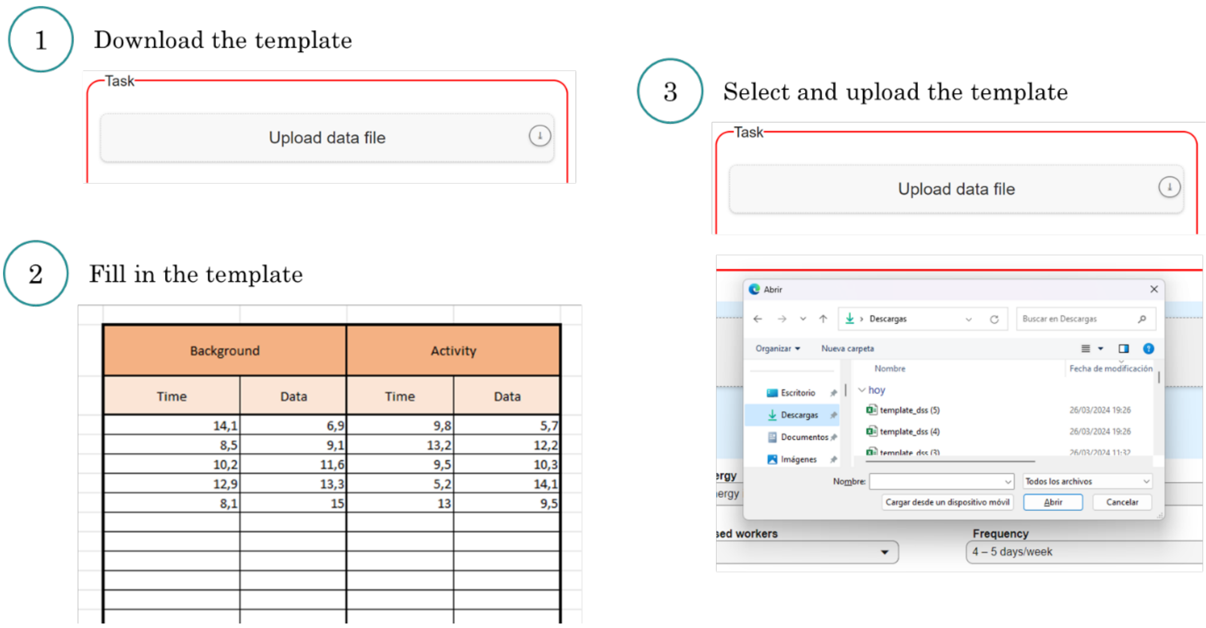

Figure 6. Steps to provide the data file

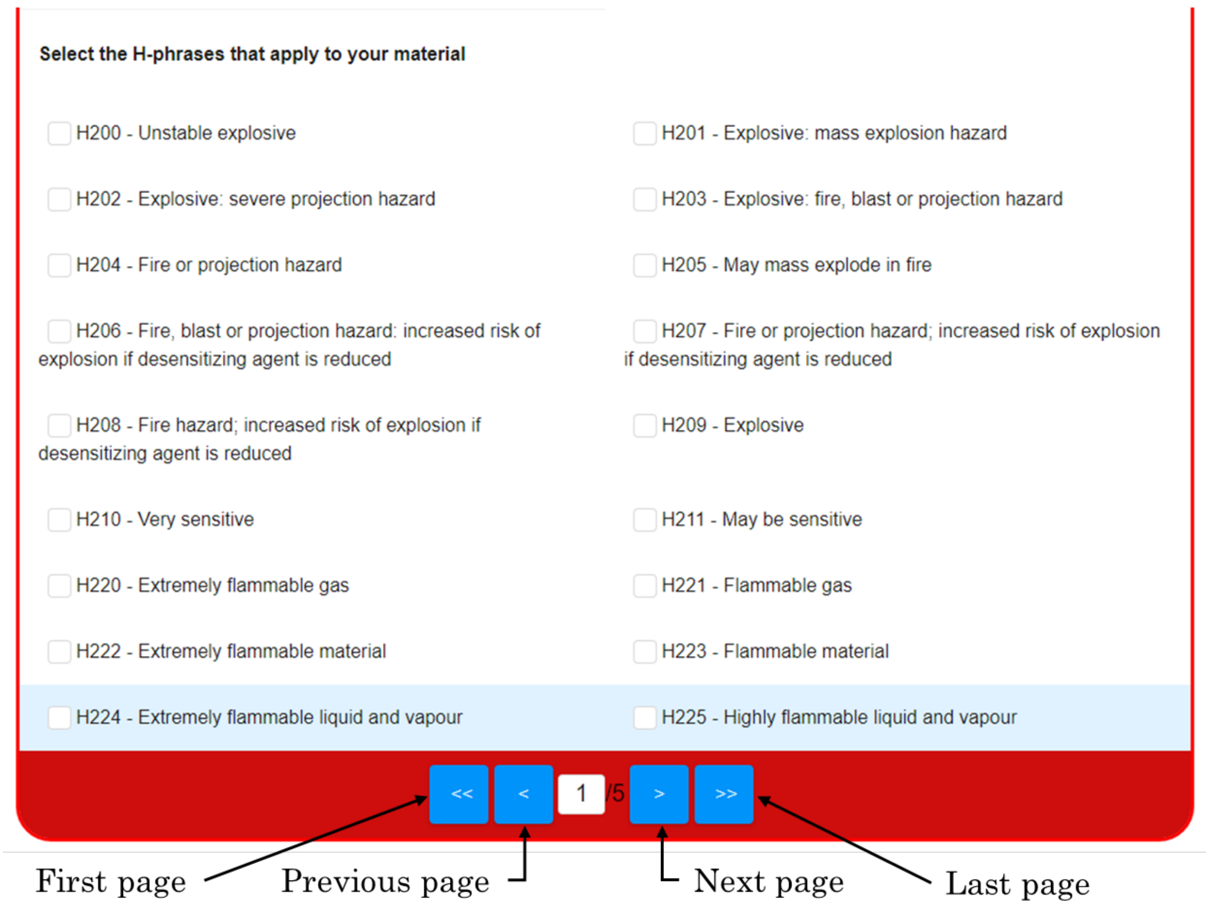

Figure 7. Use arrow buttons to view all H-phrases

Once all the information in the form has been completed, run the model by pressing the 'Compute' button.

With regards to the output generated by the RMT, so far, the RMT only provides the estimated risk band, as seen in Figure 9. In a future version of the tool, the results will be displayed as shown above in Figure 4.

Figure 8. Risk band level provided

5 Conclusion

The objective of this control-banding model is to prioritize the risks related to exposure to nanomaterials, while providing corrective measures, establishing itself as an effective assessment method. Since not all information is currently available for many nanomaterials, the DIAGONAL risk assessment model has had to make several assumptions and simplifications. More preventive measures could be included in the tool depending on the safe by process design (SbPD) evaluated in WP5.

6 Appendix

6.1 Excel template

Background		**Activity**	
Time	**Data (#/cm3)**	**Time**	**Data (#/cm3)**
14,1	6,9	9,8	5,7
8,5	9,1	13,2	12,2
10,2	11,6	9,5	10,3
12,9	13,3	5,2	14,1
8,1	15	13	9,5

6.2 H-phrases

H-phrases	
H200	Unstable explosive
H201	Explosive: mass explosion hazard
H202	Explosive: severe projection hazard
H203	Explosive: fire, blast or projection hazard
H204	Fire or projection hazard
H205	May mass explode in fire
H206	Fire, blast or projection hazard: increased risk of explosion if desensitizing agent is reduced
H207	Fire or projection hazard; increased risk of explosion if desensitizing agent is reduced
H208	Fire hazard; increased risk of explosion if desensitizing agent is reduced
H209	Explosive
H210	Very sensitive
H211	May be sensitive
H220	Extremely flammable gas
H221	Flammable gas
H222	Extremely flammable material
H223	Flammable material
H224	Extremely flammable liquid and vapour
H225	Highly flammable liquid and vapour
H226	Flammable liquid and vapour
H227	Combustible liquid
H228	Flammable solid
H229	Pressurized container: may burst if heated
H230	May react explosively even in the absence of air
H231	May react explosively even in the absence of air at elevated pressure and/or temperature
H240	Heating may cause an explosion
H241	Heating may cause a fire or explosion
H242	Heating may cause a fire
H250	Catches fire spontaneously if exposed to air
H251	Self-heating: may catch fire
H252	Self-heating in large quantities: may catch fire
H260	In contact with water releases flammable gases which may ignite spontaneously
H261	In contact with water releases flammable gas
H270	May cause or intensify fire: oxidizer
H271	May cause fire or explosion: strong oxidizer
H272	May intensify fire: OXIDISER
H280	Contains gas under pressure: may explode if heated
H281	Contains refrigerated gas: may cause cryogenic burns or injury
H282	Extremely flammable chemical under pressure: May explode if heated
H283	Flammable chemical under pressure: May explode if heated
H284	Chemical under pressure: May explode if heated
H290	May be corrosive to metals
EUH001	Explosive when dry
EUH006	Explosive with or without contact with air
EUH014	Reacts violently with water

EUH018	In use may form flammable/explosive vapour-air mixture
EUH019	May form explosive peroxides
EUH044	Risk of explosion if heated under confinement
H300	Fatal if swallowed
H300+H310	Fatal if swallowed or in contact with skin
H300+H310+H330	Fatal if swallowed, in contact with skin or if inhaled
H300+H330	Fatal if swallowed or if inhaled
H301	Toxic if swallowed
H301+H311	Toxic if swallowed or in contact with skin
H301+H311+H331	Toxic if swallowed, in contact with skin or if inhaled
H301+H331	Toxic if swallowed or if inhaled
H302	Harmful if swallowed
H302+H312	Harmful if swallowed or in contact with skin
H302+H312+H332	Harmful if swallowed, in contact with skin or if inhaled
H302+H332	Harmful if swallowed or inhaled
H303	May be harmful if swallowed
H303+H313	May be harmful if swallowed or in contact with skin
H303+H313+H333	May be harmful if swallowed, in contact with skin or if inhaled
H303+H333	May be harmful if swallowed or if inhaled
H304	May be fatal if swallowed and enters airways
H305	May be harmful if swallowed and enters airways
H310	Fatal in contact with skin
H310+H330	Fatal in contact with skin or if inhaled
H311	Toxic in contact with skin
H311+H331	Toxic in contact with skin or if inhaled
H312	Harmful in contact with skin
H312+H332	Harmful in contact with skin or if inhaled
H313	May be harmful in contact with skin
H313+H333	May be harmful in contact with skin or if inhaled
H314	Causes severe skin burns and eye damage
H315	Causes skin irritation
H315+H320	Causes skin and eye irritation
H316	Causes mild skin irritation
H317	May cause an allergic skin reaction
H318	Causes serious eye damage
H319	Causes serious eye irritation
H320	Causes eye irritation
H330	Fatal if inhaled
H331	Toxic if inhaled
H332	Harmful if inhaled
H333	May be harmful if inhaled
H334	May cause allergy or asthma symptoms or breathing difficulties if inhaled
H335	May cause respiratory irritation
H336	May cause drowsiness or dizziness
H340	May cause genetic defects
H341	Suspected of causing genetic defects
H350	May cause cancer

H350i	May cause cancer by inhalation
H351	Suspected of causing cancer
H360	May damage fertility or the unborn child
H360D	May damage the unborn child
H360Df	May damage the unborn child. Suspected of damaging fertility.
H360F	May damage fertility
H360FD	May damage fertility. May damage the unborn child.
H360Fd	May damage fertility. Suspected of damaging the unborn child.
H361	Suspected of damaging fertility or the unborn child
H361d	Suspected of damaging the unborn child
H361f	Suspected of damaging fertility
H361fd	Suspected of damaging fertility. Suspected of damaging the unborn child.
H362	May cause harm to breast-fed children
H370	Causes damage to organs
H371	May cause damage to organs
H372	Causes damage to organs through prolonged or repeated exposure
H373	May cause damage to organs through prolonged or repeated exposure
EUH029	Contact with water liberates toxic gas
EUH031	Contact with acids liberates toxic gas
EUH032	Contact with acids liberates very toxic gas
EUH066	Repeated exposure may cause skin dryness or cracking
EUH070	Toxic by eye contact
EUH071	Corrosive to the respiratory tract
H400	Very toxic to aquatic life
H401	Toxic to aquatic life
H402	Harmful to aquatic life
H410	Very toxic to aquatic life with long lasting effects
H411	Toxic to aquatic life with long lasting effects
H412	Harmful to aquatic life with long lasting effects
H413	May cause long lasting harmful effects to aquatic life
H420	Harms public health and the environment by destroying ozone in the upper atmosphere
H441	Very toxic to terrestrial invertebrates
EUH059	Hazardous to the ozone layer
EUH201	Contains lead. Should not be used on surfaces liable to be chewed or sucked by children.
EUH201A	Warning! Contains lead.
EUH202	Cyanoacrylate. Danger. Bonds skin and eyes in seconds. Keep out of the reach of children.
EUH203	Contains chromium(VI). May produce an allergic reaction.
EUH204	Contains isocyanates. May produce an allergic reaction.
EUH205	Contains epoxy constituents. May produce an allergic reaction.
EUH206	Warning! Do not use together with other products. May release dangerous gases (chlorine).
EUH207	Warning! Contains cadmium. Dangerous fumes are formed during use. See information supplied by the manufacturer. Comply with the safety instructions.
EUH208	Contains <name of sensitising substance>. May produce an allergic reaction.
EUH209	Can become highly flammable in use.
EUH209A	Can become flammable in use.
EUH210	Safety data sheet available on request.
EUH401	To avoid risks to human health and the environment, comply with the instructions for use.

6.3 Options and indexes for input parameters

Group	Param	Text	Options	Value
Working area	**surf**	Surface of the working area	Closed premises	0
			Open floor plan	1
			Outdoor works	2
	vol	Working area volume	< 100 m3	0
			100 – 1000 m3	1
			> 1000 m3	2
			Exterior	3
	vent	Working area ventilation	No general ventilation	0
			Natural ventilation	1
			Mechanic ventilation < 30 m3/h per person	2
			Mechanic ventilation > 30 m3/h per person	3
			Exterior	4
	m	Is the maintenance or inspection of the equipment carried out monthly?	Yes	0
			No	1
	cf	Cleanliness frequency	Daily	0
			> twice a week	1
			Each two weeks	2
			Monthly	3
Task description	**p**	Submit your data file		File name (route)
	h	Manipulation energy	Very high (high energy impact, trituration, aerosols evaporation, etc)	0
			High (break-fall from 0.5 to 2 m, bubbles through liquid)	1
			Moderate (less than 0.5 m drop, splashing spill)	2
			Low (lifting, stacking, pouring)	3
			Very low (careful lifting, etc)	4
			None (no manipulation nor processing)	5
	t	Task duration	< 0.5 hours/day	0
			0.5 – 2 hours/day	1
			2 – 4 hours/day	2
			4 – 8 hours/day	3
	w	Number of exposed workers	1	0
			2 – 3	1
			4 – 10	2
			11 – 30	3
			> 30	4
	tf	Task frequency	4 – 5 days/week	0
			2 – 3 days/week	1
			Once a week	2
			1 day each two weeks	3
			Once a month	4
			Once a year	5
	z	Is the task carried out close to the worker breathing zone? (head-product distance < 1m)	Yes	0
			No	1
	cpe	Collective protective equipment	Local exhaust enclosure (Glove Box)	0
			Nanoparticle hood	1
			HEPA filtered down flow booth	2
			HEPA filtered down flow room	3
			Custom-fabricated enclosures	4
			Ventilated laboratory hood + built-in water wash down systems (sprays)	5
			Negative pressure hood/room	6
			Vacuum systems with HEPA filter or wet sweep systems	7
			Ventilated laboratory hood (partial enclosure)	8

			Biological safety cabinet (small amounts of nanomaterials)	9
			Walk-in hoods	10
			Ventilated collar-type exhaust hoods	11
			Movable LEV systems with HEPA filter (extendable arms)	12
			Receiving hood (hot process)	13
			None	14
	ppe1	Respiratory protective equipment	Self-contained breathing apparatus	0
			Filtering full mask with inhalation valves (P3)	1
			Filtering half mask with inhalation valves (P3)	2
			Half-face particulate respirators (P2)	3
			None	4
	ppe2	Protective gloves	Nitrile gloves – Double glove for large exposure periods	0
			Neoprene gloves / Butyl gloves	1
			None	2
	ppe3	Protective clothing	Full body protective coverall (EN type 4-6) made of PE laminated with built-in hood	0
			Full body protective coverall (EN type 4-6) made of polypropylene with or without built-in hood	1
			Laboratory coats (Non-woven)	2
			None	3
	ppe4	Eye protection	Tight-fitting dustproof (i.e. non-vented) safety goggles	0
			Safety glasses	1
			None	2
	ppe5	Protective footwear	Boot covers	0
			Safety shoes	1
			None	2
	mpt	Is there an established working procedure for the process set?	Yes	0
			No	1
	ss	Are there secondary exposure sources present?	Yes	0
			No	1
Material	**q**	Amount of material used in the process	100 – 500 g	0
			500 – 1000 g	1
			1000 – 5000 g	2
			5000 – 10000 g	3
			> 10000 g	4
	s	Particle size	<= 50 nm	0
			50 – 100 nm	1
			> 100 nm	2
	e1	Is the material functionalized to reduce its toxicity?	Yes	0
			No	1
			Unknown	2
	e2	Nanometric percentage of the material	Pure product (100%)	0
			Main compound (50-99%)	1
			Substantial (10-50%)	2
			Traces (1-10%)	3
			Unknown	4
	e3	Shape	Dust	0
			Granules/scales	1
			Paste	2
			Liquid	3
			Unknown	4
	e4	Dustiness	Very high (> 500)	0
			High (150-500)	1
			Medium (50-150)	2
			Unknown	3

e5	Relative humidity	> 50%	0
		10-50%	1
		< 10%	2
		Unknown	3
e6	Percentage of product in dilution	No diluted	0
		50-99%	1
		10-50%	2
		1-10%	3
		0.001-1%	4
		Unknown	5
e7	Viscosity	High	0
		Medium	1
		Low	2
		Unknown	3
Hph	Select the H phrases that apply to your material	Unstable explosive	H200
		Explosive: mass explosion hazard	H201
		Explosive: severe projection hazard	H202
		Explosive: fire, blast or projection hazard	H203
		Fire or projection hazard	H204
		May mass explode in fire	H205
		Fire, blast or projection hazard: increased risk of explosion if desensitizing agent is reduced	H206
		Fire or projection hazard; increased risk of explosion if desensitizing agent is reduced	H207
		Fire hazard; increased risk of explosion if desensitizing agent is reduced	H208
		Explosive	H209
		Very sensitive	H210
		May be sensitive	H211
		Extremely flammable gas	H220
		Flammable gas	H221
		Extremely flammable material	H222
		Flammable material	H223
		Extremely flammable liquid and vapour	H224
		Highly flammable liquid and vapour	H225
		Flammable liquid and vapour	H226
		Combustible liquid	H227
		Flammable solid	H228
		Pressurized container: may burst if heated	H229
		May react explosively even in the absence of air	H230
		May react explosively even in the absence of air at elevated pressure and/or temperature	H231
		Heating may cause an explosion	H240
		Heating may cause a fire or explosion	H241
		Heating may cause a fire	H242
		Catches fire spontaneously if exposed to air	H250
		Self-heating: may catch fire	H251
		Self-heating in large quantities: may catch fire	H252
		In contact with water releases flammable gases which may ignite spontaneously	H260
		In contact with water releases flammable gas	H261
		May cause or intensify fire: oxidizer	H270
		May cause fire or explosion: strong oxidizer	H271
		May intensify fire: OXIDISER	H272
		Contains gas under pressure: may explode if heated	H280
		Contains refrigerated gas: may cause cryogenic burns or injury	H281

Extremely flammable chemical under pressure: May explode if heated	H282
Flammable chemical under pressure: May explode if heated	H283
Chemical under pressure: May explode if heated	H284
May be corrosive to metals	H290
Explosive when dry	EUH001
Explosive with or without contact with air	EUH006
Reacts violently with water	EUH014
In use may form flammable/explosive vapour-air mixture	EUH018
May form explosive peroxides	EUH019
Risk of explosion if heated under confinement	EUH044
Fatal if swallowed	H300
Fatal if swallowed or in contact with skin	H300+H310
Fatal if swallowed, in contact with skin or if inhaled	H300+H310+H330
Fatal if swallowed or if inhaled	H300+H330
Toxic if swallowed	H301
Toxic if swallowed or in contact with skin	H301+H311
Toxic if swallowed, in contact with skin or if inhaled	H301+H311+H331
Toxic if swallowed or if inhaled	H301+H331
Harmful if swallowed	H302
Harmful if swallowed or in contact with skin	H302+H312
Harmful if swallowed, in contact with skin or if inhaled	H302+H312+H332
Harmful if swallowed or inhaled	H302+H332
May be harmful if swallowed	H303
May be harmful if swallowed or in contact with skin	H303+H313
May be harmful if swallowed, in contact with skin or if inhaled	H303+H313+H333
May be harmful if swallowed or if inhaled	H303+H333
May be fatal if swallowed and enters airways	H304
May be harmful if swallowed and enters airways	H305
Fatal in contact with skin	H310
Fatal in contact with skin or if inhaled	H310+H330
Toxic in contact with skin	H311
Toxic in contact with skin or if inhaled	H311+H331
Harmful in contact with skin	H312
Harmful in contact with skin or if inhaled	H312+H332
May be harmful in contact with skin	H313
May be harmful in contact with skin or if inhaled	H313+H333
Causes severe skin burns and eye damage	H314
Causes skin irritation	H315
Causes skin and eye irritation	H315+H320
Causes mild skin irritation	H316
May cause an allergic skin reaction	H317
Causes serious eye damage	H318
Causes serious eye irritation	H319
Causes eye irritation	H320
Fatal if inhaled	H330
Toxic if inhaled	H331
Harmful if inhaled	H332
May be harmful if inhaled	H333

May cause allergy or asthma symptoms or breathing difficulties if inhaled	H334
May cause respiratory irritation	H335
May cause drowsiness or dizziness	H336
May cause genetic defects	H340
Suspected of causing genetic defects	H341
May cause cancer	H350
May cause cancer by inhalation	H350i
Suspected of causing cancer	H351
May damage fertility or the unborn child	H360
May damage the unborn child	H360D
May damage the unborn child. Suspected of damaging fertility.	H360Df
May damage fertility	H360F
May damage fertility. May damage the unborn child.	H360FD
May damage fertility. Suspected of damaging the unborn child.	H360Fd
Suspected of damaging fertility or the unborn child	H361
Suspected of damaging the unborn child	H361d
Suspected of damaging fertility	H361f
Suspected of damaging fertility. Suspected of damaging the unborn child.	H361fd
May cause harm to breast-fed children	H362
Causes damage to organs	H370
May cause damage to organs	H371
Causes damage to organs through prolonged or repeated exposure	H372
May cause damage to organs through prolonged or repeated exposure	H373
Contact with water liberates toxic gas	EUH029
Contact with acids liberates toxic gas	EUH031
Contact with acids liberates very toxic gas	EUH032
Repeated exposure may cause skin dryness or cracking	EUH066
Toxic by eye contact	EUH070
Corrosive to the respiratory tract	EUH071
Very toxic to aquatic life	H400
Toxic to aquatic life	H401
Harmful to aquatic life	H402
Very toxic to aquatic life with long lasting effects	H410
Toxic to aquatic life with long lasting effects	H411
Harmful to aquatic life with long lasting effects	H412
May cause long lasting harmful effects to aquatic life	H413
Harms public health and the environment by destroying ozone in the upper atmosphere	H420
Very toxic to terrestrial invertebrates	H441
Hazardous to the ozone layer	EUH059
Contains lead. Should not be used on surfaces liable to be chewed or sucked by children.	EUH201
Warning! Contains lead.	EUH201A
Cyanoacrylate. Danger. Bonds skin and eyes in seconds. Keep out of the reach of children.	EUH202
Contains chromium(VI). May produce an allergic reaction.	EUH203
Contains isocyanates. May produce an allergic reaction.	EUH204

	Contains epoxy constituents. May produce an allergic reaction.	EUH205
	Warning! Do not use together with other products. May release dangerous gases (chlorine).	EUH206
	Warning! Contains cadmium. Dangerous fumes are formed during use. See information supplied by the manufacturer. Comply with the safety instructions.	EUH207
	Contains <name of sensitising substance>. May produce an allergic reaction.	EUH208
	Can become highly flammable in use.	EUH209
	Can become flammable in use.	EUH209A
	Safety data sheet available on request.	EUH210
	To avoid risks to human health and the environment, comply with the instructions for use.	EUH401