

# THE NANOSAFER V1.1 RISK ASSESSMENT AND MANAGEMENT TOOL

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## OVERALL SENSITIVITY ANALYSIS AND ASSESSMENT OF THE MODEL PERFORMANCE

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DET NATIONALE  
FORSKNINGSCENTER FOR ARBEJDSMILJØ

# NanoSafer 1.1beta (www.nanosafer.org)

NanoSafer 1.1beta

HOME ABOUT CONTACT

Currently applicable for MNM powder handling  
and processes with constant source MNM emission rates

## Welcome to NanoSafer

NanoSafer is a combined control-banding and risk management tool that enables assessment of the risk level and recommended exposure control associated with production and use of manufactured nanomaterials (e.g., nanoparticles, nanoflakes, nanofibers, and nanotubes) in specific work scenarios. In addition to manufactured nanomaterials, the tool can also be used to assess and manage emissions from nanoparticle-forming processes.

**NB! NanoSafer v 1.1 is under implementation and small changes will occur over the next month! Please send us feed-back if you observe system errors or have ideas for improving the usability of the web-tool.**

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# Key elements and information requirements in the Control Banding models

Method	Number of Input parameters asked for	Number of input parameters used			Number of control bands		
		Nano-relevance	Hazard scaling	Expo. scaling	Haz.	Exp.	Risk
ANSES CB Tool <sup>α</sup>	9	1	5	3	5	4	5
<b>NanoSafer 1.0 #</b>	<b>25</b>	<b>5</b>	<b>5</b>	<b>13</b>	<b>4</b>	<b>5</b>	<b>5</b>
IVAM Guidance <sup>α</sup>	28	-	2	1	3	3	3
Swiss Precautionary Matrix	28	7	6	6	n.a.	n.a.	2
CB Nanotool	53	-	15	5	4	4	4
<b>Stoffenmanager Nano #</b>	<b>47</b>	<b>-</b>	<b>2</b>	<b>26</b>	<b>5</b>	<b>4</b>	<b>3</b>

<sup>α</sup> The technically simplest model

# The technically most advanced models



Modified from Liguori et al. (2016)

# Four Assessments in “One Go” (Near-Field and Far-Field – Acute and Daily)

NanoSafer Search material or process 🔍  kaj@nrcwe.dk ▾



Navigation

**Modules** ▾

- Dashboard
- Materials
- Processes
- Risk Assessment

**Help** ▾

⏪

**Tox**  
Score: 0.2

**Near-field**  
Acute: 18.60206

**Near-field**  
Daily: 4.78548

**Far-field**  
Acute: 0.91184

**Far-field**  
Daily: 0.33027

**RL5: Very high toxicity suspected and/or moderate to very high exposure. The work should be conducted under strict dust release control, such as in a fume-hood, separate enclosure etc. Air-supplied respirators or highly efficient filter masks (PP3 or higher quality) may be used as a supplement and must be readily available in case of accidents. Expert advice is recommended.**

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**RL4: High toxicity suspected and/or high exposure potential. The work should be performed during use of highly efficient local exhaust ventilation, fume-hood, glove-box etc. Use of respiratory protection equipment (PP3 or higher quality) may be relevant depending on the work situation. Make sure to have the personal respiratory protection equipment (PP3 or higher quality) available in case of accidents.**

**RL3: Intermediate toxicity suspected and/or moderate exposure potential. The work should be conducted in a fume-hood or with highly efficient local exhaust ventilation in combination with use of respiratory protection equipment (PP3 or higher quality) depending on the work situation. Make sure to have the personal respiratory protection equipment available in case of accidents.**

List all Material and safety data entered / selected

List all exposure situation data entered / selected

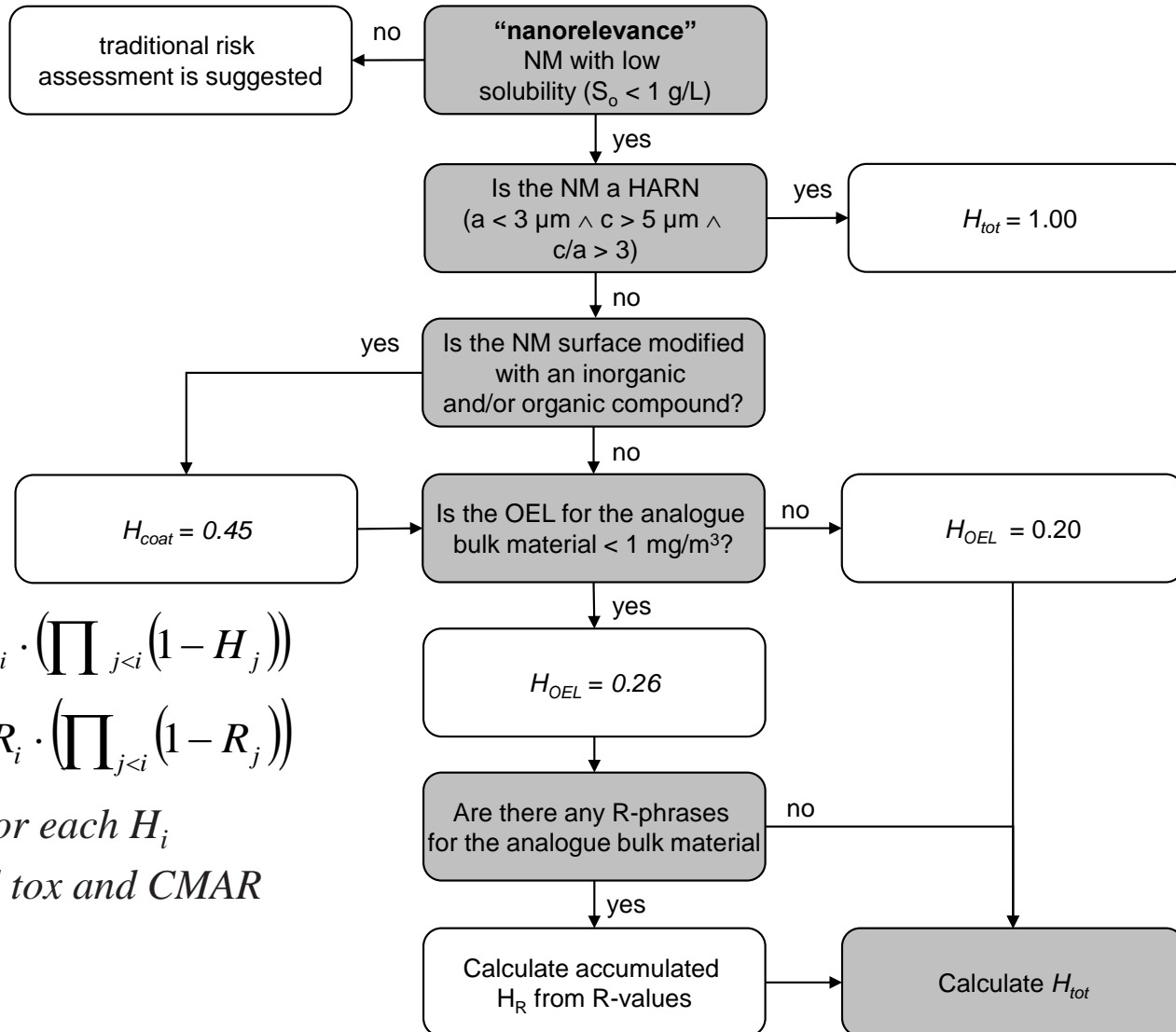
**Disclaimer**

It should be noted that the NanoSafer 1.1 output consist of an automated risk assessment and risk management recommendations considering user-dependent input. The National Research Centre for the Working Environment and other contributors as well as the program developers are not liable for any damage to humans or material or loss of income that would arise as a result of the assessments provided using NanoSafer 1.1. The outcome must be considered as a guide, but the final responsibility belongs to the safety managers using the results.



# Hazard Assessment

## - Example with R-sentences



$$H_{tot} = \sum_{i=1}^n H_i \cdot \left( \prod_{j<i} (1 - H_j) \right)$$

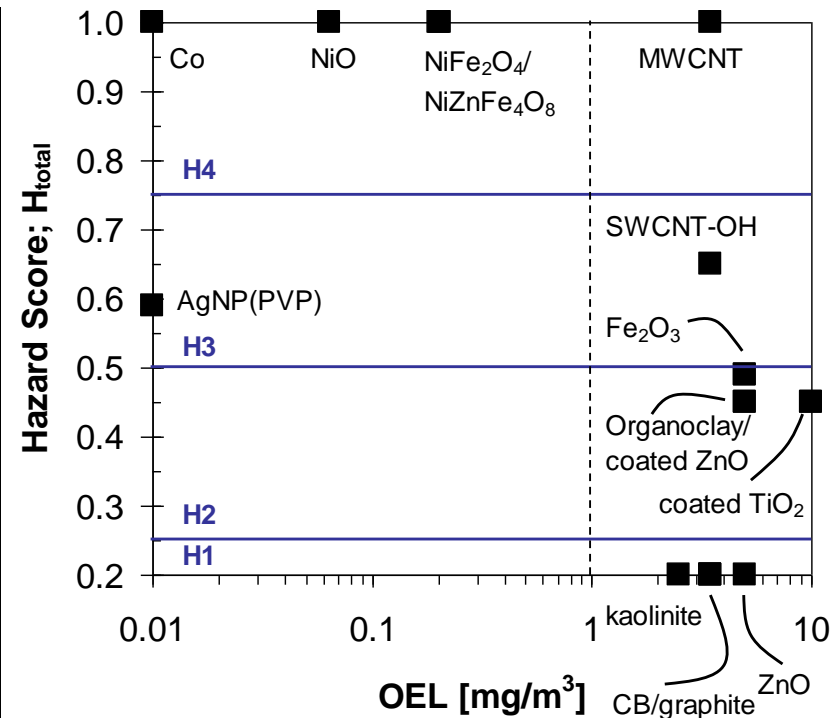
$$H_{carc} = \sum_{i=1}^n R_i \cdot \left( \prod_{j<i} (1 - R_j) \right)$$

$R_j \in [0.1; 1]$  for each  $H_j$

$H_i = \text{General tox and CMAR}$

# Examples of MNM Hazard Ranking Compared to OELs of analogue bulk materials

Material	SSA [m <sup>2</sup> /g]	HARN	Coated	OEL [mg/m <sup>3</sup> ]	R <sub>i</sub>
TiO <sub>2</sub>	21	-	0.45	10.0	-
TiO <sub>2</sub>	107	-	0.45	10.0	-
ZnO	12.4	-	-	4.98	-
ZnO	15.1	-	0.45	4.98	-
graphite	225	-	-	3.50	-
carbon black	23.8	-	-	3.50	-
carbon black	295	-	-	3.50	-
Kaolin	23.1	-	-	2.50	-
nanoclay	8.44	-	0.45	5.00	-
SWCNT-OH	407	-	0.45	3.50	R36/R37
MWCNT	233	1	-	3.50	R36/R37
Fe <sub>2</sub> O <sub>3</sub>	27.4	-	-	5.00	R36/R37/R8
Fe <sub>2</sub> O <sub>3</sub>	27.7	-	-	5.00	R36/R37/R8
NiFe <sub>2</sub> O <sub>4</sub>	87.7	-	-	0.200	R43/R49
Ni <sub>0.5</sub> Zn <sub>0.5</sub> Fe <sub>2</sub> O <sub>4</sub>	104	-	-	0.203	R43/R49
NiO	6	-	-	0.064	R49/R43/R53
Co(10% O passivated)	60	-	-	0.010	R11/R42/R43/R53
Ag	0.03	-	0.45	0.010	-

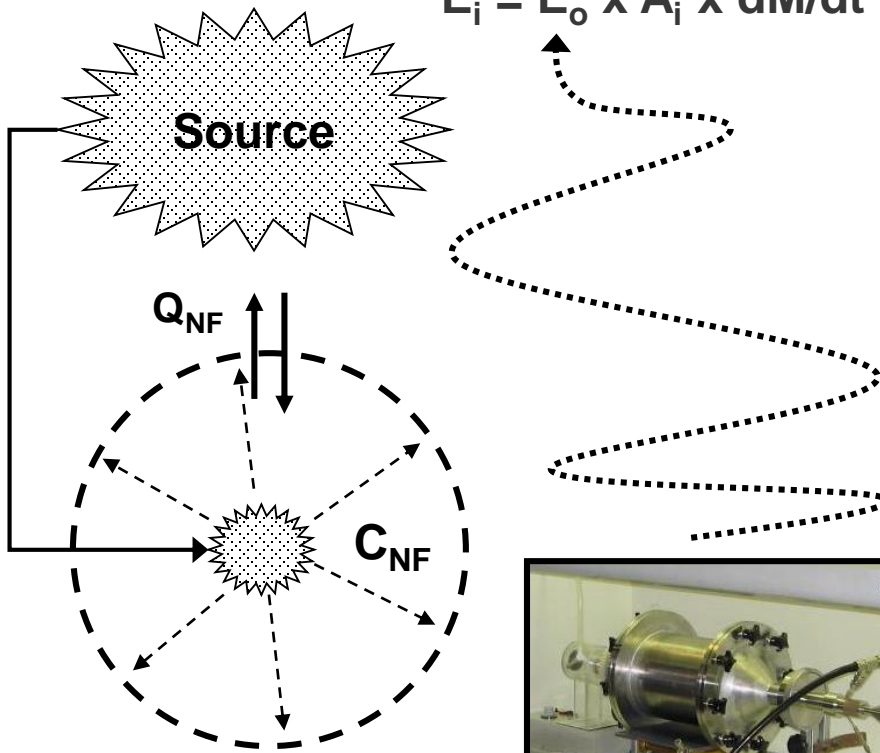


# Exposure Assessment and Scaling

## - Example of using Powders

Emission rate:

$$E_i = E_o \times A_i \times dM/dt$$



$E_i$  = release rate

$E_o$  = dustiness index

$A_i$  = activity energy factor

$A_0$ : "zero" (clean transport)

$A_1$ : very low (weighing mg's)

$A_2$ : low (< 5 cm drop)

$A_3$ : moderate (5-30 cm drop)

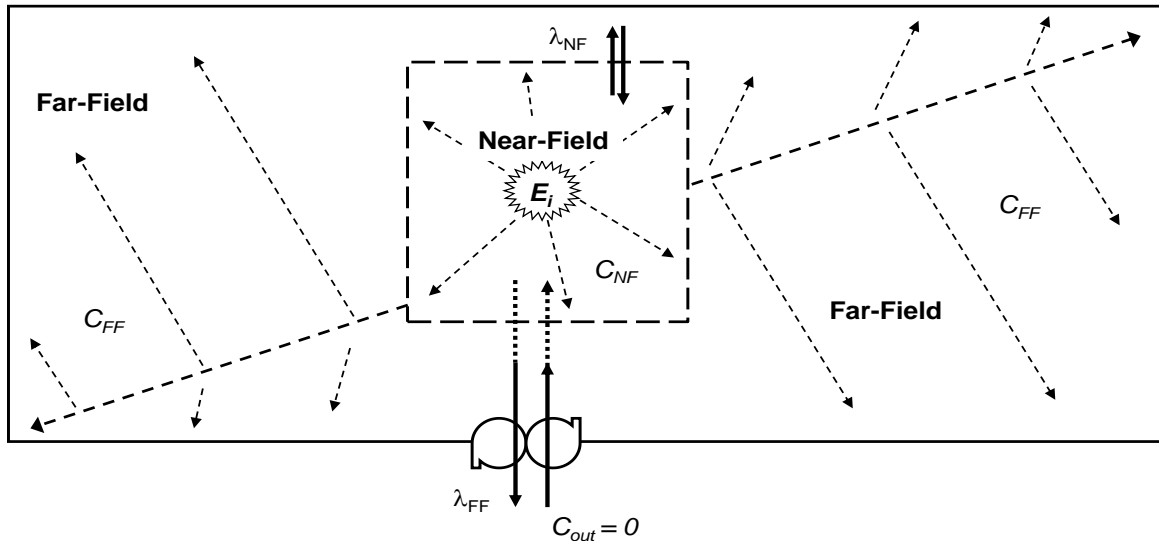
$A_4$ : high (30-100 cm drop)

$A_5$ : very high (> 100 cm drop)

$dM/dt$  = mass flow rate

# Exposure Assessment and Scaling

## - Example of using Powders



### Exposure scaling

NF Acute (15 min): Upper limit is 2 xOEL<sub>nano</sub>

NF Daily (8-hour): Upper limit is OEL<sub>nano</sub>

FF Acute (15 min) : Upper limit is 2 xOEL<sub>nano</sub>

FF Daily (8-hour) : Upper limit is OEL<sub>nano</sub>

NF volume = 12.17m<sup>3</sup> (2.3<sup>3</sup> m<sup>3</sup>)

Exposure scale: C<sub>i</sub> / OEL<sub>nano</sub>

OEL<sub>nano</sub> = OEL<sub>bulk</sub> x (VSSA<sub>nano</sub> / VSSA<sub>bulk</sub>)

### Dispersion model:

$$C_{NF,t} = \frac{E_i}{V_{NF}} \cdot \Delta t + \left[ \frac{M_{FF \rightarrow NF} - M_{NF \rightarrow FF}}{V_{NF}} \right] + R_{NF,t-1}$$

$$C_{FF,t} = \left[ \frac{M_{NF \rightarrow FF} - M_{FF \rightarrow NF}}{V_{FF}} \right] + R_{FF,t-1}$$

### Where M and R are:

$$M_{FF \rightarrow NF} = \left[ \frac{\lambda_{NF} \cdot C_{FF} \cdot V_{NF}}{\Delta t \cdot (\lambda_{NF})^2} \right] \cdot \left[ \lambda_{NF} \cdot \Delta t + e^{(-\lambda_{NF} \cdot \Delta t)} - 1 \right]$$

$$M_{NF \rightarrow FF} = \left[ \frac{\lambda_{NF} \cdot C_{NF} \cdot V_{NF}}{\Delta t \cdot (\lambda_{NF})^2} \right] \cdot \left[ \lambda_{NF} \cdot \Delta t + e^{(-\lambda_{NF} \cdot \Delta t)} - 1 \right]$$

$$R_{NF,t-1} = \left[ \frac{C_{NF,t-1}}{(\lambda_{FF} \cdot \Delta t)} \right] \cdot \left[ 1 - e^{(-\lambda_{FF} \cdot \Delta t)} \right]$$

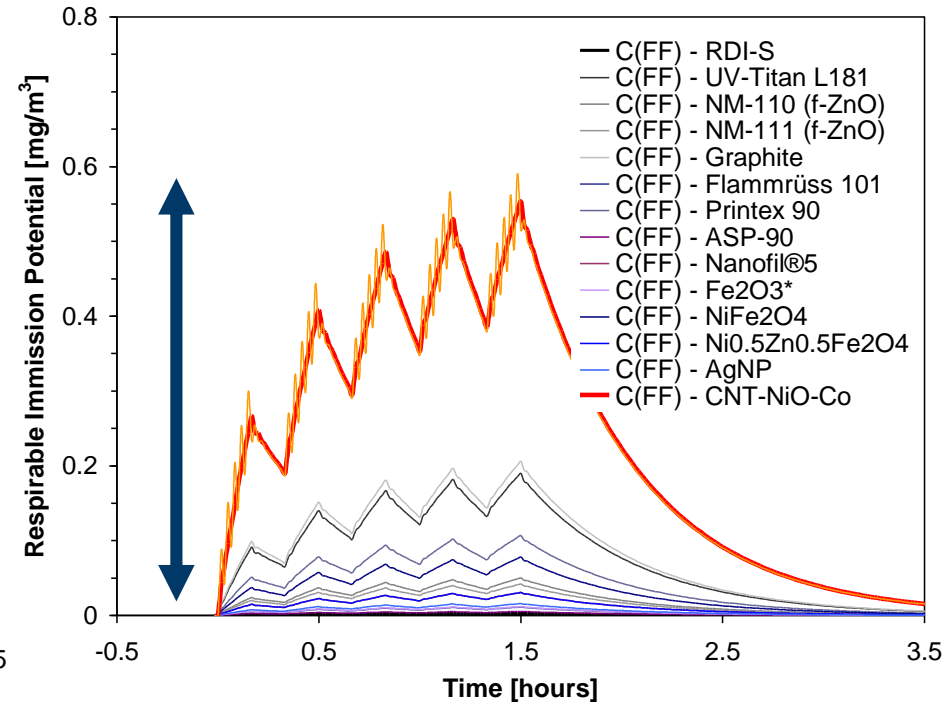
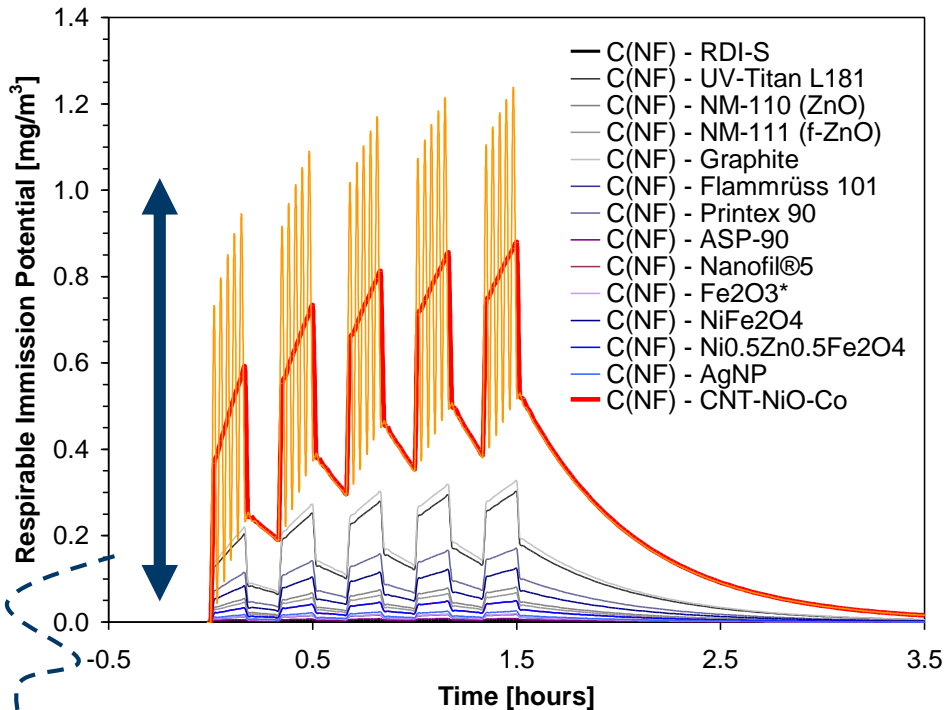
$$R_{FF,t-1} = \left[ \frac{C_{FF,t-1}}{(\lambda_{FF} \cdot \Delta t)} \right] \cdot \left[ 1 - e^{(-\lambda_{FF} \cdot \Delta t)} \right]$$





# Exposure Assessment and Scaling

## - Example of using Powders



***Variation reflects variation***

***in dustiness***

***NM not one category***

**Scoping/filling 5 x 500 g bags in small scale production:**

**Total mass: 500 g**

**Mass per transfer (spoonful): 50 g/scoop.**

**$H_i = 0.3$**

**Duration per filling: 10 minutes**

**Duration per transfer: 0.5 minute**

**Pause between each filling: 5 minutes**

**Work area: 3.5 m x 5 m long x 2.9 m high**

**ventilation rate of 5 h<sup>-1</sup>**





# NanoSafer Control Banding Report for Airborne Occupational Exposure Assessment

version 1.1

Based on the estimated hazard and exposure potential it is recommended to apply engineered protection equipment with a protection factor of 186.02

### Elaborated description of work situation assessed

This is a test scenario

### Assessment prepared by

Name: K...  
Address: N...  
Phone: O...  
E-mail: ka...  
Date: T...

### Assessment of

Material assessed:  
Producer: Claymonst  
GB-255681 Albury, U  
Classified as nanom  
Nanoflake

### Result of assess

Estimated hazard le  
The hazard level is  
Potentially hazardous  
nanomaterial No  
A high volume specific  
m2/cm3  
OEL of analogue bu  
Solubility: Insoluble  
Presence of surface  
Known hazards of a

Near-field Acute  
18.60  
EB5: Very high expos

Based on the estimated hazard and exposure potential it is recommended to apply engineered protection equipment with a protection factor of 186.02

Elaborated description of work situation assessed  
This is a test scenario



### Material, safety and contextual informat

#### Material and safety data entered

**Manufacturer:** Claymonster Inc.,. 412 Sudbury Road, GB-255681 Albury, UK  
**CAS:** NA  
**EINECS:** NA  
**Relevance:** No  
**Coated:** No  
**Known shape:** Yes

Next step is coupling with risk management library such as the ECEL developed by TNO

Pour 5 - 30 cm drop height, blending of powder in liquid medium)

**Cyclus volume:** 200 kg

**Cyclus duration:** 20 min

**Cyclus pause:** 60 min

responsibility belongs to the safety managers using the results.

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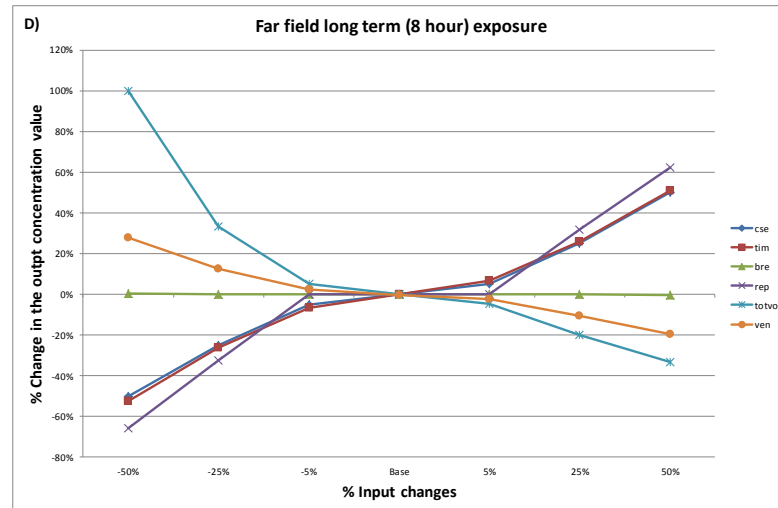
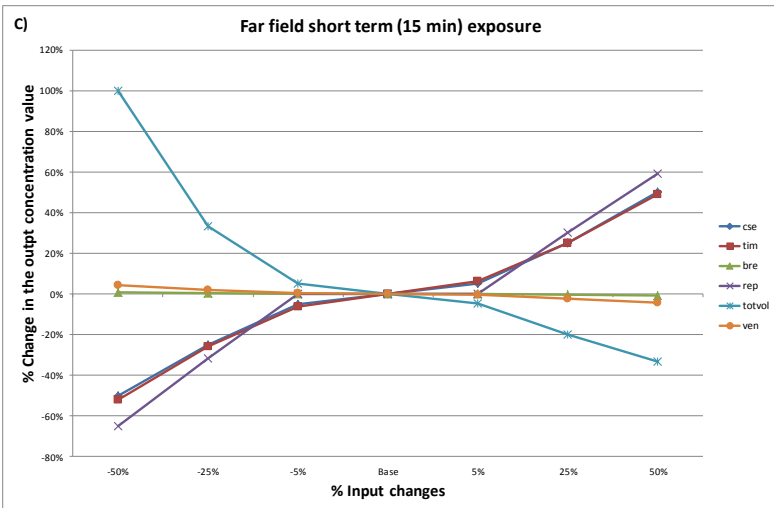
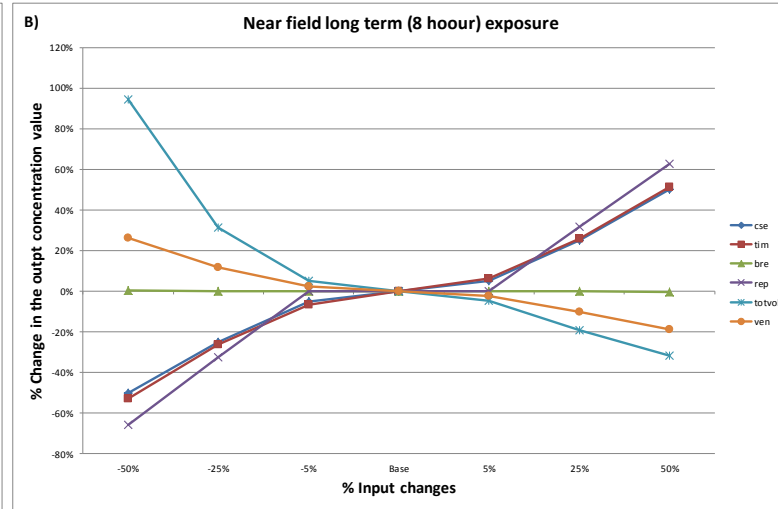
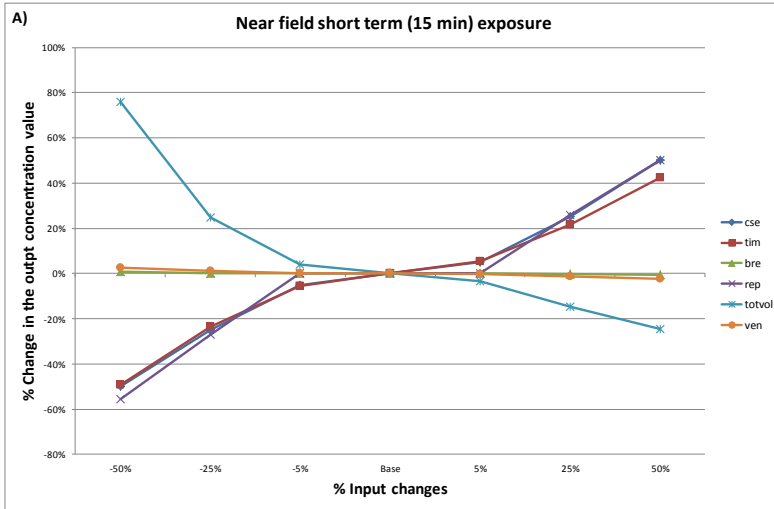
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assessment  
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# Sensitivity Analysis (Exposure Algorithm) - One At Time

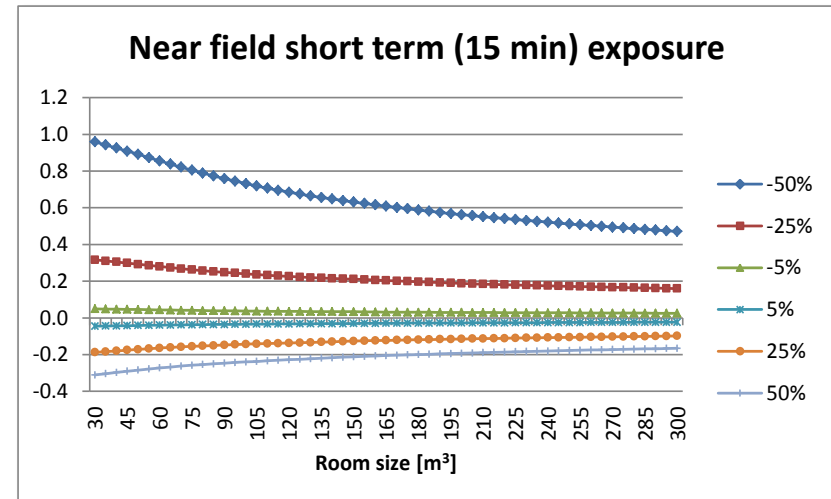


# Sensitivity Analysis (Exposure Algorithm)

## - One At Time

Main effects		
	[NF daily]	[FF daily]
CSE	50.9573	49.5076
TIM	42.8422	41.6568
REP	32.5480	31.4588
BRE	-27.0343	-26.4670
TOTVOL	-32.0269	-31.4291
VEN	-50.1953	-49.4954
	[NF Acute]	[FF Acute]
CSE	89.2789	86.3203
TIM	74.0052	72.8325
REP	65.0045	63.9056
BRE	-54.9602	-53.9095
TOTVOL	-64.2924	-63.8799
VEN	-85.7826	-86.2296

CSE	Constant Source Emission
TIM	Duration of work cycle
BRE	Pause between work cycles
REP	Frequency - Repetition of the workcycle
TOTVOL	Room size
VEN	Air Exchange rate



# Next Step is Performance Assessment and Model Calibration

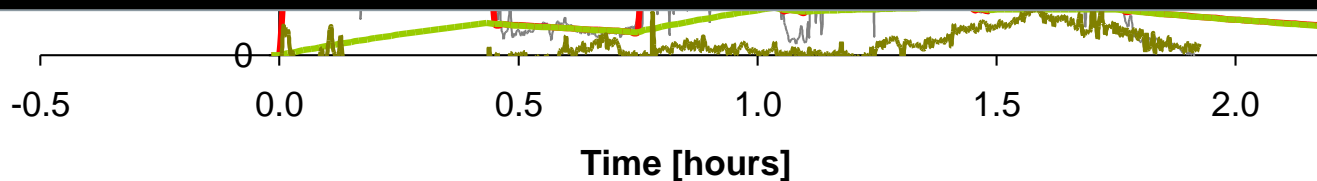
40000

— NF(FMPS) - BG

— C(NF) - Vibration feeder

**Challenge is quality and detail of the case studies for comparison**

1. Materials well-characterized
2. Suitable toxicological data on MNM (CMAR)
3. High quality MNM exposure measurement data (personal and stationary)



# THANKS TO MY CO-DEVELOPERS AND TESTERS

**Biase Liguori** (DTU; NRCWE)

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**Alexander C.Ø. Jensen** (DTU; NRCWE)

**Håkan Wallin** (NRCWE)

Danish Centre for NanoSafety

