NanoSafer Control Banding Tool v1.1

-

Pouring TiO_2 (pigment) in paint formulation

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Version log *[Add lines if needed]*			
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			Final version

Keywords [up 5 keywords should be sufficient]

TiO2, pouring, powder, wet-mixing, paint, manufacture, nanomaterial, pigment

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1 Tool description and use domains

The NanoSafer v1.1 is a combined control-banding and risk management tool (Kristensen et al., 2010; Jensen et al., in preparation) that enables assessment of manufactured nanomaterials as well as products and articles containing nanomaterials (e.g., nanoparticles, nanoflakes, nanofibers, and nanotubes) in specific work scenarios (powder handling or leak/point source). In addition to manufactured nanomaterials, the tool can also be used to assess and manage emissions from nanoparticle-forming processes such as powder handling and fugitive/point-source emissions. Depending on the process domain, the number and type of requested parameters differ. A total of 24 and 21 data entries are requested for powder handling and leak/point source, respectively. From these total data entries, 3 material identifiers are optional (manufacturer, CAS or EINICS number). A detailed description of the NanoSafer v1.1 including a complete list of required input parameters is available in Annex I. Hazard assessment and case-specific exposure potentials are currently combined into an integrated assessment of risk levels expressed in control bands with associated risk management recommendations and e-learning on how to reduce exposure or risk thereof.

The tool is currently intended for small and medium-size companies and laboratories with no or limited experience in working with nanomaterials and/or insufficient resources to perform a full precautionary risk assessment. Further developments in future aim to expand the application domains for an assessment of exposure for mechanical reduction and spraying processes and include assessment with risk management measures as part of caLIBRAte project (http://www.nanocalibrate.eu/home).

2 Description of case study

To illustrate the use of NanoSafer v1.1, the tool is applied in an industrial scenario (described in Koivisto et al., 2015), in which exposure to pigment TiO_2 arising from powder handling (pouring 25 kg bags of TiO_2 (93%), Al_2O_3, ZrO_2, organic into a mixer for paint formulation) is assessed.

3 Input parameters

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The corresponding input parameters required by NanoSafer are described in **Fejl! Henvisningskilde ikke fundet.**.

Table 1. Description of the exposure scenario "Pouring 25 kg RD3 (TiO_2 (93%), Al_2O_3, ZrO_2, organic)" according the data requirements on material properties, process, workplace and exposure situation by using NanoSafer v1.1 tool.

	Data/information entered in the tool	Relevant comments
Process type/work situation assessed	Powder handling	Work situation assessed: Pouring 25 kg RD3 (TiO_2 (93%), Al_2O_3, ZrO_2, organic)
Material identifiers		
Material name	TiO_2 particles (93%, mean 220 nm)	Characterization provided in Table 1 from Koivisto et al. (2015). No characterization of the surface, (93% TiO_2 can be considered, 3.5% ZrO_2 and 3.5% Al_2O_3). Relative density TiO_2 = 4 g/cm3 (extracted from material safety data sheet)
Manufacturer	Sachtleben Pigment GmbH, Pori, Finland)	
CAS number	13463-67-7	-
EINICS number	2366755	-
Material information		
Is the nanomaterial labeled with a nano-specific word or term?	No	-
Is the nanomaterial coated or surface modified	Yes	-
Morphology	Spherical /Isometric	Mean size 220 nm (obtained from XRD) and standard deviation 22 (this is an assumption, 10%)
Dimensions of the primary nano-object (a ≤ b ≤ c)	220 nm	-
Relative density (specific gravity) density of the nanomaterial	4 g/cm^3	Value extracted from corresponding material safety data sheet
Solubility of the material [is the material water soluble]	Insoluble (< 1 g/L)	-
The specific surface area of the nanomaterial	6.82 m^2/g	-
Respirable dustiness of powder	5.3 mg/kg	-
Safety data /Hazard		
Is there a nanospecific occupational exposure limit (OEL_{nano}) or target value?	No	-
Respirable OEL for the nearest analogue material	10 mg/m^3	-
Known hazards of analogue bulk material	H351: suspected of causing cancer	According to the material safety data sheet

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	Data/information entered in the tool	Relevant comments
Process type/work situation assessed	Powder handling	Work situation assessed: Pouring 25 kg RD3 (TiO2 (93%), Al2O3, ZrO2, organic)
Contextual information (exposure situation)		
Activity handling energy factor[£]	H6	e.g. Pouring of powders with 20-40 cm drop in free air; filling of bags and big bags
Total mass of material handled in each work cycle	26 kg	-
Duration of the work cycle	1 min	-
Pause between work cycles	1 min	Idle time between cycles is 1 min
Number of work cycles per day	10 times	-
Amount of material handled in each transfer	26 kg	-
Time required per task in cycle (spoon, bag, big-bag etc.)	1 min	-
Volume of the work room (width x length x height)	20 m x 30 m x 2.5 m	Volume of the room: 1500 m3
Air exchange rate	5 times/h	
Activity level in the room*	Moderate	-

[£] *H0 "Zero energy" (e.g. Removal and handling of clean barrels and plastic containers)*

H1 (e.g. Pouring of powders with up to 1 cm drop in free air; careful balancing)

H2 (e.g. Pouring of powders with 1-2 cm drop in free air; careful wet mixing)

H3 (e.g. Pouring of powders with 2-5 cm drop in free air; wet mixing)

H4 (e.g. Pouring of powders with 5-10 cm drop in free air; open conveying of powder)

H5 (e.g. Pouring of powders with 10-20 cm drop in free air; handling contaminated or leaking bags)

H6 (e.g. Pouring of powders with 20-40 cm drop in free air; filling of bags and big bags)

H7 (e.g. Pouring of powders with 40-60 cm drop in free air; careful dry mixing)

H8 (e.g. Pouring of powders with 60-80 cm drop in free air; dry mixing)

H9 (e.g. Pouring of powders with 80-100 cm drop in free air; vigorous handling, folding open bags)

H10 (e.g. drop heights > 1 m, dry mixing, cleaning with brusher or compressed air, accidents)

* Recommend to use intermediate activity. This choice is expected eliminated in the near future for control banding assessments

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4 Results

The NanoSafer control banding report for airborne occupational exposure assessment provided by the tool for this exposure scenario is shown in Annex II. In this specific case, a risk sentence *"H351: Suspected of causing cancer"* was listed and adopted from the bulk material. In consequence, the TiO_2 RD3 pigment material scored a relatively high hazard score of 0.89 (finite four-step linear scale ranging from 0 to 1 with increase in hazard level at 0.25, 0.5 and 0.75 points). The exposure score in NanoSafer ranges from 0 to ∞ and the exposure risk level increases in five steps at 0.1, 0.25, 0.5, and 1.0, where occupational exposure limit (OEL) is exceeded when the exposure risk level is larger than 1. For this case modelled, the daily near field (NF) exposure potential was 0.0037 resulting in very low exposure potential and a final risk level of RL4 due to the high toxicity suspected. This risk level was associated with general recommendations for risk management such as:

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.

For this exposure scenario, the 8-hours time weighted (8h-TWA) average were re-calculated based on 20 min exposure and the reported respirable mass concentration for this time period of 167.1 µg/m^3 (Koivisto et al., 2015). This resulted in an 8h-TWA respirable mass concentration of 7 µg/m^3.

The conversion of the NanoSafer NF daily score to daily mass concentration was 5.3-fold higher than the 8h-TWA measured concentrations for this exposure scenario.

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5 References

Jensen, K.A., Saber, A.T., Kristensen, H.V., Liguori, B., Jensen, A.C.Ø., Koponen, I.K., et al. NanoSafer version 1.1: A web-based precautionary risk assessment and management tool for manufactured nanomaterials using first order modeling (manuscript in preparation).

Koivisto, Antti Joonas, a. C. Ø. Jensen, M. Levin, K. I. Kling, M. Dal Maso, S. H. Nielsen, K. a. Jensen, and I. K. Koponen. 2015. "Testing the near Field/far Field Model Performance for Prediction of Particulate Matter Emissions in a Paint Factory." Environ. Sci.: Processes Impacts 17. Royal Society of Chemistry: 62–73. doi:10.1039/c4em00532e.

Kristensen, H.V., Hansen, S.V., Holm, G.R. 2010. Nanopartikler I Arbejdsmiljøet: Viden Og Inspiration Om Håndtering Af Nanomaterialer. [Internet] Available from: http:// nanosafer.i-bar.dk/media/Nanopartikler_i_arbejdsmiljoet_samlet.pdf.

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Annex I - Detailed description of NanoSafer v1.1

The NanoSafer v1.1 input parameters should be easily accessible and therefore, the basic product and safety input are the producers' technical data, MSDS, the national occupational exposure limit (OEL) for the nearest analogue bulk material, which currently is the material referred to in the MSDS, and finally the contextual information about the work process and workplace. Table below lists all of the selected input parameters with indication on in which modules the information is used.

The NanoSafer control-banding tool includes four modules:

- Materials collects the information regarding the material information
- Hazard information collects the information regarding safety data
- Processes information collects the information regarding the process and contextual information
- Risk Assessment evaluates the risk and predicts the hazard and exposure potential and the protection level that one should apply conducting the work described in the Process module with the selected materials.

Table I. Data requested by NanoSafer v1.1 and indication of their application in specific modules of the risk evaluation system.

Input data	Type of Process		Unit	"Nano relevance"	Hazard	Exposure
	Powder handling	Leak/point source (constant release)				
Material identifiers						
Material name	x	x	Text	-	-	-
Manufacturer	optional	optional	Text			
CAS number	optional	optional	Text	-	-	-
EINICS number	optional	optional	Text	-	-	-

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Input data	Type of Process		Unit	"Nano relevance"	Hazard	Exposure
Material information						
Is the nanomaterial labeled with a nano-specific word or term?	x	x	yes/no	x		-
Is the nanomaterial coated or surface modified	x	x	yes/no	x	x	-
Dimensions of the primary nano-object (a ≤ b ≤ c)	x	x	nm	x	x	-
Relative density (specific gravity) density of the nanomaterial	x	x	g/cm^3	x		x
Solubility of the material [is the material water soluble]	x	x	binary	x	x	-
The specific surface area of the nanomaterial	x	x	m^2/g	x		-
Respirable dustiness of powder€	x	x	mg/kg	-		x
Safety data /Hazard						
Is there a nanospecific occupational exposure limit (OEL_{nano}) or target value?	x	x	yes/no	-	x	x
Respirable OEL for the nearest analogue material	x	x	mg/m^3	-	x	x
Risk sentences	x	x	decimal unit	-	x	-
Contextual information					-	-
Emission rate if constant source emission or leak	-	x	mg/min	-	-	x
Activity handling energy factor£	x	-	decimal unit	-	-	x
Total mass of material handled in each work cycle	x	-	kg	-	-	x
Duration of the work cycle	x	x	min	-	-	x
Pause between work cycles	x	x	min	-	-	x
Number of work cycles per day	x	x	n	-	-	x
Amount of nanomaterial handled in each transfer	x	-	kg	-	-	x
Time required per task in cycle (spoon, bag, big-bag etc.)	x	-	min	-	-	x
Volume of the work room (width x length x height)	x	x	m^3	-	-	x
Air exchange rate	x	x	h^{-1}	-	-	x
Activity level in the room*	x	x	decimal unit	-	-	x

€ choose dustiness level if you do not have the test result

£ H0 "Zero energy" (e.g. Removal and handling of clean barrels and plastic containers)

H1 (e.g. Pouring of powders with up to 1 cm drop in free air; careful balancing)

H2 (e.g. Pouring of powders with 1-2 cm drop in free air; careful wet mixing)

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H3 (e.g. Pouring of powders with 2-5 cm drop in free air; wet mixing)
H4 (e.g. Pouring of powders with 5-10 cm drop in free air; open conveying of powder)
H5 (e.g. Pouring of powders with 10-20 cm drop in free air; handling contaminated or leaking bags)
H6 (e.g. Pouring of powders with 20-40 cm drop in free air; filling of bags and big bags)
H7 (e.g. Pouring of powders with 40-60 cm drop in free air; carefull dry mixing)
H8 (e.g. Pouring of powders with 60-80 cm drop in free air; dry mixing)
H9 (e.g. Pouring of powders with 80-100 cm drop in free air; vigorous handling, folding open bags)
H10 (e.g. drop heights > 1 m, dry mixing, cleaning with brusher or compressed air, accidents)
** Recommend to use intermediate activity. This choice is expected eliminated in the near future for control banding assessments*

In NanoSafer, exposure levels are calculated using the potential emission rate (constant release or activity energy × dustiness index × mass-flow), duration and frequency of the activity, and information about the volume of the work area and its ventilation rate. The theoretical acute and 8-hour exposure level at NF and FF is scaled by normalization to a theoretical nanospecific OEL, which is derived from the ratio between the specific surface area of the bulk OEL (using 200 nm spherical sizes as the bulk particle reference) and the specific surface area of the nanomaterial in question.

The exposure score ranges from 0 to ∞ and the exposure risk level increases in five steps at 0.1, 0.25, 0.5, and 1.0, where OELnano is exceeded when the exposure risk level is larger than 1. The hazard estimate is a finite four-step linear scale ranging from 0 to 1 with increase in hazard level at 0.25, 0.5 and 0.75 points.

The hazard and exposure level are estimated and evaluated by five control-banding risk levels (RL1 to RL5) for the acute and daily NF and FF exposure in the scenario. Each control band (risk level) is associated with general recommendations for risk management such as use of local exhaust ventilation and personal protection. The output is a recommendation on the requirements to achieve a safe working environment.

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Annex II - NanoSafer v1.1 output result

Web-based NanoSafer v1.1 tool report for the exposure scenario "*Pouring 25 kg RD3 (TiO_2 (93%), Al_2O_3, ZrO_2, organic)*" is shown below.

NanoSafer Control Banding Report for Airborne Occupational Exposure Assessment

version 1.1

Assessment prepared by

Name:
Address:
Phone:
E-mail:
Date: Friday, Oct 4, 2019

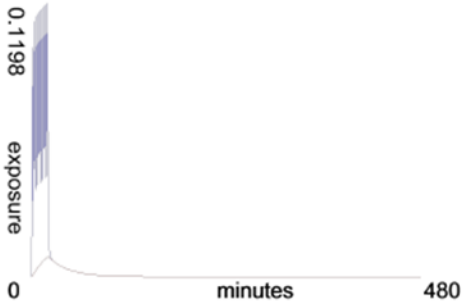
Assessment of

Material assessed: (C1, C3) TiO2 RD3 **Producer:** Sachtleben Pigment GmbH, Pori, Finland) **Classified as nanomaterial consisting of:** Nanoobject	**Work situation assessed:** (C3) Pouring 25 kg RD3 (TiO2 (93%), Al2O3, ZrO2, organic) **Process type:** Powder Handling

Result of assessment

Estimated hazard level 0.89
The hazard level is estimated based on
High aspect ratio material: No
OEL of analogue bulk material: 10 mg/m3
Solubility: Insoluble (< 1 g/L)
Presence of surface coating: Yes
Known hazards of analogue bulk material
H351 Suspected of causing cancer

Estimated time-resolved exposure index



Near-field Acute	Near-field Daily	Far-field Acute	Far-field Daily
0.0402 EB1: Very low exposure potential	0.0037 EB1: Very low exposure potential	0.0038 EB1: Very low exposure potential	0.0007 EB1: Very low exposure potential

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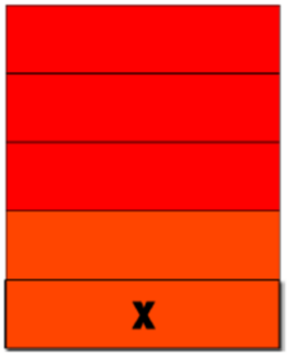
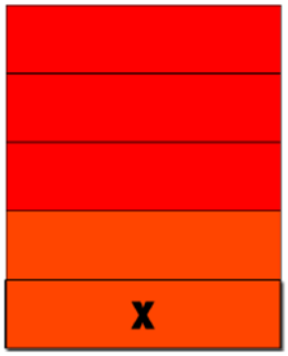
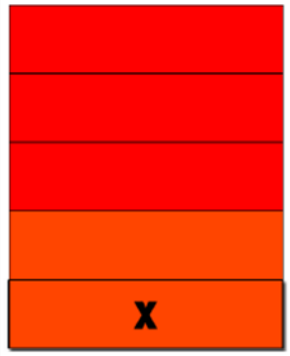
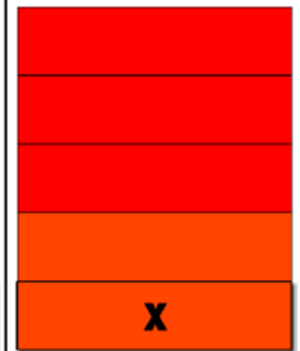
<table>
<tr><td>  </td><td>  </td><td>  </td><td>  </td></tr>
<tr><td>RL4: High toxicity suspected and/or high exposure potential. The work should be performed during use of highly efficient local exhaust ventilation, fume-hood, glove-box etc. Use of respiratory protection equipment (PP3 or higher quality) 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.</td><td>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.</td><td>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.</td><td>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.</td></tr>
<tr><td colspan="4">Based on the estimated hazard and exposure potential it is recommended to apply engineered protection equipment with a protection factor of 1 or higher
- corresponding to an efficacy of -2388 %
If the estimated risk level is low with exposure ratios lower than 0.1, it is recommended to consider working under at least local exhaust ventilation or in a fume hood as possible depending on the work situation.</td></tr>
<tr><td colspan="4">Elaborated description of work situation assessed</td></tr>
</table>

Material, safety and contextual information used in the assessment

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Material and safety data entered	Exposure situation data entered
Manufacturer: Sachtleben Pigment GmbH, Pori, Finland) **CAS:** 13463-67-7 **EINECS:** 2366755 **Relevance:** No **Coated:** Yes **Known shape:** Yes **Morphology:** Spherical / Isometric **Shortest dimension:** 220 nm **Size is known:** No **Average size:** No **Size range known:** No **Surface area:** 6.82 m2/g **Relative density:** 4 g/cm3 **Solubility:** Insoluble (< 1 g/L) **Respirable dustiness:** 5.3 mg/kg	**Process type:** Powder handling **Energy level:** H6: (e.g., pouring of powders with 20-40 cm drop in free air; filling of bags and big bags) **Amount used in cycle:** 26 kg **Cyclus duration:** 1 min **Number of cycles per day:** 10 times **Pause between cycles:** 1 min **Mass handled per task in cycle:** 26 kg **Time required per task in cycle:** 1 min **Length room:** 30 meters **Width room:** 20 meters **Height room:** 2.5 meters **Room air exchange rate:** 5 times per hour **Activity level room:** Moderate
Further information and guidance on exposure management to MNM: e-Learning tool.	

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 contributers 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.

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