Scaffold Public Documents – SPD23



Innovative strategies, methods and tools for occupational risks management of manufactured nanomaterials (MNMs) in the construction industry

CUSTOMIZED CONTROL BANDING APPROACH FOR POTENTIAL EXPOSURE TO MANUFACTURED NANOMATERIALS (MNMS) IN THE CONSTRUCTION INDUSTRY

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1 EXECUTIVE SUMMARY

This document describes the software prototype developed in the SCAFFOLD project. The tool is a customization of Control Banding (CB) using the work done at SCAFFOLD on the assessment and prevention of occupational risks of Manufactured NanoMaterials (MNMs) when used in the construction industry. The tool considers the materials and construction processes treated at Scaffold according to input from SCAFFOLD's reports on risk assessment and risk protection and from SCAFFOLD partners. It can be applied to construction scenarios not studied in SCAFFOLD as well. The allocation of hazard bands is according to the ISO/TS 12901-2 (2014) standard.

The exposure algorithms developed here are strongly based on well-established models, mainly Stoffenmanager and DREAM. In particular, the respiratory exposure algorithm follows the Stoffenmanager source-receptor approach and incorporates modifying factors related to source emission and dispersion of contaminants. The generic exposure is represented as a multiplicative function of type of handling and intrinsic properties of the product. The dermal exposure algorithm is according to the DREAM model. Significant simplifications are applied so that the resulting dermal algorithm requires the minimum possible input. An effort is also made to avoid overlapping of the input data used in the respiratory and dermal exposure algorithms. The ranking of various combinations of exposure and hazard bands in terms of risk follows the approach suggested by Oliveira Nunes (2015). Risk levels are divided into five risk bands according to the BS 8800 (2004) standard.

2 SCOPE

The goal of this work was to develop a new control banding (CB) tool suitable for the occupational risks of MNMs in the construction industry. The work included the following activities:

- Analysis and development of risk scenarios applicable to the construction industry
- Setting occupational exposure limits (performed by FIOH: see Scaffold Public Document SPD7) and occupational exposure bands especially for construction industry workplaces.
- Development of suitable control bands, relative to exposure targets and hazard groups, and appropriate hazard communication policies.
- Testing of the applicability of the Stoffenmanager Nano-tool in the construction work area (performed by FIOH: see Scaffold Public Document SPD10)
- Selection of the PPE [Personal Protective Equipment] used by workers in construction area such as gloves, masks and technical suits, according to nanoparticles risks.

The elaboration of the CB tool also took into account results from other work within the Scaffold project, on risk prevention, risk protection and risk assessment.

CB approaches have long been used for qualitative assessment and management of occupational risks, in the absence of relevant Occupational Exposure Limits. The CB method has been proven particularly useful for providing hazard control guidance to small and medium size enterprises, while larger businesses may use CB strategies for prioritizing hazards and hazard communication. In view of their growing presence in workplaces and the lack of toxicological data for setting up occupational exposure limits, several CB tools have lately been developed for manufactured nanomaterials (MNMs) and associated processes.

The present document describes the Control Banding tool, how it was developed, the underlying theory and assumptions, and how it can be used. In particular, chapter 3 describes the hazards database. Chapter 4 gives the theoretical background for the respiratory exposure and presents the exposure algorithm used here. Chapter 5 gives the theoretical background for the dermal exposure and presents the exposure algorithm used here. Chapter 6 presents the implementation of the algorithms and the databases in Microsoft Excel and describes the software.

3 HAZARD

Respiratory and dermal hazard bands for generic materials can be allocated based on the ISO/TS 12901-2 (2014) standard, which proposes a table of characteristic properties. In addition, Van Duuren-Stuurman et al. (2012) suggest a classification database for nanomaterials to be used when insufficient data are available.

The approach proposed here, employs four options for hazard band allocation in the following order:

- Hazard band allocation for a known material using information provided by the SCAFFOLD partners. The data collection is further discussed in section 3.1.
- Hazard band allocation using the Van Duuren-Stuurman et al. (2012) hazard classification database. Note that this database relates to respiratory hazards. We assume the same classification for dermal hazards.
- Collection of information on the material using the ISO/TS 12901-2 (2014) standard table.
 The hazard band is allocated based on the worst observed category among the supplied material property classifications. Properties not related to dermal hazards are not taken into account for dermal hazard band allocation. Similarly for respiratory hazard bands.
- Collection of information on the parent material using the ISO/TS 12901-2 (2014) standard table. In this case, the nanomaterial respiratory/dermal hazard bands are taken as plus one of the respective parent bands.

3.1 Data collection on SCAFFOLD materials

In order to assess the hazard potential for the materials used in the SCAFFOLD project specific toxicological data are needed. Data were collected from SCAFFOLD partners (ACCIONA, CEA, FIOH, NETCOMPOSITES and TECNAN) using a list of generic characteristics for each material. The list provided was based on ISO/TS 12901-2 (2014), OECD/ENV/JM/MONO(2009)20/REV and existing CB tools (see Figure 1). The responses cover carrier materials and nanomaterials.

The answers that were collected are presented in Figures 2 – 12. More specifically, in figure 2 the toxicological data for the carrier material from NETCOMPOSITES (Unsaturated polyester resin) are presented. In figure 3 the toxicological data for the nanomaterial 1 from NETCOMPOSITES (dimethyl dihydrogenated tallow ammonium modified bentonite) are presented. In figure 4 the toxicological data for the carrier material from TECNAN (distilled water) are presented. In figure 5 the toxicological data for the nanomaterial 1 from TECNAN (TiO₂) are presented. In figure 6 the toxicological data for the nanomaterial 2 from TECNAN (SiO₂) are presented. In figure 7 the toxicological data for the carrier material from ACCIONA (cement) are presented. In figure 9 the toxicological data for the nanomaterial 2 from ACCIONA (SiO₂) are presented. In figure 9 the toxicological data for the nanomaterial 2 from ACCIONA (SiO₂) are presented. In figure 9 the toxicological data for the nanomaterial 2 from ACCIONA (SiO₂) are presented. In figure 9 the toxicological data for the nanomaterial 2 from ACCIONA (SiO₂) are presented. In figure 9 the toxicological data for the nanomaterial 2 from ACCIONA (SiO₂) are presented. In figure 9 the toxicological data for the nanomaterial 2 from ACCIONA (Titanium dioxide-sepiolite supported) are presented. In figure 10 the toxicological data for the nanomaterial 1 from the nanomaterial 2 from ACCIONA (carbon nanofiber) are presented. In figure 12 the toxicological data for the nanomaterial 2 from ACCIONA (carbon nanofiber) are presented. In figure 12 the toxicological data for the nanomaterial 2 from ACCIONA (TiO₂) are presented.

As noticed in figures 2 to 12, most of the entries that refer to the necessary toxicological data include the notion "Unknown". Assessing the Hazard Band with most of the toxicological parameters being unknown results in high Hazard Band levels. For certain material parameters this yields Hazard Category D, and in the remaining cases we get Hazard Category E. Note that, the material hazard band is derived based on the worst observed category. So if a material has one characteristic property classified as E and the rest classified as A, B and C, the allocated hazard band is E. In many cases, the property entries increasing the hazard class to D and E are the "unknown" ones. The above is also concluded in SCAFFOLD report 4.10 as follows:

"MSDSs of the products do often not give any details (hazardous properties, size or shape) about the nanocomponents and the concentration of the nanomaterial in the product is unclear... If you use the inhalation hazard "unknown" for the nanomaterial, you end up in the hazard band D. This is one big question related to the weaknesses of the Stoffenmanager Nanotool, where almost all the nanomaterials end up in the hazard classes D or E".

For the cases where the NMN used is a well-defined substance (like TiO_2 or SiO_2) the Hazard Bands as assessed by Van Duuren-Stuurman et al. (2012) are used.

4 🔹 i 🔀 🧹 🕺 Titanium die	oxide-sepiolite su	pported		× 1	34 - i 🖂 🖌 🦿 fix 🛛 Titanium d	lioxide			
A	8	C	1 1		A	0	C		
PRODUCT CHARACTERISTICS - Severity factors (pa	rt B: nanomateri	al(s))	d de	1	PRODUCT CHARACTERISTICS - Severity factors (p	art B: nanomateria	ll(s))		
NANOMATERIAL (NOAA) IDENTIFICATION	OATA & CHUTH IN	IORMATION	NOTES	1	NANOMATERIAL (NOAA) IDENTIFICATION	CATA'S GTURNEIN	DUMATION	N9/05	
Name of nanomaterial	Titanium dioxide-s	epiolite supported	-		Name of nanomaterial	Titanium dioxide		-	
Structural formula/molecular structure	TID2-Mg45(6015)		6	-		Multimalied Crimanotub		A	
Nanocomponent MSDS + date	Ves	All known names by	which the		Structural formula/molecular structure	Nanoclay Shows Availa		thich th	he
Nanocomponent Information Sheet + date	and a	material may be acci	urately or	. 5		Silvernanoparticle		ately	or
	A mail	commonly described	must be	6	Nanocomponent MSDS + date	Single-valled C-nanos	de .	must b	90
	King Uppersystems	provided, Examples i	include CAS	13	Nanocomponent Information Sheet + date	Zino ceide		clude	CAS
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	sol-gel process. Th	Name, trivial name a	nd common	. 8	Basic morphology	Spherical	Name, trivial name	e and com	mon
	activated in acid si	trade names if wide!	y used.	1	Chrystalline or amorphous material?	Chrystalline	trade names if wid	dely used.	
Basic morphology	nano-spheres supp fibers	orted on sepiolite micro-		-	Description of surface chemistry (e.g. coating or modification)	In dispersion some a to avoid aggiomera product stability	additives are included tion and to increase		
Chrystalline or amorphous material?	Chrystalline			3	8			1	
Description of surface chemistry (e.g. coating or modification)	supported on sepic	lite fibers		3	Toxicological data on NOAA (qualitative information)				
Known catalytic activity	High					FIGH/Scaffold		1	
Known photocatalytic activity	High			1	Occupational Exposure Limit of NOAA, in µg/m3	proposal: 100.			
Fiber Length of contained fibers or fiber-like particles	1000 nm			4		NIOSH: 300			
Fiber Diameter of contained fibers or fiber-like particles	25 nm					Conflicting			
Fiber L/D (aspect ratio) of contained fibers or fiber-like particles	40 nm			4	is the NDAA carcinogenic?	information	In vivo		
Dustiness (mg/kg)	Ueknown			1.00			in vivo, Limited		
Moisture content %w/w	Unknown				is the MOAA second wis?	I Information	amount of data, not		
	Non-Monthly-				is the north reprototica	University of	enough evidence for	4	
Physicochemical properties and NOAA characterization	BATA & OTHER IN		NOTE	-42	2		classification		
Agglomeration/aggregation	Yes					Conflicting	In vivo and in vitro.		
Solubility (mg/mL) + fluid medium1	Soluble/dispersible	Water			ts the NDAA mutagenic?	information	Different types of		
Solubility (mg/mL) + fluid medium2 (if available)	Concentration of Stations		•	4	and the second		tests.		
Solubility (mg/ml) + fluid medium3 (if available)				4	Is the NDAA dermally absorbed?	Definitely No		-	
Describe crystalline phase	tetragonal			4	is the NDAA toxic on the skin?	Non toxic			
Crystallite size	Unknown			4	Is the NOAA an asthmagen?	Unknown			
Particle size distribution - dry and in relevant media (length)	Unknown			4				-	
Particle size distribution - dry and in relevant media (thickness)	Unknown			4	Toxicological data on NOAA parent (bulk) material	DATAS OTHER IN	OWNATION	NOTES	
Particle size distribution - dry and in relevant media (width)	Unknown					Inholohio: hotoopo			
Sperific purface area	Unknmwn					5000 and 11000.			
r density	Linknown					and respirable			
Real density	Unknown				Occupational Exposure Limit of NDAA parent material, in µg/m3	between 3000 and			
Denocity	Unicoman				and the second	4000 in different			
Octanol-water partition coefficient (where relevant)	Irrelevant					countries in the EU.			
second when partners second where relevantly	March 1 Production of the					NIO5H: 2400.			





Figure 2 Screenshots of the toxicological data for the Carrier material of NETCOMPOSITES

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PRODUCT CHARACTERISTICS - Severity factors (part	t 8: nanomaterial(s))	K. Con		3	Other relevant information (where available						
An an owner water to be a stand of the stand				1	Toxicological data on NOAA (qualitative info	rmation	EALA & OTHER AND	Unistantifican	27.17	1	
hane of nanomaterial	hanoclay						Scattine/Prov		-		_
	desated the foregoing	of talks	and the second second second second		Occupational Exposure Limit of NOAA, in up	ima.	recommendation:				
Structural formula/molecular structure	ammonium modified b	entonite	brokawia, falo	14	0		300				
Nanocomponent MSDS - data	Delite 67G		untereur data	4	I Is the NOAA cardinogenic ³		Unknown				
Nanocomponent information Sheet + date				4	2 Is the NOAA reprotoxic?		Unknown		-		
Method of production	Organomodifier is adde	d duing ion-		4	Is the NOAA demaily absorbed?		Unit nown	-		arrest of same	
	exchange reaction in wi	18.		- 4	is the NOAA toxic on the skin?		Unlingen		Vertil	dy ref.	
basic morphology	-			- 4	is the NDAA an asthmagen?		Unknown				
Chrystaine or amorphous materiair				- 4	7						
Description of surface chamintry (a.e. costing or modification)	As indicated above, the	modification is the	1	4	Toxicological data on NGAA parent (bulk) m	aterial	BATA & OTHER IST	Series a Thôre	NOT	1	
contract to second left much a second	ammonulm los.						Sepicite Sweden:				
Endown catalytic activity							0.5 fibres/cm3.				
known photocatalytic activity	-					AND DESCRIPTION OF	Finland: 2 mg/m2.				
Fiber Length of contained fibers of fiber-like particles			Note we are taking about platest film materials - where they associate the samplase from in a position handows religion in films. The ambout planetic, in the same sam many from a factor of	2	Occupational Exposure Limit of NOAA parent	runteral, in HB/W3	Other values not found. Kaolin: 2-10 mg/m3 in Europeon countines.				
			Teo Sino of Alexans.	1	Is the NOAA parent material carcinogenic ⁵		Unknoom		Weiella	alu nati	
Fiber Diameter of contained fibers or fiber-like particles	6			- 5	Is the NDAA parent material reprotoxic?		Unitrown				
			Pia departs on Dasjek Sught-Labon men	5	to the NOAA parent material mutagenic?		Unknown				
Fiber U/D (aspect ratio) of contained fibers or fiber-like particles			na be das in man, be das a bet so cielto		to the NOAA parent material dormally about to the NOAA parent material toxic on the skin	led?	Unknown		Med 14	efe +et	
200000000000000000000000000000000000000					is the NOAA parent material an arthmapen?		Unknown		1000	AV/200	
Dustness (mg/kg)	1			3							
Moleture content New W				5	7 Destailed NOAA toxicological data						
Physicochemical properties and NOAA characterization	OATA & OTHER MODE	MARTINE	WOTTH	-51	Pharmacokinetic model for absorption		Not available				
Aggiomeration/aggregation				3	Pharmacokinetic model for distribution		Not available		_		
solubility (mg/ms) + fuid medium3	6		and the second sec		21amacokinetic model for metabolism		Not available		_		
Solubility (mg/mL) + fluid medium2 (if available)	k ()			1.0	Acute touchu (inhelation)		Ind an analysis	-	-	and the state	
Solubility (mg/mL) + fluid medium3 (if available)					Arute toxicity (dermal)		Urknown.		Magine 1		
Describe crystalline phase		_		1	Acute toxicity (prail)		Definitely to				
Crystalite size	-				Repeated dose toxicity (inhalation)		Unknown				
Particle size distribution - dry and in relevant media (thickness)	-				E Repeated dose toxicity (dermail)		Unknown		Meetin	ida 'tea'	
Particle size distribution - dry and in relevant media (width)			1	18	 Repeated dose toxicity (oral) 		Unknown				
Specific surface area	1				Chronic toxicity		Unkopan				
Pour density	1		1	- 4	s Reproductive toxicity		Unknown		_		
Real density	1			1	Canadia Invidia		URANDOR			-	
Porosity	6			1.85	Experience with human exposure		and a second second	-			
Octanol-water partition coefficient (where relevant)	1			1	Other relevant test data (where available)			_			
Reduction-oxydation potential				2					-		
Aber relevant information (where available)			1	7	Flace here TEM/SEM picture(s) (if available	1					
And and an and a second s				- 2							_
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Figure 3 Screenshots of the toxicological data for the Nanomaterial of NETCOMPOSITES

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	Name of product international		Dicitled water		110	- Merica	
	Product Broduct		Devined water	1		-	
	Productingues - usite						
,	Description of construction activities involving	the product					
	Description of exposure scenarios involving the	r product					
i.	Description of product appearance		Transparent lie	bud		-	
	Product physical form		Other (specify)		viquite		
1	Concentration of nanomaterial(s) in product N	w/w			20		
	Ingurities or additive(s) in product like/w		No impurities				
ì	Naterial safety - flamability				23		
4	Naterial safety - explosivity						
£	Naterial safety incompatibility					1	
6					_		
ž	Toxicological data on carrier product						
	Occupational Exposure Limit of NOAA parant m	eterial, in pg/m3	Definitely non toxic				
				+			
9	Is the NOAA carrier product carcinogenic?		DefinitelyNo	_			
0	is the NOAA carrier product reprotocic?		Definitely No				
1	Is the NOAA carrier product mutagenic?		Definitally No				
2	Is the NOAA carrier product cermally absorbed	2	Unknown				
3	Is the NDAA carrier product toxic on the akin?		Defrisely No				
4	Is the NOAA carrier product an asshmagen?		DefnitelyNo				

Figure 4 Screenshots of the toxicological data for the Carrier material of TECNAN

<u>x</u> <u>-</u> • • • • =	SC	AFFOLD CB data (TECNAN+C	EA+X	[a] *7 • C* - *			SCAFFOLD CB data
File Home Insert Page Layout Form	ulas Data Review	View		File Home Insert Page Layout	Formulas	Data F	teview View
Ruler	🕅 Formula Bar		1		Ruter	Formula Ba	
Normal Page Page Break Custom Full Gridi Layout Preview Views Screen	ines 🗹 Headings Zool	n 100% Zoom to New Selection Window	AnN	ormal Page Page Break Custom Full Layout Preview Views Screen	Gridlines	E Headings	Zoom 100% Zoom Select
Workbook Views	Show	Zoom		Workbook Views	Sho	9WV	Zoom
8100 - (- fr				B100 - fe			
	8 C	D	1 kus	A		ę.	0
PRODUCT CHARACTERISTICS - Severity factors (part)	8: nanomaterial(s))		58 39	Toxicological data on NOAA (qualitative information)		Call Lands	NUTS
NANOMATERIAL (NOAA) IDENTIFICATION Name of nanomaterial	Plana a construir ar jundamola Thomas poside	AUTO	-	Desupational Depasture Limit of NOAA, in up in 3	PiDruScaPlane proposal 100.		
Structural formula/molecular structure	TICS		41	is the NOAA servicegenis?	Conflicting	In view	
3 Sanaromponent MSDS + date	MSDS TO2	10-11			increase.	In vivo, Limited	1
7 Nanocomponent information Sheet + date	Data sheet FiO2	alid4 -m		is the NOAA reproceeds*	Usenown	not enough	
Method of production	Flame Spray Pyrolysis - PSP		42		ex-carrie	evidence for classification	
g Basic morphology	Spherical			is the NOLA mutagenie?	Conflicting	In vivo and in vitre, Different	
10 Chrystalline or amorphous material ²	chrystalline		-45	and some and the second s	Contraction for	types of tests.	
	In dispersion some additives are inclu-	ded	40	a the NOAA taxic on the skin?	Non toxic	1	
Description of surface chemistry (e.g. coating or modification)	to avoid aggiomeration and to moves product stability	24	40	is the NOAA an authmagen?	Usknown		
11	School ()	-	47	Textrainstrai data an 10041 percent (build material	THE PROPERTY AND	17711111 B	AUTOR
In a compared the set of the set	100			and the second second second second second second			
Fiber Length of contained fibers or fiber-like particles			45	Occupational Separate Unit of NOAA parent material, in up ind	and respirable between 5000 and 4000 in #/Retent countries in the 50, WIDSH 2,800		
The parter of contained roles of the rise particles				is the NOAA parent material carcinogenic?	Conflicting	In vice	
Fiber L/D (aspect ratio) of contained fibers or fiber-like particles			52	is the NOAA parent material reprotoxic?	Definitely No		PERMIT NOT
10	10 million - 10 mi		32	is the NOAA parent material mutagenic?	Definitaly No	_	Indicating as hubbles
17 Dustiness (mg/kg)	law		34	is the VOAA parent material toxic on the skin?	Definitely No		Contraction of the second seco
Molsture content %w/w	42%		35	is the NOAA parent material an asthmagen?	Ustrown		Paralan Para at the
18			196				
10 Physicochemical properties and NOAA characterization	DATA & CITIEP INFORMAND DR	2010122	37	Destalled NOAA toxicological data	Not supplishing		- AL 173
11 Villoue.ator/sillelator		Carlan agreemation of Do nanopoular	29	Pharmacokinetic model for distribution	Not available		
22 solubility (mg/ms) + hub mediuma		643	60	Pharmacokinetic model for metabolism	Not acaliable		
In Society (mg/mc) + nue meterna (f available)			-61	Pharmacokinetic model for alimination	Not available		
The Country ing the three measures in an analysis	SON Anatasa 200 Surlia		6	Acute toxicity (intralation)	Linksburg	-	
	Give value or range of values [spect		6.0	Acute toxicity (arai)	Definitely No	Tel vive	- grad dag takes 1761 rg hg
Crystalite size	unita)	2000	65	Repeated dose toxicity (initiation)	Potentially Yes	Its vive	
 Particle size distribution – dry and in relevant media (length) 			66	Repeated doce toxicity (dental)	Definitely No.		arge as of the set of
28 Particle size distribution - dry and in relevant media (thickness)			87	Repeated door toxicity (oral)	L'HRROWR.		
20 Particle size distribution – dry and in relevant media (width)	when the second of the second			Direnie tevicity	Conflicting	le vive :	very high dates and, affects mail that particip
so Specific surface area	units)	**************************************	80	Reproductive toxicity	Uninguin		
11 Pour density	Give value or range of values (specifi units)	B SBE gimt (built dataffel	70	Developmental tasisity	Linenown	amount of data	
Real density	Give value or range of values (specification)	2.04 y/m		Genetic envicing	Conflicting	Je vive and in view. Elifferent	
an Poresity	and the second s	114.4 Argeben (per anaged ander /// 0.4	71	Departures with human expectants	micesson	Types of tests.	
a Octanol-water cartition coefficient (where relevant)	-		75	Other relevant test data (where available)			
Reduction-dividetion potential			74		1		
36 Radical formation potential	1		75	Place here TEM/SEM picture(s) (if available)	-		
			1.28		-		and the second se

Figure 5 Screenshots of the toxicological data for the Nanomaterial 1 of TECNAN

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			n dorariter terna	additions are included				-44	Is the NOLL der	maily absorbed	3			Definitely No		-	
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	1.01.000000000000		WINDOW STRATE					46	is the NOAA and	Stragen?				UNRhown		71.000	
Known catalytic activity		1						47								and conserves	
Known photocetalytic activity								48	Texicological dat	a on NOAA par	ent (bulk) m	aterial.					
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Pour benany				of street beautiful	-			- 64	Acute toxicity (or					Danislary No	(IN VING	Same signal state int	
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Bernelle					212.50	nte lantering de	nes/// p.485	65	Repeated deset	exicity (dermai)				Definitely NO		Paralasia, but ya ma	er is manifere elle
					and it for	id previous at		47	Repeated dose t	excity (erail)				Definitely No	10.000		
Octanoi-water partition coefficient (where relevant)				1000			58	Obviorie taxielty					Definitely NO	In vieo		
Reduction-oxydation potential								45	Reproductive to	icity				Definitely No	IN VIED		
nancai tomistion potential								70	Developmental	tsixicity.				Definitely No	10.990		
Other relevant information (where a	ivalabie)													Conficting	In this and in the		
								75	Concern revenue					Information	In the set of the	Contraction of the second	5
TOXICOLOGICAL DATE ON NOAA (quality	tive afformation)		COLOR COMPLEX	CONSERVICE.	ACCUPATE N			- 72	Experience with	human exposur							
Decudational Evolution Lines of Long	a in calmin		ICH/Scattold					28	Other relevants	est data (where	available)						
comparison and states and states	a se	1	Heposal son.					74						1			
IS the NISAA CIrchogenic?		0	perficitely no	IN VIED	1			75	Place here TEM	SEM picture(s)	(if evaluable)						
IS the NOAA reprotect?		10	seficitely no	In vien	1			.76						-		V- market	
		1	ordining.		1			.77	Contraction .	a della della	These.	1000	10000		47.9	and the second	and the second
Is the NOAA mutagenic?			nformation	In vivo and in vitro.	Bulmast	Craffic reactions		28	IN STREET, STR	1000	Con all	1000	Contraction of the		1/102	10 - 10 - 10 - 10 - 10 - 10 - 10 - 10 -	1000
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Figure 6 Screenshots of the toxicological data for the Nanomaterial 2 of TECNAN

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CARMER PRODUCT IDENTIFICATION	former and the second second	and shares	ALC: N		märmanam är	1000		
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Product physical form	rowdar		1					Nano(6)
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Inconstitues or additional allo product New Av	Enknown Interuntie							
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7 Toxisological data on carrier product					Souther reservices for			
	1000-10000 (m							
Occupational Exposure Limit or NDAA parent material, in µg/m3	different ED							
1	Idunties							
Is the NDAA camier product carcinogenic?	Definitely No							
Is the NDIA carrier product reprotouic?	Definitely Sn							
Is the NOAA can ler produce mutagenic?	Definitely No					(Lorent)	0	
Is the NDAA carrier product dermally absorbe#?	Definitely fo							
Is the NDIA ramer product toxic on the skin?	Definitely fin		-					
Is the NDAA carrier product an estimatern*	@ckpown							
7								
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3								
L								
1								
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Figure 7 Screenshots of the toxicological data for the Carrier material of ACCIONA

X	- · · · · · · ·		SCAFF	OLD CB	data (AC	CIONA+CE	A+FIOH)	X	1 - 1 - 1	4 - IV.		-			SCAL	FOLD C	data (AC	CIONA+CEA+RO
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			¢			D									1	c		P
4	PRODUCT CHARACTERISTICS - Severity factors (part	B: nanomaterial	(5))					37 4	Other relevan	t information	n (where i	rvaliable)			_			
4	NAMORAL TIRES (MOLLA) INCRETING A TION	A COLUMN TO A COLUMN TO A COLUMN		-	(1) (1) (1) (1) (1) (1) (1) (1) (1) (1)		_	20	featrological (lata on NOAA	L focustings	ten informat	tion	ALCO PUBLICATION		10000	-	
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2	Ten et un france de la company de	502		_				41	a the NOAA ra	reinsganis b								
1	Name component MSTR + data	No.	1	_				42	to the NOAA ve	period and a								
1	Name and a state of the state of the state	141						43	Is the NOAA m	stagenic?								
		the Property						44	to the NOAA de	mally aboo	12+27			-				
		ine two men	an interest of the local data	and in				45	Is the NOAA to	aic on the ski	un P							
		the production of	nano-silica a	rethe				46	to the NOAA at	atthinagen	9							
	Method of production	neutralization of a	odium silica	te.				47							_			
		solutions with acl	d and the file	me				42 7	fexicological	lata on NOAA	a parent ()	with) materi	al.					
5		hydrolysis						42 4	Occupational	Exposure Lin	nit of NOA	Aperentmi	Emilial, in sight 3					
9	Basic morphology	Spherical						10	Is the NOAA pr	rent materia	el carcina	ganic?						
10	Chrystalline or amorphous material?	Amorphous						51 1	a the NOAA pr	rent materia	alregrote	1968						
12	Description of surface chemistry (e.g. coating or modification)	untreated						\$2.1	ly the NOAA pi	rent materia	al mutage	mie?						
12	Known catalytic activity	Unitroien.						53	is the NOAA pr	rent materia	el dermal	ly absorbed	0					
13	Known photocatalytic activity	Unineett						54 1	to the NGAA p	rent materia	al toxic or	Chida with						
14	Fiber Length of contained fibers or fiber-like particles							55	is the NOAA pr	irent materia	al an asth	magan?						
15	Fiber Diameter of contained fibers or fiber-like particles	1.1						56										
16	Fiber L/D (aspect ratio) of contained fibers or fiber-like particles	1.0						57 1	Destailed NO	LA textcologi	cal data							
27	Dustiness (mg/kg)	Unknown						58	Pharmacokini	nic model for	r sheerpt	ion .						
18	Moisture content Nw/w	Uninder						55	Pharmecoain.	Nic model for	- distribut	sign						
19		1						60	Pharmacoking	rtic model for	metabo	itere.						
20	Physicochemical properties and NOAA characterization	CALCULATION OF THE	COMMITTEE		1111			41	Pharmacokin	nic model for	relimina	Depres.		-				
22	Aggiomeration/aggregation	TRE						62.4	ACULE DEVICITY	(inhalation)								
22	Solubility (mg/mL)+fluid medium1	solucia/disparate	Water					63 4	Acute toxicity	(dermal)							_	
23	Sclubility (mg/mL)+fluid medium2 (if evailable)				*				cute tonicity	and the second second	1000							
24	Solubility (mg/mL)+fluid medium3 (if available)				-			00	epeated dos	e society pro	naration)			-				
25	Describe crystalline phase	No applicable							apentes dos	a solution of the								
16	Crystallite size								Thermole Secolar	a successively per-								
27	Particle size distribution – dry and in relevant media (length)	Unikmowern							Croppent Epiciti	And a building of								
28	Particle size distribution - dry and in relevant media (thickness)	Uninown								al branchestern								
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30	Specific surface area	Sector 10						4 C										
31	Pour density							100	Cath and call the bar	these data ha		debiet.			_			
32	Real density							24							_			
33	Peresity							75 4	Place here TER	A/SEM pictur	radal (of an	(able)		3				
34	Octanol-water partition coefficient (where relevant)							76		1.517.61								
35	Reduction-oxydation potential							77										
16	Radical formation potential							78										
37	Other relevant information (where available)							79										
30				_	_			80										
35	Texicological data on NOAA (qualitative information)	CONTA & OTHER HAP	Contract of the local					10										
10	Occupational Exposure Limit of NOAA, in ug/m3	L.			DATE NOLIDE	ID IN THE TECHNI	TABLET	83										
*	A M CARRIER Nano(1) Nano(2) Nano(3)] Nano(4) 1	lano(5)	Nano(t	67 62			24. 4	F.H	ARRIER	Nano(1) Nand	(2) Nano(3) Nano(4) N	ano(5)	Nano	(5) 2.2	

Figure 8 Screenshots of the toxicological data for the Nanomaterial 1 ACCIONA

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	PRODUCT CHARACTERISTICS - Severity factors Inart	e R: nanomaterial/	c11		37	Other relevant information	(where subilable)					- V		
2	rhoboer enviolerents inco seventy nectors (part	Dimanomotoria	211		30						-			
3	NANOMATERIAL (NOAA) IDENTIFICATION	Onte a tribert her	in Although		29	Toxicological data on NOAA	(qualitative informa	tion)	DATA A OTHER MICH	entertime:	AUTO			an Brenner finn Rap
4	Name of nanomaterial	Titanium dioxide-si	epiolite sup	berrogo			Contraction of the second		1	1				
5	Structural formula/molecular structure	TI02-Mg4516015(0	HIZ SHIJO			Des series IF see at the	in established to under				2000			
8	Nanocomponent MSDS + date	Ves				Occupational Exposure Lim	it of normal, in µg/ms					a recursion of the	Contraction (
7	Nanocomponent Information Sheet + date	Yes			40									
					41	Is the NOAA carcinogenic?								
		Undisclosed plasm	a process, p	physical	42	Is the NOAA reprotoxic?								
		vapor synthesis, la	ser pyrolisis	5,	43	Is the NOAA mutagenic?								
	Method of production	mechanical milling	apl-gal pro	cess. The	44	is the NOAA dermaily absor	bed?							
		sepiolite fibers are	activated	n scid	45	Is the NOAA toxic on the ski	50							
		BOIGDON			46	is the NOAA an asthmagen?								
-				and a local division of	47									
	Basic morphology	minor fibers	United unite	shuburd	48	Toxicological data on NOAA	parent (bulk) materi	al						
9		and a second sec			-				Sweden: 0.5					1110.01
10	Chrystalline or amorphous material?	Chrystalline				Occupational Exposure Lim	it of NOAA parent m	sterial, in us/m3	fibres/cm3. Finland:					INCLUDED HERE NO
11	Description of surface chemistry (e.g. coating or modification)	supported on sepic	ite fibers					and the second sec	2 mg/m3. Other					DATA AVALABLE ON
17	Known catalytic activity	High			43		1		connecting		_			receivering
13	Known photocatalytic activity	High			51	is the NUW parent materia	il carcinogenic?							
14	Fiber Length of contained fibers or fiber-like particles	1000 mm			24	is the NUAA parent meteria	I reprotosic?		Unknown	-		1903		
15	Fiber Diameter of contained fibers or fiber-like particles	29 nm			52	is the NOAA parent materia	il mutagenic?		Unknown		Swidet Like	y not		
16	Fiber L/D (aspect ratio) of contained fibers or fiber-like particles	40 mm			53	is the NOAA parent materia	dermally absorbed	(Unknown		Mad the	y net		
17	Dustiness (mg/kg)	Unknown			24	is the NOAA parent materia	I toxic on the skin?		Unknown		NOT UNE	y net		
18	Molsture content New/w	Unknown			20	is the NOAA parent materia	I an asthmagen?		Unknown	-				
19					96	Description and the second sectors in the	at down							
20	Physicochemical properties and NDAA characterization	DATA & OTHER DATA	WALKTION		27	Descaned now concologie	al Ceta		Contrate contrations of	AND TRACE	NV/LL			and an
21	Aggiomeration/aggregation	Ant			00	Pharmacouneur model for	Autorpeten							
22	Solubility (mg/mL) + fluid medium1	Soluble/dispersible	Water			There are a set of the set of the	and the balling				_			
23	Solubility (mg/mL) + fluid medium2 (if available)	-				Pharmarchicatic model for	alialization							
24	Solubility (mg/mL) + fluid medium3 (if evailable)				67	An de traje de linke la traje	annuna 1900.			1				
25	Describe crystalline phase	tetragonal			63	Acude society (meresion)								
26	Crystallite size	Unicodwin				And a second by (see 1)								
27	Particle size distribution – dry and in relevant media (length)	Unknown			60	Recented dose socion lint	atariaal							
28	Particle size distribution – dry and in relevant media (thickness)	Unknown			02	Repeated dose toxicity (int	(mail)		-					
29	Particle size distribution - dry and in relevant media (width)	CLARKING MAN			67	Repeated dose toxicity (of	1							
20	Specific surface area	Unknown			0/	Changes and concity joint								
31	Pour density	Unknown			60	Reproductive toxicity								
22	val density Unknown				70	Developmental toxicity								
33	Porosity	rosity Unknow				General Inviting								
34	Octanol-water partition coefficient (where relevant)	Wrelevant			74	for a second sec								
35	Reduction-oxydation potential	CHARGE W			73	Other relevant test date	bace pupilable!							
36	Radical formation potential	WTENEV201			12	on an energy clear opta (a	inere erandbiej			1	-			
37	Other relevant information (where available)	12			75	Place here TEM/SEM pictur	e(s) (if available)		•					And the second second
22					76	and any other present	and a second second							
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Figure 9 Screenshots of the toxicological data for the Nanomaterial 2 ACCIONA



Figure 10 Screenshots of the toxicological data for the Nanomaterial 3 ACCIONA

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Figure 11 Screenshots of the toxicological data for the Nanomaterial 4 ACCIONA

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33 Porosity	Unknown		7	7										
34 Octanol-water partition coefficient (where relevant)	Irrelevant		7	18										
35 Reduction-oxydation potential	4 g/emil		2	9										
16 Radical formation potential	Irrelevant		1	0										
37 Other relevant information (where available)				3										
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Toxicological data on NOAA (qualitative information) CARRIER Nano(1) Nano(2) Nano(3) Nano(4)	lano(5) Nano	(6)		CARRIER	Nano(1)	Nan	(2) Nano(3) Nano(4)	Nano(5)	Nano	(6)		

Figure 12 Screenshots of the toxicological data for the Nanomaterial 5 ACCIONA

4 RESPIRATORY EXPOSURE

Respiratory exposure is the most common case of exposure in the construction industry. This can occur through activities generating dust or forming aerosol. Inhalation of hazardous substances can also be followed by ingestion (Scaffold's Guide on Risk Protection, SPD13).

Respiratory exposure to manufactured nanomaterials (MNMs) in the construction industry is assessed according to Van Duuren-Stuurman et al. (2012), Marquart Hans et al. (2008), Tielemans et al. (2008) and the ISO/TS 12901-2 (2014) Standard. Following the Stoffenmanager Nano approach (Van Duuren-Struuman et al., 2012) possible worker exposure situations in the life cycle of nano products are distinguished in four general source domains (Schneider et al., 2011). These are further subdivided into six source domains- to better accommodate the MNOs and corresponding materials used in the Construction Industry- as follows:

- SD1. Point or fugitive emission during the production phase prior to harvesting the bulk material (e.g. leaks through connections, seals, etc. during MNO synthesis/incidental release; examples of production processes are flame pyrolysis and chemical vapour condensation);
- SD2. Handling and transfer of bulk powdered MNOs (e.g. bagging or dumping of powder);
- SD3. Dispersion of solid intermediates or ready-to-use MNO-containing products
- SD4. Spraying of ready-to-use nano-products
- SD5. Handling of liquid intermediates containing MNO's
- SD6. Activities resulting in fracturing and abrasion of MNO-containing end products (e.g. sanding of surfaces).

Source domain SD6 refers to processes that should be treated using a conventional non-nano Control-Banding tool Van Duuren-Stuurman et al. (2012). This is outside the scope of this work.

The activities in the construction industry considered in SCAFFOLD are classified in the six general source domains as shown in Table 1. Accidental scenarios (see grey cells) are not suited for Control Banding assessment.

	Substance		SCAFFOLD SCENARIOS	Source Domain
		ES1	Manufacturing NMs	SD1
		ES1	Formulations containing MNMs	SD2
Depollutant		ES2	Monolayer rendering application Mortar application (construction site)	SD2
mortar	1102	ES3	On site assembly/Machining Machining of the mortar at pilot scale	SD2
		ES4	Deconstruction: Demolitions, retrofitting ES4 Demolition of the mortar at pilot/lab scale	SD6
		ES5	Accidental fire: MNMs combustion Accidental fire simulation at lab scale	n.a.
Self-		ES6	Manufacturing NMs	SD1
compacting concrete	SiO2	ES7	Concrete mixing for piles, slabs and special structures CASE STUDY Concrete manufacturing/application process	SD2

Table 1 Activities using MNOs in construction

		ES8	On site assembly/Machining; Machining of the concrete at pilot scale	SD2
		ES9	Maintaining, demolition or failure of the structure ES9 Demolition of the concrete at pilot/lab scale	SD6
		ES10	Accidental fire: MNMs combustion Accidental fire simulation at lab scale	n.a.
		ES11	Manufacture in-site (of the coating) ES11 Manufacturing process (coating with CNF)-lab	SD1
Coating	CNE	ES12	Machining for superficial fitting of other elements Machining the coating pilot scale	SD2
couning	CIVI	ES13	Maintenance or demolition of the coating ES13 Demolition of the coating at lab scale	SD6
		ES14	Accidental fire: MNMs combustion Accidental fire simulation at lab scale	n.a.
		ES15	Preparation, dosification, application of coatings CASE STUDY Coating application (spraying sol-gel)	SD4
Self- cleaning TiO2 coating	TiO2	ES16	Superficial machining; Machining of the coating at pilot scale	SD2
		ES17	Demolition, end of life ES17 Demolition of the coating at lab scale	SD6
		ES18	Accidental fire: MNMs combustion Accidental fire simulation at lab scale	n.a.
		ES19	Offsite manufacturing CASE STUDY Manufacturing process	SD1
Fire	Nanoclay	ES20	Fitting of the panels and machining for the superficial installations of other elements Machining of the FR panels at pilot scale	SD2
panels		ES21	Demolition, end of life ES21 CASE STUDY Demolition of the FR panels at lab scale	SD6
		ES22	Accidental fire: MNMs combustion Accidental fire simulation at lab scale	n.a.
		ES23	Offsite Manufacturing ES23 Insulation manufacturing	SD1
Insulation	Cellulose	ES24	Fitting of the panels and machining for the superficial installations of other elements ES24 Machining of the insulation panels at pilot scale	SD2
	2011000	ES25	Demolition, end of life ES25 Demolition of the insulation panels at lab scale	SD6
		ES26	Accidental fire: MNMs combustion	n.a.

The exposure algorithm used in Stoffenmanager follows a source-receptor approach and incorporates modifying factors related to source emission and dispersion of contaminants. The model is a modification of a model developed by Cherrie and Schneider (1999) and Cherrie et al (1996) as modified by Schneider (2011). Stoffenmanger has introduced some modifications to this model to make it more suitable for use by SME employers.

Exposure is represented as a multiplicative function of type of handling, intrinsic properties of the product, local controls and general ventilation. A general exposure score is calculated according to the following equation

$$B = \left[(E \cdot H \cdot _{lc_nf} \cdot _{gv nf}) + (E \cdot H \times _{lc_ff} \cdot _{gv_ff}) + (E \cdot a) \right] \cdot \boldsymbol{\eta}_{ws} \cdot _{imn} \cdot t_h \cdot f_h$$
(1)

where

B : respiratory exposure score;

E: intrinsic emission score for respiratory exposure;

H : handling (or task) score for respiratory exposure;

lc : multiplier for the effect of local control measures;

- gv_nf : multiplier for the effect of general ventilation in relation to the room size on the exposure due to near-field sources;
- gv_ff : multiplier for the effect of general ventilation in relation to the room size on the exposure due to far-field sources;

 η_{ws} : multiplier for worker separation;

a : multiplier for the relative influence of background sources;

imm : multiplier for the reduction of exposure due to control measures at the worker;

t_h : duration of the handling;

f_h: frequency of the handling;

Further simplification made in this tool is to assume that *far-field sources* and background emissions are relative small compared to the near field sources. As mentioned in the Stoffenmanager model (Marquart Hans et al (2008)) this means that for the far-field source the emission due to a period of evaporating, hardening or dying does not include products with vapour pressure >10Pa. Similarly it has been chosen to ignore the background source assuming that the activities of interest (construction activities involving use of nanomaterials) are characterized by high direct emission. As a result, the exposure index B used in the Scaffold model is given by

$$B = E \cdot H \cdot \eta_{lc_nf} \cdot \eta_{gv\,nfj} \cdot \eta_{imn} \cdot \eta_{ws} \cdot t_h \cdot f_h \tag{2}$$

where:

B : respiratory exposure score;

E: intrinsic emission score for respiratory exposure;

H : handling (or task) score for respiratory exposure;

lc : multiplier for the effect of local control measures;

 $_{gv_nf}$: multiplier for the effect of general ventilation in relation to the room size on the exposure due to near-field sources and

imm : multiplier for the reduction of exposure due to control measures at the worker;

 η_{ws} : multiplier for worker separation;

 t_h : duration of the handling;

 f_h : frequency of the handling

Parameters E, H, t_h , f_h characterize the basic scenario and are not subject to modification through control measures. Of course it might be possible to decrease the frequency and the duration of a particular task. This kind of measures is not considered as such that can by adopted by employees of SME construction firms. More general management and expert involvement is required. The SCAFFOLD tool can however be used for evaluation of such measures.

Parameters $\eta_{lc} \eta_{gv} \eta_{imm}$ on the other hand, depend on the adopted control measures and are used to quantify the effect of these measures.

4.1 Intrinsic emission for Respiratory Exposure

The intrinsic emission is a substance related parameter. Different formulae are followed according to the source domain.

Note that, for the source domain SD1, it is assumed that emission potential does not vary between different types of MNO for the same process. Therefore, the substance emission potential is included in the score for handling and not further included in the algorithm. This is in agreement Van Duuren-Stuurman et al. (2012).

4.1.1 Intrinsic emission for liquids

MNOs dispersed in a liquid are processed in the source domains SD4 and SD5. The substance emission potential (score) E is then given by the following the product:

$$E = E_1 \cdot E_2 \cdot E_3 \tag{3}$$

where:

 E_I : score depending on the weight fraction of the MNOs (Table 2);

 E_2 : score depending on the percentage dilution of the substance in water (Table 3), and

 E_3 : score depending on the viscosity of the liquid (Table 4)

Table 2 . Respiratory scores for	or weight fraction E ₁	(table adapted from	Marquart et al., 2008)
----------------------------------	-----------------------------------	---------------------	------------------------

Category	Score
Undiluted	1
50–99%	0.75
10–50%	0.3
1–10%	0.05
0.01–1%	0.005
< 0.01%	0.00005
Unknown	1

Table 2	Desminatory	· · · · · · · · · · · · · · · · · · ·	dilustic on a	of MANO	in wotor	r (table	a da nata d	function I	Mount.		2000
ladie 5	Respiratory	scores for	anution		in water	Entlable	adabled	TOTT	viarduart	et al.	. 20001.
						-2 (, ,

Category	Score
Undiluted	1
55–99%	0.75
10–50%	0.3
1–10%	0.05
0.01–1%	0.005
< 0.01%	0.00005
Unknown	1

Table 4 Respiratory scores for viscosity of liquids E₃ (table adapted from Marquart et al., 2008)

Category	Score
Liquids with low viscosity (like water)	1
Liquids with medium viscosity (like oil)	0.3
Liquids with high viscosity (like resin, syrup, paste)	0
Unknown	1

4.1.2 Intrinsic emission for solids

Solid MNOs are processed in the following source domains SD2 and SD3. The substance emission potential of solid MNOs E is given by the product of the scores for weight fraction, dustiness, and moisture content, according to the formula:

$$E = E_1 \cdot E_2 \cdot E_3 \tag{4}$$

where:

 E_1 : score depending on the weight fraction (Table 2);

- E_2 : score depending on the dustiness (Table 5 and Table 6 for nano-powders and granules/flakes, respectively); and
- E_3 : score depending on the moisture content (Table 7).

Van Duuren-struuman et al. (2012) suggest that until more is known about the dustiness of nanopowders, the highest dustiness class ought to be used for dusts, i.e to use $E_2=1$ if solid is dust.

Intrinsic emission parameter	Explanation - Indicative dustiness test results (respirable fraction)	Score					
Very High	>500mg kg ⁻¹	1					
High	150-500 mg kg ⁻¹	0.3					
Medium	$50 - 150 \text{mgkg}^{-1}$	0.1					
Unknown		1					

Table 5 Respiratory scores for intrinsic emission of powders E₂ (table adapted from Marquart et al., 2008).

Table 6 Scores for intrinsic emission of granules /flakes E_2 (table adapted from Marquart et al., 2008).

Category	Examples	Score
Granules or flakes that may	washing powder, sugar or fertilizer	0.03
fall apart and crumble		
Firm granules or flakes	firm polymer granules, granules covered with a layer of wax, bound fibers, such as in cotton. No dust emission without intentional breakage of the product	0.01
Unknown		0.03

Table 7 Respiratory scores for moisture content of solids E_3 (table adapted from Marquart et al., 2008; Van-Wendelde-Joode et al., 2003)

Category	Description	Score
Dry product (<5% moisture	Dry powder or granules/flakes	1
content)		
5-10% moisture content	Powder or granules/flakes of which the particles stick to each other while the dry	0.1
	form is not sticky less dusty than the dry product	
Sticky, waxy or moist	Powder or granules/flakes that is/are clearly wet; sticky or waxy products	0.01
product (>10% moisture		
content)		
Unknown		1

4.2 Handling – Activity emission potential for Respiratory Exposure

The Handling – Activity emission potential *H* is a score related to the process. Different multiplier data are considered according to the source domain.

The source domain SD1 involves (new) production processes that are not described in the handling categories included in the generic Stoffenmanager. It is difficult to define Handling scores for these

processes as the tasks performed mostly concern controlling the (closed) process. During a production process, particles might, for example, be released unintentionally through leaks. Despite the lack of exposure data, conservative relative multipliers are defined for this source domain that is in line with the precautionary principle. Doing this gives the user the opportunity to perform a risk assessment for these processes (Table 8).

The scores proposed by Stoffenmanager for handling of liquids and solids are reported in Table 9 and Table 10, respectively. Note that, the production processes of Table 8 and the process categories of Table 9 and Table 10 are limited to those of interest to the construction industry.

Production process	Description	Score
Mechanical reduction	Machining (turning, milling) of larger products to create smaller products	2
(machining)		5
Chemical vapor condensation	Synthesis of inorganic materials to create nanomaterials by passing inert gases, hydrogen,	
	and hydrocarbon-containing gases in a tube furnace over catalyst particles deposited on	1
	substrates	
Wet chemistry	Functionalization of nanomaterials by mixing with a solution that contains desired	0.3
(functionalization)	functional groups and removal of excess chemical by washing with solvents	0.5
Wet chemistry (synthesis—	Synthesis of nanoparticles by adding parent solution into solvent solution within a	
into solution)	container, stirring the mixture for extended period at temperatures from room level to	0.3
	higher	

Table 8 Respiratory scores for handling for SD1 (table adapted from Marquart et al., 2008).

Table 9 Respiratory scores for handling of liquids (table adapted from Marquart et al., 2008).

Category	Examples	Score
Handling of liquids at high pressure resulting in substantial	Spraying of product (using high-pressure or spray painting)	30
generation of mist or spray/haze	fogging a product producing a visible mist spraying of	
	Nanofilm spray	
Handling of liquids (using low pressure, but high speed)	Mixing of products under high velocity using a mixer,	3
resulting in generation of a mist or spray/haze	uncontrolled pouring of a liquid from a large altitude	
Handling liquids using low pressure and low speed in large	Mixing/diluting liquids by stirring, manually drawing off or	0.1
or medium quantities	pouring product, painting of casings using a roller or a brush	

Table 10 Respiratory scores for handling of solids (table adapted from Marquart et al., 2008).

Category	Examples	Score
Handling of products where due to high pressure, speed, or	Spraying of powders (powder coating),dumping of product	100
force large quantities of dust are generated and dispersed	from big bags, cleaning of contaminated machines or objects	
	with compressed air	
Handling of products with a relatively high speed/force,	Bagging of large quantities of product, mechanical mixing	30
which leads to dispersion of dust	or sieving of large quantities of product	
Handling of products with medium speed or force, which	Manual dumping of bags, mechanical mixing or sieving of	10
leads to some dispersion of dust	medium quantities of product	
Handling of products with low speed or little force, which	Sweeping of product, manual mixing or sieving of product,	3
leads to some dispersion of dust	uncontrolled handling of objects that are heavily	
	contaminated with product	
Handling of products with low speed or little force or in	Handling of contaminated objects, scooping of (kilograms)	1
medium quantities (several kilograms)	product, weighting of product (kilograms)	
Handling of products in closed containers	Transport/shifting of barrels, bottles, or plastic bags	0

4.3 Duration and frequency of Respiratory Exposure

Tables 9 and 10 report the scores for the duration and frequency of exposure, respectively. Note that, these scores are derived from the fraction of work time that an individual worker performs

the task and is therefore exposed to the hazardous substance. The software also includes the option of inputting the time fraction, as in some cases, the duration and the frequency of the work might be difficult to interpret (SCAFFOLD report SPD10 on StoffenManager Nano-tool).

Parameter	Score
1–30 min a day	0.06
0.5–2 h a day	0.25
2–4 h a day	0.50
4–8 h a day	1.00

Table 11 Scores for duration of exposure t_h (table adapted from Marquart et al., 2008).

Table	12 Scores	for frequency	v of e	xposure f	(table adapted	from Mar	quart et a	I., 2008)
Table	12 300103	ior nequene		Aposure Ih	(table adapted	II OIII IVIAI	quarteta	1., 2000)

Parameter	Score
1 day a year	0.01
1 day a month	0.05
1 day per 2 weeks	0.10
1 day a week	0.20
2–3 days a week	0.60
4–5 days a week	1.00

4.4 Modifying the Respiratory Exposure Score through protective measures

As discussed before the remaining coefficients $_{lc}$, $_{gv}$, $_{ws}$, $_{imn}$ in Equation 2 refer to existing or proposed protection measures. In particular, η_{gv} refers to general ventilation dependent on room size; η_{lc} refers to local controls; η_{ws} refers to worker separation; and η_{imn} refers to scores for protection by PPE. Table 13 gives the suggested scores for general ventilation controls, Table 14 gives the suggested measures for localized controls. Table 15 gives the scores for worker separation measures, while Table 16 provides the suggested scores for the various PPEs.

Boom sizo	No general ventilation	Mechanical and/or natural	Spraying booth
KOOIII SIZE	(0.3–1 ACH)	ventilation (3 ACH)	(>10 ACH)
Volume <100 m3	10.00	3.00	0.10
Volume 100–1000 m 3	3.00	1.00	0.30
Volume >1000 m3	1.00	1.00	1.00
Work performed outside	n.a.	1.00	n.a.

Table 13 Scores for general ventilation (table adapted from Marquart et al., 2008).

Table 14 Scores for localized controls (table adapted from Marquart et al., 2008).

Local control measure	Description	Score
No control measures at the source		1.000
Use of a product that limits the emission	Wetting a powder, spraying of water	0.300
Local exhaust ventilation	Removal of air at the source of the emission; the dangerous substances are	0.300
	captured by an air stream leading them into a hood and dust system	
Containment of the source	The source is fully contained however, no local exhaust ventilation is used	0.300
	within the containment;	
Containment of the source with local exhaust	Containment of the source in combination with local exhaust ventilation, e.g. a	0.030
ventilation	fume cupboard	
Glove boxes/bags	Any form of permanent encapsulation or encasing of the source (which are not	0.001
	opened during the given activity) with a well-designed local exhaust	
	ventilation system	

Table 15 Scores for separation (or personal enclosure) of the worker (table adapted from Marquart et al., 2008).

Separation measure	Scores
The worker does not work in a cabin	1.000
The worker works in a cabin without specific ventilation system	0.100
The worker works in a separated (control) room with independent clean air supply	0.030

Table 16 Scores for Respiratory Personal Protection Equipment (PPE)

Local Control measure	Score
None	1
FFP2 filtering half masks	0.40
FFP3 filtering half masks	0.20
P2 replaceable filter Half Mask	0.40
P3 replaceable filter Half Mask	0.20
A1P2 combined half mask	0.20
A1P3 combined half mask	0.10
Full-Face masks with P3 filters	0.10
A powered filtered device incorporating a TH1 hood	0.20
A powered filtered device incorporating a TH2 hood	0.10
A powered filtered device incorporating a TH3 hood	0.05

4.5 Respiratory Exposure Bands

Assessment of the exposure determining parameters (see sections 4.1 to 4.3) along with the control measures modifying factors (see section 4.4) determine an overall exposure score *B* according to Equation 2. The range of possible Exposure scores is divided into ten bands as shown in Table 17. The reason for considering ten exposure bands is to be able to quantitatively distinguish between the improvements (reduction of exposure) of the various protective measures. This point is further discussed in Chapter 6.

Respiratory	Respiratory Exposure Score			
Exposure Band	Lower	Upper		
1	0	0.000005		
2	0.000005	0.00005		
3	0.00005	0.0005		
4	0.0005	0.005		
5	0.005	0.001		
6	0.001	0.05		
7	0.05	0.1		
8	0.1	5		
9	5	100		
10	100	∞		

Table 17 Respiratory Exposure Bands

5 DERMAL EXPOSURE

Penetration of the skin during construction activities is still under investigation. If the skin is intact, it provides a good barrier. Nanoparticles can, however, penetrate through damaged or diseased skin and end up in the systemic circulation (Scaffold's Risk Protection Guide, SPD13).

Dermal exposure to manufactured nanomaterials (MNMs) in the construction industry is assessed according to the DREAM method (Van-Wendel-de-Joode et al., 2003, 2005). The DREAM method provides structured, semi-quantitative assessment of dermal exposure for chemical and biological agents. SCAFFOLD's report SPD6 presented the method in detail and tested the applicability of the method to the scenarios considered in the SCAFFOLD project.

The DREAM method stars by assessing the potential dermal exposure, that is the exposure of naked skin without any protective clothing. The potential exposure score for annual exposure is quantified as the following formula:

$$B_0 = (R_E + R_T + R_T) \cdot t_h \cdot f_h \tag{5}$$

where:

 R_E : score depending on exposure through the emission route;

 R_D : score depending on exposure through the deposition route;

 R_{τ} : score depending on exposure through the transfer route;

 t_h : score depending on duration of the handling; and

 f_h : score depending on frequency of the handling.

The method assigns a weight factor for each route, making the exposure through emission 3 times more important that through deposition and transfer. In the present work, and considering the SCAFFOLD scenarios, it is assumed that exposure via transfer is negligible. In addition, for reasons of simplicity, the exposure through deposition is modeled as a fraction, r_D , of the emission exposure. Therefore, Equation 5 becomes:

$$B_0 = R_E \cdot (1 + r_D) \tag{6}$$

Table 18 gives the scores for fraction r_D .

Table 18 Dermal exposure scores for the importance of deposition over emission

Case	Score
High importance	1/3
Medium importance	0.1
No deposition occurs	0

According to DREAM, the exposure through emission is then formulated as follows:

$$R_E = 3 \cdot E \cdot \sum_{i=1}^9 s_i \cdot P_i \cdot I_i \tag{7}$$

where:

E : score for intrinsic emission potential;

- P_i : score for probability of emission on body part *i*;
- I_i: score for intensity of emission on body part *i*; and
- *s_i*: surface factor of body part *i*.

Note that, the DREAM method considers 9 different body parts, namely the head, the upper arms, the forearms, the hands, the front torso, the back torso, the lower body, the lower legs and the feet.

As explained in section 5.2, the intensity of emission is herein considered processes specific, and treated similarly to the handling activity emission potential defined in section 4.2 for Respiratory Exposures . Therefore, a single score is assigned to the intensity *I*, and Equation 7 becomes:

$$B_0 = 3 \cdot E \cdot I \cdot P \cdot (1 + r_D) \tag{8}$$

where $P = \sum_{i=1}^{9} s_i \cdot P_i$ and it is the overall probability of emission *P* on the entire body.

5.1 Intrinsic emission for Dermal Exposure

The intrinsic emission potential is calculated as a product based on the physical characteristics of the material involved in the process. Different formulae are followed according to the phase of the substance, in agreement with the DREAM method (Van-Wendel-de-Joode et al., 2003, 2005). For SD1, it is assumed that the emission potential does not vary between different types of MNO for the same process (Van Duuren-Stuurman et al, 2012). Therefore, the substance emission potential is included in the multiplier for exposure intensity, as in section 4.1.

5.1.1 Intrinsic emission for liquids

For MNOs dispersed in a liquid (see SD4 and SD5), the substance emission potential (score) for dermal exposure is given by the following the product:

$$E = E_1 \cdot E_2 \cdot E_3 \cdot E_4$$

where:

 E_1 : score depending on the weight fraction of the MNOs (Table 19);

 E_2 : score depending on the percentage dilution of the substance in water (Table 20), and

 E_3 : score depending on the boiling point temperature of the substance (Table 21); and

 E_4 : score depending on the viscosity of the liquid (Table 22).

Table 19 Dermal scores for weight fraction E_1 (table adapted from Van-Wendel-de-Joode et al., 2003).

Category	Score
Undiluted	1
<1%	0.1
1–90%	0.3
90–99%	1
Unknown	1

Table 20 Dermal scores for dilution of MNO in water E_2 (table adapted from Van-Wendel-de-Joode et al., 2003).

Category	Score
Undiluted	1
<1%	0.1
1–90%	0.3
90–99%	1
Unknown	1

Table 21 Dermal scores for boiling point temperature E₃ (table adapted from Van-Wendel-de-Joode et al., 2003).

Category	Score
Tb < 50°C	3
50 < Tb < 150°C	1
Tb > 150°C	0.3
Unknown	3

Table 22 Dermal scores for viscosity of liquids *E*₄ (table adapted from Van-Wendel-de-Joode et al., 2003).

Category	Score
Liquids with low viscosity (like water)	1
Liquids with medium viscosity (like oil)	1.75
Liquids with high viscosity (like resin, syrup, paste)	3
Unknown	3

5.1.2 Intrinsic emission for solids

The substance emission potential for dermal exposure to solid MNOs (see SD2 and SD3), is given by the product of the scores for weight fraction, dustiness, and moisture content, according to the formula:

$$E = E_1 \cdot E_2 \cdot E_3 \tag{10}$$

where:

 E_1 : score depending on the weight fraction of the MNOs (Table 19);

 E_2 : score depending on the dustiness of the solid MNOs (Table 23); and E_3 : score depending on the sticky-waxy-moist of the solid MNOs (Table 24).

Table 23 Dermal scores for dustiness of solids E_2 (table based on Van-Wendel-de-Joode et al., 2003)

Category	Score
Granules or flakes	1
Powder with medium dustiness (50–150 mg/kg)	1
Powder with high dustiness (150–500 mg/kg)	3
Powder with very high dustiness (>500 mg/kg)	3
Powder with unknown dustiness	3

Table 24 Dermal scores for stickiness of solids *E*₃ (table based on Van-Wendel-de-Joode et al., 2003)

Category	Score
Dry product (<5% moisture content)	1
5–10% moisture content	1
Sticky, waxy or moist product (>10% moisture content)	1.75
Unknown	1.75

5.2 Intensity of emission for Dermal Exposure

Similarly to the respiratory exposure (see Chapter 4), the intensity of emission for dermal exposure is considered processes-specific. So, a score is defined for each one of the process cases considered here. The multiplier values range between 0 and 10, in accordance to the DREAM multipliers which ranged between 1 (Small amount (<10 % of body part)) to 10 (Large amount (\geq 50% of body part)). Table 25, Table 26 and Table 27 give the multipliers proposed here for the intensity of dermal exposure (handling multipliers). The multipliers of Table 25 include the intrinsic emission potential for dermal exposure.

Table 25 Dermal scores for handling for SD1 (based on Marquart et al. (2008); Van Duuren-Stuurman et al. (2012)	Table 25	Dermal scores	for handling for SD1	L (based on Marquart	et al. (2008); Van	Duuren-Stuurman et a	l. (2012)).
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Production process	Description	Score
Mechanical reduction	Machining (turning, milling) of larger products to create smaller products	3.00
(machining)		
Chemical vapor condensation	Synthesis of inorganic materials to create nanomaterials by passing inert gases, hydrogen,	1.00
	and hydrocarbon-containing gases in a tube furnace over catalyst particles deposited on	
	substrates	
Wet chemistry	Functionalization of nanomaterials by mixing with a solution that contains desired	0.30
(functionalization)	functional groups and removal of excess chemical by washing with solvents	
Wet chemistry (synthesis—	Synthesis of nanoparticles by adding parent solution into solvent solution within a	0.30
into solution)	container, stirring the mixture for extended period at temperatures from room level to	
	higher	

Table 26 Dermal scores for handling of liquids (based on Marquart et al. (2008); Van Duuren-Stuurman et al. (2012)).

Category	Examples	Score
Handling of liquids at high pressure resulting in substantial	Spraying of product (using high-pressure or spray painting)	10
generation of mist or spray/haze	fogging a product producing a visible mist spraying of	
	Nanofilm spray	
Handling of liquids (using low pressure, but high speed)	Mixing of products under high velocity using a mixer,	1.00
resulting in generation of a mist or spray/haze	uncontrolled pouring of a liquid from a large altitude	
Handling liquids using low pressure and low speed in large	Mixing/diluting liquids by stirring, manually drawing off or	0.033
or medium quantities	pouring product, painting of casings using a roller or a brush	

Category	Examples	Score
Handling of products where due to high pressure, speed, or	Spraying of powders (powder coating),dumping of product	10.00
force large quantities of dust are generated and dispersed	from big bags, cleaning of contaminated machines or objects	
	with compressed air	
Handling of products with a relatively high speed/force,	Bagging of large quantities of product, mechanical mixing	3.00
which leads to dispersion of dust	or sieving of large quantities of product	
Handling of products with medium speed or force, which	Manual dumping of bags, mechanical mixing or sieving of	1.00
leads to some dispersion of dust	medium quantities of product	
Handling of products with low speed or little force, which	Sweeping of product, manual mixing or sieving of product,	0.30
leads to some dispersion of dust	uncontrolled handling of objects that are heavily	
	contaminated with product	
Handling of products with low speed or little force or in	Handling of contaminated objects, scooping of (kilograms)	0.10
medium quantities (several kilograms)	product, weighting of product (kilograms)	
Handling of products in closed containers	Transport/shifting of barrels, bottles, or plastic bags	0.00

Table 27 Dermal scores for handling of solids (based on Marquart et al. (2008); Van Duuren-Stuurman et al. (2012)).

5.3 Probability of emission for Dermal Exposure

To simplify the tool developed here for the construction industry, the following five cases are considered for dermal exposure due to emission:

- 1. Only hands
- 2. Mainly hands (also above waist and head)
- 3. Hands, above waist and head
- 4. Bellow waist
- 5. All the body

The probability of emission *P* on the entire body, for each one of these cases is then calculated using the body part surface factors proposed by (Van-Wendel-de-Joode et al., 2003). The resulting probability scores P_j are reported on Table 14, where $j \in \{1,2,3,4,5\}$ denotes one of the five cases. The multipliers for the exposed body parts range between 10 and 3, while the respective multipliers proposed in DREAM are: 10 (almost constantly (or \geq 50% of task duration)) and 3 (repeatedly (or 10–50% of task duration)). In the case of occasional exposure (or <10% of task duration), we herein take this exposure as negligible.

Body part	Surface factor	1 Only hands	2 Mainly hands (also above waist and head)	3 Hands, above waist and head	4 Bellow waist	5 All the body
head	0.69		3.0	10.0		3.0
upper arms	0.67		3.0	10.0		3.0
forearms	0.53		7.0	10.0		3.0
hands	0.47	10.0	10.0	10.0		3.0
front torso	1.22		7.0	10.0		3.0
back torso	1.22					3.0
lower body	2.43				3.0	3.0
lower legs	1.15				10.0	3.0
feet	0.63				10.0	3.0
P_j	9.01	4.7	21.03	35.8	25.09	27.03

Table 28 Dermal scores for the five cases of exposed body parts (surface factors from Van-Wendel-de-Joode et al., (2003))

5.4 Duration and frequency of Dermal Exposure

The dermal exposure scores used for duration and frequency of exposure are the same as for respiratory exposure (see section 4.3).

5.5 Modifying the Dermal Exposure Score through protective measures

The actual exposure can be significantly lower compared to the potential exposure due to the use of personal protection equipment such as gloves, hyvecs, boots etc. The DREAM method calculates the actual exposure score as the sum of the products of protective measures multipliers and the potential exposure scores:

$$B = \sum_{i=1}^{9} s_i \cdot B_{0,i} \cdot n_i \tag{11}$$

where

 $B_{0,i}$: potential exposure score for body part *i* n_i : clothing factor for body part *i*

The nine body parts defined by Van-Wendel-de-Joode et al. (2003) are herein grouped into five sets. Table 29 shows that, according to the case of exposed body parts, one or more of these sets does not require protective clothing.

	i	ii	iii	iv	v
	hands	torso/arms	lower body	feet/lower legs	head
1. Only hands	see Table 30				
2. Mainly hands (also above waist and head)	see Table 30	see Table 31			see Table 31
3. Hands, above waist and head	see Table 30	see Table 31			see Table 31
4. Bellow waist			see Table 31	see Table 31	
5. All the body	see Table 30	see Table 31	see Table 31	see Table 31	see Table 31

 Table 29 Proposed personal protection equipment for skin (based on the selected body parts)

The clothing factor depends on the material of the glove/cloth and the frequency of replacing it. For gloves, DREAM proposes additional considerations, i.e. whether they are connected well to clothing or arms, if a second pair of gloves used and how frequently these are replaced, or if a barrier cream is used. The clothing factor formula used here is the following:

$$n_i = t_i \cdot f_i \cdot g_i \tag{12}$$

where:

- t_i : score for the type of protective cloth (see Table 30 and Table 31 for gloves and other clothes, respectively)
- f_i : score for the frequency of protective cloth replacement (see Table 32)
- g_i : score for the use of inner pair of gloves, equal to 0.3 if inner gloves are applied and equal to 1 in all other cases. Note that, looking at the DREAM multiplies for this entry, it is only worth to consider inner gloves replaced daily.

Table 30 and Table 31 report the simplified options and the multipliers used in the SCAFFOLD CB tool, taking into account the work of Van-Wendel-de-Joode et al. (2003).

o n .	
Type of gloves	multiplier
No gloves	1
Woven clothing	0.3
Non-woven permeable, not connected well to clothing or arms	0.3
Non-woven permeable connected well to clothing or arms	0.1
Non-woven impermeable connected well to clothing or arms	0.03
Non-woven impermeable, not connected well to clothing or arms	0.09

Table 30 Scores for gloves t_H (based on Van-Wendel-de-Joode et al. (2003))

Table 31 Scores for clothing other than gloves t_i , $i \neq H$ (based on Van-Wendel-de-Joode et al. (2003))

Type of clothing	multiplier*
No clothing	1
Woven clothing	0.09
Non-woven permeable	0.03
Non-woven impermeable	0.009

* multipliers include protection factor 0.3 (Van-Wendel-de-Joode et al. (2003))

Table 32 Score for replacement frequency for dermal PPEs f_i (from Wendel-de-Joode et al. (2003))

Replacement frequency	multiplier
Single use	0.3
Daily	1
Weekly	3
Monthly	10

5.6 Dermal Exposure Bands

Assessment of the exposure determining parameters (see sections 5.14.1 to 5.44.3) along with the control measures modifying factors (see section 5.5) determine the overall actual exposure score *B* (Equation 11). According to Van-Wendel-de-Joode et al. (2003), the range of possible exposure scores is divided into seven dermal exposure categories (Table 33).

6 RISK LEVEL CATEGORIZATION

A combination of specific Hazard Band and a Specific Exposure band represent a level of occupational risk. Different risk levels are considered here for respiratory and dermal risks. The following discussion focuses on the respiratory risks. For respiratory exposure we have considered N_E =10 Exposure bands and N_H =5 Hazard bands there are 50 combinations of Hazard and Exposure bands as shown in Figure 13.

Dermal Exposure	Dermal	Dermal Exposure Score			
Category	Exposure Band	Lower	Upper		
No exposure	1	0	10 ⁻¹⁰		
Very low	2	10^{-10}	10		
Low	3	10	30		
Moderate	4	30	100		
High	5	100	300		
Very high	6	300	1000		
Extremely high	7	1000	8		

Table 33 Dermal Exposure Bands (from Van-Wendel-de-Joode et al. (2003))

		HAZAR	D			
		1	2	3	4	5
	1					
	2					
	3					
	4					
	5					
	6					
щ	7					
SUR	8					
Ď	9					
Ĕ	10					

Figure 13 Risk Matrix consisting of 50 combinations of Hazard and exposure bands.

These combinations ought to be ranked among themselves to define relative risk bands and identify the need for necessary risk –reducing measures, as well as, the initial and final risk levels. As it has been already mentioned in the corresponding section, we have considered so many exposure bands so that the effect of the application of different sets of protective measures is visible to the user.

To rank the various combinations of exposure and hazard bands in terms of risk we follow the approach suggested by Nunes (2015). According to this approach each combination of two risk contributors corresponds to a quantitative risk level (RL) normalized from 1 to 100 percent according to the following relationship:

$$RL = \frac{w_H \log(H_i) + w_E \log(E_j)}{w_H \log(N_i) + w_E \log(N_j)} \cdot 99 + 1$$
(13)

where

RL= Risk Level (from 1 to 100%)

i –index over the Hazard bands (1,..., N_H)

j --index over the Exposure bands (1,..., N_E)

 N_H -- number of Hazard bands (=5)

 N_E -- number of Exposure bands (=10)

 w_H , w_E – weighting factors for risk contributors Hazard and Exposure respectively.

If both Hazard level and Exposure level are equally important ($w_H = w_E = 1$) then Equation 13 provides the Risk Matrix shown in Figure 14.

		HAZARD				
		1	2	3	4	5
	1	1	19	29	36	42
	2	19	36	46	54	59
	3	29	46	57	64	70
	4	36	54	64	71	77
	5	42	59	70	77	82
	6	46	64	74	81	87
	7	50	68	78	85	91
RE	8	54	71	81	89	94
nso	9	57	74	84	92	97
EXP	10	59	77	87	94	100

Figure 14 Risk Matrix with equal importance of Hazard and Exposure bands

The risk matrix shown in Figure 14 assigns a distinct risk level to each and every combination of Hazard and Exposure bands. Furthermore it satisfies the obvious rule that "two risk levels with same band of one of the risk contributors are ranked according to the other risk contributor". For example, if $RL(E_j, H_i)$ denotes the risk level associated with Exposure band E_j and Hazard band H_i Equation 13 ensures that:

RL(8,1) < RL(8,2) < RL(8,3) < RL(8,4) < RL(8,5) (see Figure 14).

Consideration of this fine mesh of Exposure / Hazard combination and relative ranking ensures that the effect of two different control (protective) measures will be distinguishable since that they will usually result in different final risk levels. Application of a risk control measure is affecting only the exposure band since the Hazard band depends on the physical, chemical and toxic properties of the nanomaterial and these are not affected by the possible protective measure considered by the proposed Control Banding tool. For this reason we consider the Exposure band to be more important in defining the corresponding risk level.

The effect of this consideration is shown in Figure 15 where the risk levels have been calculated by Equation 13 with:

w_{H} ,=1 and w_E =3

Risk Matrix of Figure 15, for example, assigns a higher RL to the combination (E=2, H=1) than to (E=1, H=2).

		HAZARD)			
		1	2	3	4	5
	1	1	9	14	17	20
	2	25	33	38	41	44
	3	39	47	52	55	58
	4	49	57	62	65	68
	5	57	65	70	73	76
	6	63	72	76	80	82
	7	69	77	82	85	88
RE	8	74	82	86	90	92
nso	9	78	86	90	94	96
EXF	10	81	89	94	97	100

Figure 15 Risk Matrix with Exposure band three times more important than the Hazard band.

To improve the communication characteristics of the tool, the 100 risk levels have been divided into five risk zones corresponding to those suggested by the BS 8800 (2004). The risk levels responding to each risk band are given in Table 34 and they have been subjectively assessed by the authors of this report.

With the adoption of the five risk zones and the corresponding colour scheme the Control Band Risk Matrix of Figure 3 becomes as shown in Figure 16.

For dermal exposure we have $N_E=7$ Exposure bands and $N_H=5$ Hazard bands, yielding 35 combinations of Hazard bands and Dermal Exposure bands. Similarly to respiratory risks, dermal risk levels are calculated using Equation 13. Dermal risk bands are allocated according to Table 34.

Table 34	Risk Bands	according	to BS	8800	(2004)
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RISK BANDS								
Risk Level	LOWER	UPPER	Tolerability: Guidance on necessary action and timescale					
1—Very Low/Acceptable	0	25	These risks are considered acceptable. No further action is necessary other than to ensure that the controls are maintained					
2—Low /Tolerable	25	60	No additional controls are required unless they can be implemented at very low cost (in terms of time, money and effort). Actions to further reduce these risks are assigned low priority. Arrangements should be made to ensure that the controls are maintained					
3—Medium	60	75	Consideration should be given as to whether the risks can be lowered, where applicable, to a tolerable level, and preferably to an acceptable level, but the costs of additional risk reduction measures should be taken into account. The risk reduction measures should be implemented within a defined time period. Arrangements should be made to ensure that the controls are maintained, particularly if the risk levels are associated with harmful consequences					
4—High	75	90	Substantial efforts should be made to reduce the risk. Risk reduction measures should be implemented urgently within a defined time period and it might be necessary to consider suspending or restricting the activity, or to apply interim risk control measures, until this has been completed. Considerable resources might have to be allocated to additional control measures. Arrangements should be made to ensure that the controls are maintained, particularly if the risk levels are associated with extremely harmful consequences and very harmful consequences					
5—Very High / Unacceptable	90	100	These risks are unacceptable. Substantial improvements in risk controls are necessary, so that the risk is reduced to a tolerable or acceptable level. The work activity should be halted until risk controls are implemented that reduces the risk so that it is no longer very high. If it is not possible to reduce risk the work should remain prohibited					

		HAZARD)			
		1	2	3	4	5
	1	1	9	14	17	20
	2	25	33	38	41	44
	3	39	47	52	55	58
	4 5	49	57	62	65	68
		57	65	70	73	76
	6	63	72	76	80	82
	7	69	77	82	85	88
POSURE	8	74	82	86	90	92
	9	78	86	90	94	96
EXI	10	81	89	94	97	100

Figure 16 Risk Matrix for Exposure/Hazard band combinations showing the five risk zones of Table 34 and the fine relative risk levels of Equation 13

7 DESCRIPTION OF THE CONTROL BANDING TOOL

Based on the previous theoretical background we developed a Control Banding prototype as an XML-based macro-enabled Microsoft Excel 2013 workbook. The final file is also compatible with Microsoft Excel 2010, while Excel 2007 cannot handle some of the dynamic lists used in the tool. The Control Banding tool has built-in databases for hazard bands for known compounds, exposure scores, protection measure scores etc, and the exposure algorithms presented in the previous chapters. The tool consolidates the work done in SCAFFOLD, and also includes options for generic scenarios not considered in the project, while they comply with the assumptions made for the typical construction-related activities.

The Control Banding tool is organized as follows:

- *Cover*: A welcome worksheet with links to the other worksheets (see Figure 17)
- *HazardBand*: this worksheet guides the user to fill-in the properties of the nanomaterial. There are different options and questions according to the information that the user can provide (see Figure 18, Figure 19 and Figure 20). All the choices are provided in built-in drop down lists. Error messages are also provided to help the user. The worksheet includes two message boxes, one for help and another to reset (clear) the worksheet.
- **ExposureBand**: this worksheet guides the user to fill-in the process data, along with information on the intrinsic exposure (see Figure 21 and Figure 22). The worksheet is linked to hidden databases and the user response is input to the exposure algorithms for the calculations of respiratory and dermal exposure scores, without the use of protection measures (see Figure 23). The worksheet includes two message boxes, one for help and another to reset (clear) the worksheet.
- *Measures*: this worksheet supports the selection of protective measures to reduce dermal and respiratory exposures. For the former, the clothing options are according to the exposed body parts specified in worksheet ExposureBand. The worksheet includes two message boxes, one for help and another to reset the worksheet. In this case, the reset option does not clear the table, but rather provides the options to set the table to highest and lowest protection schemes available in the tool. Figure 24 shows the message boxes. Figure 26 shows the result of choosing the highest actual exposure by not using protective equipment. Clearly, the scores and the exposure bands for Figure 23 and Figure 25 are exactly the same. Figure 26 shows that the scores can be reduced and we move to lower exposure bands when protective equipment is selected. Scores are calculated automatically as the user selects protection options using the exposure algorithms built in the tool.
- RiskMatrices: this worksheet shows the risk matrices for respiratory and dermal exposure, and highlights the combination of hazard bands and exposure bands (with and without protective measures). shows the two risk matrices with the assessment results for respiratory and dermal risks. The risk levels are quantified using Equation 13, whereas the

fraction w_H/w_E is defined by the user. In the scenario of Figure 27, the bands for respiratory and dermal hazards are assigned to levels C and D, respectively. The respiratory exposure bands are 9 and 6 without and with the introduction of protection measures, respectively. The risk level is 80 and 73 without and with the measures, respectively. The resulting risk band without protection is "4-High", and reduces to "3-Medium" when the user-specified protection is applied.

The authors considered integrating the pre-assessment risk knowledge method developed during the iNTegRisk project in the present prototype, so that the level of uncertainties is quantified and information researches are oriented. In iNTegRisk Deliverable 1.3.1.1 the goal was to improve risk management for SMEs dealing with nanotechnologies and to develop reference methods and documents for self-assessment. A questionnaire was proposed by TÜV, with four sets of questions on Organizational, Material, Exposition and Hazards aspects. Normalized weights were assigned to each question and each aspect, to calculate the Total Knowledge Fraction score. Four knowledge classes were considered based on this score, namely little knowledge, some knowledge and excellent knowledge.

The questions on *organizational aspects* involve e.g. the presence of risk and/or OHS managers etc. in the company. This set of questions is irrelevant to control banding. *Exposition aspects* refer to information that can be extracted from the exposure scenario, such as the type of process, the duration and frequency of handling (see sections 4.2, 4.3, and 5.2 to 5.4). This information is expected to be provided with high degree of certainly. Information on *material aspects* refers to material physical properties, collected in the tool intrinsic emission data. A lot of effort is spent on requesting this information in a practical and descriptive manner (see sections 4.1 and 5.1). A significant amount of information on the *nanomaterial hazards* is not expected to be available (see Chapter 3). The primary cause for this unavailability is that toxicological research on manufactured nanomaterials is still at a quite early stage. The target group considered in this work consists of practitioners in small and medium size construction companies, not involved in the design of future toxicological experiments.

In conclusion, the authors acknowledge the work done on developing a pre-assessment risk knowledge method in iNTegRisk project, but consider that the TÜV questionnaire would not add to the present control banding tool.

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A n C n r r r r r r 1 1 i i i i i i 1 i SCAFFOLD: Innovative strategies, methods and tools for occupational risks management of manufactured nanomaterials (MNMs) in the construction industry 8 CONTROL BANDING TOOL 9 System Reliability and Industrial Safety Laboratory National Centre for Scientific Research "Demokritos" 11 Hedp Input Hazard Data Input Laposure Input Measures. Atmit		K16		- - (*)	J.										8
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Image: Control Banding Tool 5 D4.9 (WP4 - Task 4.5) 9 System Reliability and Industrial Safety Laboratory 10 National Centre for Scientific Research "Demokritos" 11 Help Input Hazard Data Input Laposure Input Measures Atouct 12 Help Input Hazard Data Data Input Measures Atouct 14 15 Input Measures Input Measures Input Measures Input Measures	1 2 3 4 5 8	SEVERITY HAA	ALE MICHAN	SCAFI tool man	FOLD: I Is for o Iufactu	red r	ative ation anor struct	al ris nate	tegies, sks man rials (M industry	mat lagel NM	hods : ment s) in t	and of he			
9 System Reliability and Industrial Safety Laboratory 10 National Centre for Scientific Research "Demokritos" 11 Imput Liposare Imput Liposare 11 Imput Hazard Data Imput Liposare Imput Messares 14 Imput Liposare Imput Liposare Atout 15 Imput Liposare Imput Liposare Imput Liposare	2 2 8				CONTR D4.9	OL B	ANDIN I – Tas	G TO k 4.5)	DL						
Display Input Having Dula Imput Leposure Data Imput Messares Atout 11 15 5	9 10 11		S	Bystem Re ational Ce	liability intre for	and In Scien	idustri tific Re	al Saf	cty Labo h "Demo	rator krito	у .s‴				
12	12 1J	не	lp	Input Haz	od Dala	Inp	ut L×po Data	sure	Input N	Actana	nes -	Aboul			
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Figure 17 Cover worksheet: Welcome screen

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			А					R			C.	D	-
1	Allocatio	on of Hazard B	aggregates	and a	gglomer	rates (NOA A)	Help	Reset Hazard Data				
3	Main questions						DROP-DO			Res	piratory haz	ard Dermal Hazard	
4	4 Is the NO/VA In the list of known materials?												
5	Has the NDAA already been classified and labelled according to national or regional legislation or GHS?						for Concre for Mortar rator Self (e resistance ulations app ating/paint (50nm	ele applications applications dearing coatin e per els applic plozitons applications	s g appfcations alians	•			
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Figure 18 HazardBand worksheet: list of available materials, including SCAFFOLD substances and other MNM's

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				A						В		С		D	E		
1 2	Allocatio	on of Ha	zard Banc	l to nano	-object	s, and I	heir	aggregate	s and a	igglome	rates (NOAA)	Help		Reset Hozard Date	1		
3	Main quest	lons						SELECT FROM	DROP-DO	OWN LISTS		Respiratory	hazar	d Dermal Hazard	i 🗍		
4	Is the NOAA In the list of known materials?						Not in the list										
5	Has the NUAA already been classified and labelled according to national 5 or regional legislation or GHS?						No							-			
6	Is the NOAA highly soluble in water (i.e. solubility in water higher then 0.1 e/l)?						No										
7	Does the Ne	OAA contai ricte to app	h biopersiste by the fibre to	nt fibres or fi oxidity paradi	bre-like gm to the	structures NOAA?)	? (i.e.	No									
8	Questions	on toxicolog	ical data														
9	Are there to	oxicological	data for the	NCAA?				Yes, see table	below			HAZARD BAND C Missing data					
10 11	NUAA toxic	ological cha	aracteristics														
15	LD50 derma	al route mg/	'kg					Unknown				Category D:	Scrio	us hozard			
16	LC50 inholo	tion 4H (mg	/I) Aerosols/	particles				1 5 mg/l				Category B:	Slight	hazard Slightly			
17	Severity of	Acute (life	threatening)	ettects				Not significar	nt/Notap	oplicable		Category A:	: No sig	gnificant health ris	k		
18	Adverse ett	tects seen p	er oral route	(mg/kg) (sin	gle expos	sure)		Unknown			Category C:	Mode	rate hazard				
19	Adverse ett	tects per or	al route (mg/	kg-day) (90 c	hronic stu	idy)		10-100 mg/kg	-day			Category C:	Category C: Moderate hazard				
20	Adverse eff	fects seen p	er dermal ro	ute (mg/kg) (single ex	posure)						-					
21 H Rea	Adverse eff	fects per de er Hazardi	and Expos	sureBand / M	0 day chr leasures	RiskMatri	tes 🦯	Not significant / I 1000-2000 mg/kg ≤ 1000 mg/kg Unknown	Vot app <mark>ica</mark> hi 9	Þ		terory D: II III III	Serio 100%	is bezard	•		

Figure 19 HazardBand worksheet: Filling-in the toxicological data – dermal hazards' data are still missing

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۵	в	с	D			
Allocation of Hazard Band to nano-objects, and their	aggregates and agglomerates (NOAA)	Help R	lesel Hazard Data			
3 Main questions	SELECT FROM DROP DOWN LISTS	Respiratory hazard	Dermal Hazard			
4 Is the NOAA in the list of known materials?	Not in the list					
Has the NOAA already been classified and labelled according to national 5 or regional legislation or GHS?	NC					
Is the NOAA highly soluble in water (i.e. solubility in water higher than 6 - 0.1 g/l)?	No					
Does the NOAA contain biopersistent fibres or fibre-like structures? (i.e. / Is it appropriate to apply the fibre toxicity paradigm to the NOAA?)	No					
Questions on toxicological data						
5 Are there toxicological data for the NCAA?	Yes, see table below	HAZARD BAND C	HAZARD BAND C			
10 11 NOAA toxicological characteristics						
7 Severity of Acute (life threatening) effects	STOTSE1	Category C: Moderate hozard				
3 Adverse effects seen per oral route (mg/kg) (single exposure)	300-2000 mg/kg	Category B: Slight hazard Slightly				
 Adverse effects per oral route (mg/kg day) (90 chronic study) 	Not significant / Not applicable	Category A: No sign	inficant health risk			
Adverse effects seen per dermal route (mg/kg) (single exposure)	1000 2000 mg/kg	Category B: Slight h	azard Slightly			
1 Adverse effects per dermal route (mg/kg-day) (50 day chronic study)	20-200 mp/kg-day	Category C: Modera	ate hazard			
2 Irritant / Corrosiveness	None to irritant (Eye Imit. 2; Skin Irrit. 2; EUH 056)	Category A: No sign	inficant health risk			
3 Carcinogenicity [C]	Negative	Category A: No sign	inficant health risk			
4 Mutagenicity / Genotoxicity [M]	Negative	tegory A: No sign	ifficant health risk			
Developmental / Reproductive toxicity [R]	Mutageric in most relevant in vivo and in vitro assays (Muta 2, 1A-1E)	tegory A: No sign	ificant health risk			
5 Sensitization [S]	Unknown	tegory B: Slight h	azard - Slightly			
/ Likelihood of chronic effects (e.g. Systemic)	Possible (STOT RE 2)	Category C: Modera	ate hazard			
Cover J. HazardBand / ExposureBand / Measures / RiskMatrices /	£2					

Figure 20 HazardBand worksheet: Location of hazard band when sufficient toxicological data are available

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	R4	- (∎ fx	Other (speci	fy bellow	u)									¥	
				А								В		C		
1 2	Allocatio	on of Po	tential E	qoosure Ba	ands (v	without	prote	ction mea	isures]).		неір	Re	is t		
3	Source dom	ain proces	5				5	ELECT FROM D	ROP-DO	WN LISTS						
4	Select the n	nanufactur	ing / product	ion process			0	Other (specify hellow)								
25	Allocated Fa	posure Ba	n <mark>ds (witho</mark> ut	any protectiv	re measu	res)	1	Monolayer rendering application of depolutant mortar								
26	Score/Band	for patent	ial respirator	y exposure			C	Concrete mixing / On site assembly or machining of concrete								
27			Allocated re	spiratory expr	isure han	ul (1 to 10)	=	Preparation, dootication, application of coatings Machining for the superficial installations of elements (e.g. fine-resistant or insulation panels)								
28	Score/Band	for potent	ial dermal ex	posure			-	Superficial machine								
29			Allocate	ed dermal exp	osure ba	nd (1 to 7)	= 0	Ther (specify belo	uw)					-		
30															1	
14 4	H Cove	r 🏑 Hazard	Band Expo	sureBand M	easures _	RiskMatric	es 🖉]/						+		
Read	y 🛅											🔲 🗖 🛄 100% 🕞	-0	-0	12	

Figure 21 ExposureBand worksheet: Selection of manufacturing/production process, including SCAFFOLD processes

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	BIG • (Inv product (<5% moisture content)		111	(E)	12		3			
Z	A	51				В	C			
1 2	Allocation of Potential Exposure Bands (without prot	tection meas	sures]	ľ		He	ip Res et			
3	Source domain process	SELECT FROM DE	ROP-DO	WNUSTS						
4	Select the manufacturing / production process	Other (specify b	ellow)							
5	Select specific manufacturing / production process	Handling of bulk	REPTER	ated/agglo	meraledi	nano-powdets				
9	Handling activity emission potential for selected process									
10	Specify activity for: Handling of bulk aggregated/agglomerated nano- powders									
11	Specify exposed body parts during the activity	Hands, above wa	aist and	head						
12	Specify importance of deposition over emission during the activity	Medium importe	ance							
13	Assessment of substance intrinsic emission potential for solids									
14	What is the weight fraction of active ingredient of interest in your product?	50-30%								
15	What is the dustiness of your nanopowder product?	Very high dustiness (>500 mg/kg)								
16	is your solid product sticky, waxy or moist? What is its moisture content?	? Dry product (<5% moisture content)								
22	Duration and frequency of exposure						1000			
23	Provide the daily duration of exposure (in hours per day)	4–8 h a day								
24	Provide the frequency of exposure (in days per week, month or year)	1 day per 2 weeks								
25	Allocated Exposure Dands (without any protective measures)									
26	Score/Dand for potential respiratory exposure	Data missing or y	wrong	on: handlin	g activity -					
27	Allocated respiratory exposure band (1 to 10) =									
28	Score/Band for potential dermal exposure	Data missing or v	wrong	on: handlin	g activity -	9				
29	Allocated dermal exposure band (1 to 7) –									
30										
H	HorizardBand ExposureBand Measures RiskMatrices	1					-			
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Figure 22 ExposureBand worksheet: Filling-in data for a generic (other, non-SCAFFOLD) process

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B16 • 🕼 🖈 Dry product (<5% moisture content)		×						
A	B	с –						
Allocation of Potential Exposure Bands (without pro 2	etection measures)	Res =						
3 Source domain process	SELECT FROM DROP-DOWN LISTS							
4 Select the manufacturing / production process	On site assembly/machining of depollutant mortan							
9 Handling activity emission potential for selected process		_						
Specify activity for: Handling of bulk aggregated/agglomerated nano- 10 powders	Handling of products where due to high pressure, speed, or force large quantities of do generated and dispersed	istare						
11 Specify exposed body parts during the activity	Hands, above waist and head							
12 Specify importance of deposition over emission during the activity	Medium importance							
13 Assessment of substance intrinsic emission potential for solids		_						
What is the weight fraction of active ingredient of interest in your 14 product?	Undiluted							
15 What is the dustiness of your solid product?	Very high dustiness (>500 mg/kg)							
Is your solid product sticky, waxy or moist? What is its moisture content?	Pry product (<% moisture content)	-						
22 Duration and frequency of exposure	Dry product (<5% moisture content)							
23 Provide the daily duration of exposure (in hours per day)	Sticky, waxy or maist product (> 10% moisture content)							
24 Provide the frequency of exposure (in days per week, month or year)	Histown 4-5 days a week							
25 Allocated Exposure Bands (without any protective measures)		_						
26 Score/Dand for potential respiratory exposure	D(R) = 100.000000 (work performed outside without protective equipment)	_						
27 Allocated respiratory exposure band (1 to 10) =	EXPOSURE BAND 10							
28 Score/Dand for potential dermal exposure	D(R) = 10532.600000 (work performed without protective equipment)	_						
29 Allocated dermal exposure band (1 to 7) –	EXPOSURE BAND 7							
30								
31		*						
H + H Cover HazardBand ExposureBand Heasures RiskMatrices	<u>/0</u> /	1						
Ready 🔝	100% (-)	V 🕑 .:						

Figure 23 ExposureBand worksheet: Calculated exposure scores for a highly risky process

Reset Measures	Reset Measures	Add controls
Do you went to reset the Measures table?	Reset to highest (Y) or lowest (N) actual exposure?	Check your general ventilation and the room size before adjusting your risk control measures.
<u>Y</u> es <u>No</u>	<u>Ycs</u> <u>N</u> o	

Figure 24 Measures worksheet: The reset message box, the message box with the two reset options and a message box urging the user to correct the space conditions

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	Hame	Insert Pace Layout	Formulas	Data A	Review E	View	Developer	Y1	Acrobat	Team Y2		Ŵ -	T X
	1/14	A		1			В				C	D	E
1	Selected	elected Control Strategies (protective equipment)									Help	Reset Measures	
3	APPLIED CONTROL MEASURES SELECT FROM DROP DOWN LISTS										-		
4	General ver	tilation		No gen	eral venti	lation (0.	3-1 ACH)						
5	Room size (volumc)		Volume	e >1000 m.	3							
6	Local contro	ls		No con	trol measu	ures at th	ic source						
7	Worker sep	aration		The wo	orker does	not work	k in a cabin						
8	Respiratory	PPE for cust		None									
9	Dermal PPE	tor hands (gloves)		Noglo	ves				Replacement frequency				
10	Second pair	of gloves worn inside							Replacement frequency				
11	Dermal PPE	for head		Noclot	hing				Replacement frequency				
12	Dermal PPE	for torso and arms		No clot	hing				Replacement frequency				
13	Dermal PPF	for lower body									Replacement frequency		
14	Dermal PPF	for feet and lower legs									Replacement frequency		
15													-
16	ALLOCATED	EXPOSURE BANDS (WITH	PROTECTIO	N MEASU	JRES)								
17	Score for ac	ual respiratory exposure	-	B(R) = 1	100.000000	(actual)							
18	Allocated r	es <mark>pl</mark> ratory exposure ban	d (1 to 10)=	EXPOSURE BAND 10									
19	Score for ac	rual dermal exposure		B(D) - 1	10632.6000	00 (actua	əl)						
20		Allocated dermal exposi	ne band =	FXPC	SURF BAR	VD 7							
14	N N Cove	r 🖉 HazardBand 🛒 Exocs	ureBand Me	easures	RiskMatri	ces 2							*
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Figure 25 Measures worksheet: Automatic input when the table is reset to the highest actual exposure

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BG 🔹 🏂 Loca	exhaust ventilation			×					
A	В	C	D	E					
1 Selected Control Strategies (protective equipment)	Help	Reset Measures						
3 APPLIED CONTROL MEASURES SELECT FROM DROP DOWN LISTS									
4 General ventilation	No general ventilation (0.3–1 ACH)			1					
5 Room size (volume)	Volume >1000 m3								
6 Local controls	Local exhaust ventilation		-	9					
7 Worker separation	No control measures at the source								
8 Respiratory PPE for dust	Loca exhaust ventilation								
9 Dermal PPE for hands (gloves)	Containment of the source with local exhaust ventiation								
10 Second pair of gloves worn inside	<u>Glove boxes/bags</u>		oony	1					
11 Dermal PPE for head	Non-woven impermeable	Replacement frequency	Single use						
12 Dermal PPE for torso and arms	Non-woven impermeable	Replacement frequency	Daily						
13 Dermal PPE for lower body		Replacement frequency							
14 Dermal PPE for feet and lower legs		Replacement frequency							
15									
16 ALLOCATED EXPOSURE BANDS (WITH PRO	OTECTION MEASURES]								
17 Score for actual respiratory exposure	B(E) = 0.150000 (actual)								
Allocated respiratory exposure band (1	Io 10)= EXPOSURE BAND 6								
18									
18 19 Score for acrual dermal exposure	B(D) = 73.988640 (actual)								
18 19 Score for acrual dermal exposure 20 Allocated dermal exposure b	D(D) = 73.989649 (actual) Hand - EXPOSURE BAND 4								
18 19 Score for acrual dermal exposure 20 Allocated dermal exposure b H H Cover Hardbard	D(D) = 73.989640 (actuel) Hand - EXPOSURE BAND 4 and Measures RiskHatrices	119		+					

Figure 26 Measures worksheet: Exposure scores (and the bands) are reduced with the use of measures

G.	SCAFFOLD CETool v11macro Microsoft Excel														
P	Hame Insert	Pace Layout	Formulas 7	Data A	Review	View D	Eveloper EDE	Accobat	Team N2				@ -	n x ¥	
12	A	B	С	D	E	F	G	Н	1	J	K	L	M	N	
1 Risk Matrices															
3	3 RESIPIRATORY EXPOSURE MATRIX DERIMAL EXPOSURE MATRIX														
4	Respiratory Hazard Band -			HAZARD	BAND C		Dermel He	zaud Band –			HAZARE	BANDD			
5	Respiratory Exposure Poten	tial Bard =		EXPOSUR	E BAND 9		Dermal Exc	oosure Potentia	Eand =		EXPOSU	E BAND 6			
6	Respiratory Exposure Actua	l Band =		EXPOSUR	E BAND 6		Dermal Exc	nosure Actual R	land =		EXPOSU	RE BAND 2			
7	Importance of hazard over a	exposure =		4	6		Importance	e of hazard ove	r exposure =		1.000 (d	efault=1)			
8															
10	Baseirateru		Hazard Band					ormal		Hazard Band					
11	Exposure Band	HAZARD	HAZARD	HAZARD	HAZARD	HAZARD	Expo	sure Band	HAZARD	HAZARD	HAZARD	HAZARD	HAZARD		
12		BANDA	EANDE	BAND C	BANDD	BANDE	- Top -		BANDA	EAND B	BANDC	BAND D	BANDE		
13	EXPOSURE BAND 1	1	26	-10	51	59	EXPOS		1	20	32	40	46		
14		13	38	53	63	/1	EXPOS	URE BAND 2	20	40	51	59	65		
15		21	46	ЬÜ	/0	/8	EXPOS		32	51	62	70	/6		
16	EXPOSURE BAND 4	26	51	65	/b	84	EXPOS	UKE BAND 4	40	55	/U	18	84		
17		30	55	69	80	88	EXTOS		46	55	76	84	91		
18	EXPOSURE BAND 6	33	58	73	83	91	EXPOS	URE BAND 6	51	70	81	89	96		
19		36	51	75	85	94	EXPOS		55	74	86	94	100		
20		38	53	78	83	96								_	
21	EXPOSURE BAND 9	40	65	80	90	- 98	RISI	K BAND 1	0 to	25	Very	Low/Accep	table		
22	EXPOSURE BAND 30	/12	67	82	92	100	RISE	K BAND 2	25 to	60	D	ov/iolerab	le		
23							RIS	K BAND 3	50 Lu	75		Medium			
24							RIS	RISK DAND 4 75 to		90 I		High	High		
25							RIS	K BAND 5	90 to	100	Very H	igh / Unacce	ptable		
14	🕨 H 🔁 Cover 🏑 HazardBa	nd 🏑 Exposi	ureBand 🏑	Measures F	RiskMatrices	s / 🖓 /				11		111			
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Figure 27 RiskMatrices worksheet: presentation of final results and the 5 risk bands

8 **REFERENCES**

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