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Classification of Dermal Exposure Modifiers and Assignment of Values for a Risk Assessment Toolkit

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This paper describes how default dermal exposure values can be adjusted with modifier values for specific work situations. The work presented here is supplementary to a toolkit developed for the EU RISKOFDERM project. This toolkit is intended for the assessment and management of dermal risks in small and medium sized enterprises. Potential dermal exposure (on the outer envelope of the body) is estimated with an algorithm whereby modifier values are applied multiplicatively to dermal default exposure values. These exposure modifiers with their assigned factors are intended to increase or decrease the potential (default) dermal exposure accordingly. Default estimates are modified to obtain two modified defaults: potential exposure rate to the hands and to the body. Quantitative exposure data is at present inadequate and insufficient to derive meaningful information that can be used for the selection of independent modifiers and the assignment of appropriate values. Instead, available information from the literature was considered and, in combination with expert judgement, 15 potential dermal modifiers were selected. Modifiers were classified and grouped into non-overlapping groups in order to avoid double scoring. Values were assigned to modifiers in three different exposure routes, i.e. direct contact, surface contact and deposition. Depending on the significance of a modifier, the values assigned to modifiers were weighted in equal steps on a log-scale. The values assigned to modifiers as presented in this paper are open to validation and revision once new data become available.

Keywords: dermal; determinant; exposure variables; modifier; risk assessment; toolkit

INTRODUCTION

At present, methodologies for the assessment of dermal exposure remain inadequate. In the absence of a dermal risk assessment and management toolkit, small and medium-sized enterprises (SMEs) are currently unable to assess and manage dermal risks in the work environment. The importance of introducing a practical toolkit for employers has been accentuated in recent years, with statistics showing that work-related skin diseases are responsible for a large number of claims and lost working days. There are very few dermal exposure assessment methods, and those that are available are either very generalized (EASE model: ECB, 1996; Friar, 1998), not thoroughly validated (US EPA, 1987; EUROPOEM, 1996) or specialized for specific work conditions (e.g. the substance-specific OAR model for spray painting: Brouwer and De Pater, 2001). A new development in dermal risk assessment includes a semi-quantitative method called DREAM (Van Wendel de Joode *et al.*, 2003) that can supply estimates of potential dermal exposure, gives insight into the distribution of dermal exposure over the body and could be useful for the ranking of tasks or jobs.

The aim of the EU-funded RISKOFDERM project (Project QLK4-CT-1999-01107) discussed here is to develop a validated predictive model for estimating dermal exposure, and to devise a practical dermal exposure toolkit for SMEs. This publication is the third in a series of four, and focuses on the development of a dermal assessment toolkit. The toolkit framework is described by Oppl *et al.* (2003) and

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addresses dermal exposure in three consecutive steps, i.e. (1) the assessment of the potential dermal exposure on the outer envelope of the body, (2) the assessment of the actual dermal exposure on the skin by using a 'clothing factor', and (3) the assessment of the systemic dose due to actual skin exposure.

This paper is a contribution to step 1. In the toolkit, potential dermal exposure on the outer envelope of the body is estimated by using a multiplicative method to adjust default dermal exposure values. The derivation of default dermal exposure values is described in Warren *et al.* (2003).

Our objective was to develop (generic) dermal exposure modifiers to account for differences in, among others, the substances, tasks, process and equipment and control measures. For this purpose, exposure modifiers are defined as those factors that directly or indirectly increase or decrease dermal exposure (Burstyn and Teschke, 1999).

To select modifiers and assign values to each, well-documented information and detailed studies are required that describe the effects of modifiers in a work environment setting. This paper is supported by a comprehensive literature overview of dermal exposure determinants as described in Marquart *et al.* (2003). However, the availability of conclusive data on dermal exposure modifiers proved to be limited, which meant that in many instances the evidence from the literature, expert judgement and technical knowledge of physical and chemical aspects had to be combined to propose independent modifiers and their modification factors.

OUTLINE OF THE TOOLKIT

The toolkit assumes an evidence-based methodology. For this purpose, dermal exposure operation (DEO) units associated with dermal exposure were adopted from a qualitative survey in the RISKOFDERM project. These DEO units were derived during an in-depth analysis of dermal exposure situations in different industry sectors and include several task-groups or scenarios. The DEO units include handling of contaminated objects, manual dispersion, hand tool dispersion, spray dispersion, immersion and mechanical treatment.

Dermal exposure can be significantly different for solid and liquid applications (Popendorf *et al.*, 1995; SAIC, 1996). The effect of the physical state of a substance is also inherent in other models such as EASE (ECB, 1996). Similarly, this toolkit explicitly considers the physical state of the product by specifying for each DEO unit whether a solid or liquid is used, e.g. manual dispersion of solids.

Methods used for the measurement of skin contamination may include, among others, hand washing methods, patches and whole body sampling (Schneider *et al.*, 1999). During the derivation of default values from quantitative exposure data (Warren *et al.*, 2003), significant variation in exposure levels was detected for body and hand exposure measurements. It was decided to incorporate two dermal exposure estimates into the toolkit, namely potential 'hand' and 'body' estimates. This implies that adjustments made by modifiers will be applied independently to both hands and body.

Modifiers can affect dermal exposure in different ways, and this is largely dependent on the mechanism or route of dermal exposure. A conceptual model for dermal exposure assessment was developed by Schneider *et al.* (1999), who describe the mass transport processes. The main exposure routes described in the model of Schneider *et al.* (1999) have been adopted and simplified, and brought together into three main exposure routes, i.e. direct contact (DC), surface contact (SC) and deposition (DEP). Direct contact refers to the direct transfer of substances from the source to the skin or clothing, e.g. immersion of body parts, exposure through splashes or exposure by large particles (≥100 μm) ejected from the source (also referred to as impaction). Surface contact occurs when a substance is transferred from contaminated surfaces onto the skin or clothing, whereas deposition (DEP) involves the transfer of airborne particles (<100 μm) to the skin or clothing. To incorporate these main dermal transport processes, a modifying value was assigned to each of the three routes of exposure.

METHODOLOGY

Figure 1 gives an overview of the procedure that is involved in adjusting default values with modifiers. Generic default values have been derived for each DEO unit or task group (Warren *et al.*, 2003), expressed as the potential exposure rate per unit of surface area (mg/cm^2/h) as presented in Table A1. Also, based on the outcome of the derived exposure data and by applying expert judgement, dermal exposure is qualitatively ranked into exposure classes, i.e. very low to very high (Table A2). Values assigned to the modifiers are intended to adjust the default value and subsequently to attain the associated qualitative exposure class. Values assigned to modifiers (as presented in this paper) correspond to the modifier values applied in Warren *et al.* (2003) to derive default values.

Classification of modifiers

The starting point for the classification of modifiers and the assignment of values was an extensive literature review of dermal exposure modifiers (Marquart *et al.*, 2003). Findings from this literature overview were used to develop a preliminary list of dermal exposure modifiers. However, the modifiers selected for the toolkit do not directly correspond to

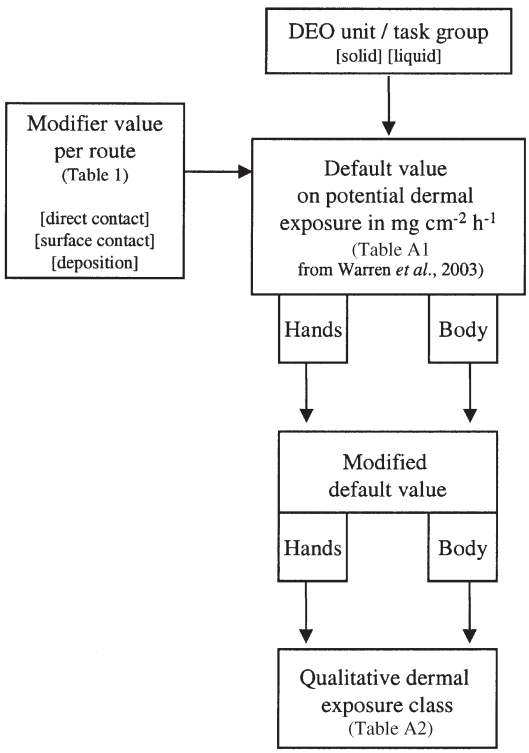

Fig. 1. A flow diagram to illustrate how default values are adjusted with modifier values, leading to a qualitative dermal exposure class for potential dermal exposure.

those used for exposure modelling as suggested by Marquart *et al.* (2003). The reason for this is that the main framework of the toolkit already incorporates a number of potential dermal modifiers. Potential determinants such as 'general product features', 'duration/frequency', 'clothing' and 'gloves' are addressed in the main framework of the toolkit (Oppl *et al.*, 2003). In an attempt to keep the toolkit simple for application in SMEs, potential modifiers of a more subjective and inconsistent nature were excluded, e.g. various modifiers associated with worker characteristics and the work environment, 'moistness of the skin' and 'personal care/hygiene'. One should also note that some modifiers are inherent to the DEO unit selected by the toolkit user, and it is assumed that the effect of these modifiers forms an intricate part of the derived default value (e.g. type of equipment).

An objective for the development of the toolkit was that it should be kept pragmatic and user friendly. Seen from this viewpoint, modifiers had to be selected based on criteria that could narrow down and simplify the complex network of modifiers. Therefore, the preliminary list of modifiers was reviewed and, based on expert judgement, potentially significant modifiers were identified and selected on a consensus basis. The general guideline for selecting modifiers implied that independent modifiers with a significant effect on dermal exposure are given priority. Also, seen in the context of a universal toolkit application, preference was given to modifiers with a generic nature. Determinants that are dependent and related to other independent modifiers (e.g. the area treated versus the amount used) were dropped from the list to avoid double scoring and to prevent subsequent over- or under-rating of exposure estimates by using a multiplicative method.

Modifiers were categorized into three groups that represent different components of an exposure scenario. It allows for a more transparent classification system and helps to organize the modifiers into logical, non-overlapping groups. A brief description of the three groups is given below:

Substance-specific modifiers. Modifiers associated with the substance and product characteristics that determine the release and transfer of a chemical, e.g. volatility.

Workplace-related modifiers. Modifiers related to the process or equipment, task and worker characteristics, work practices and work environment, e.g. amount of product.

Control measure modifiers. These modifiers concern control measures that are expected to reduce dermal exposure significantly, e.g. containment. It should be noted that a separate section of the toolkit addresses a more extensive analysis of control measures (including actual exposure) for the purpose of control actions and risk management (Oppl *et al.*, 2003).

Assignment of values

DEO unit default exposure values applied in this toolkit are normalized for all the modifiers, meaning that modifier values are set at the reference values (Warren *et al.*, 2003). These reference values represent the 'normal' conditions that are assumed to occur during a given scenario (operation, task). A variable of a specific modifier that may incur a substantial increase or decrease in dermal exposure is qualitatively described, and these changes in modifiers are translated to step changes in exposure estimates. The qualitative description ensures that the modifier variables are explicit and, for application purposes in SMEs, it will also ascertain that the toolkit user is presented with clear and unambiguous choices. An example of the rationale applied for this purpose is illustrated in the modifier *volatility* where the reference value (factor 1) of the modifier 'volatility' is described as 'like water', while two variables are presented, e.g. 'like solvent' or 'like oil'.

Each variable of a modifier was assigned a modifying value. However, information on the relationship between dermal modifiers and their associated dermal exposure variance remains largely insuffi-

cient and inconclusive. In the absence of large and representative exposure data sets that can be used for retrospective modelling, information from various studies had to be applied semi-quantitatively and by means of expert judgement for the assignment of generic values.

The assignment of values to modifiers in this study has been based on an incremental log-scale as previously proposed by Cherrie *et al.* (1996). Depending on the significance of a modifier, the effects of modifiers were weighed in equal steps on a log-scale. The log-scale values correspond to the log-normal distribution that is generally associated with occupational exposure distributions. Modifier values are assigned that will either induce an increase (e.g. 3; 10) or decrease (e.g. 0.3; 0.1) in dermal exposure. A study by Cherrie and Schneider (1999) revealed that statistically significant correlations with exposure measurements were obtained in five validation studies by using a similar log-scale approach.

In the 'volatility' example presented earlier, the implementation of this approach can be illustrated by adopting a generic value (for surface contact) of 0.3 for 'like solvent' (decrease in exposure) and a factor 3 for 'like oil' (increase in exposure). The assumption is therefore that a volatile substance evaporates rapidly from surfaces and results in a decrease in dermal surface contact.

RESULTS

Modifiers and their assigned values

A summary of the proposed dermal modifiers and their assigned values for each route of exposure is presented in Table 1. A total of 15 modifiers have been listed. Two modifiers are task-specific and are specifically included for the DEO units 'handling of objects' and 'spray dispersion'.

Values assigned to the respective modifiers range from 0.001 to 10. This range implies that well-established control measures (e.g. containment, 0.001) can affect dermal exposure significantly, while values inducing an increase in dermal exposure (e.g. dustiness, 3) are generally less pronounced. The relevance of the different exposure routes (DC, SC, DEP) varies from one modifier to another. For example, a number of modifiers are assigned with equal values for all three routes of exposure, notably particle size, restricted workplaces, amount of product and complete containment. The most substantial intervention is incurred by values allocated to the control measures, particularly in the case of complete containment where dermal exposure can be reduced significantly or altogether.

Range of modifier values

Since the values assigned to modifiers are applied multiplicatively, minimum and maximum values are proposed to limit the collective effect of modifiers. Retrospective modelling of inhalation data can give some idea of the typical ranges of principal modifiers. For inhalation exposure, historical exposure data of many years can be applied for retrospective modelling purposes (Armstrong *et al.*, 1996; Glass *et al.*, 2000). These studies elucidate the typical ranges that can be expected for some principal modifying factors such as volatility, equipment, technology, ventilation, work practices and duration of exposure. Modifiers and their assigned values were obtained from benzene (inhalation) exposure data in the petroleum industry and were either data-driven or derived from expert judgement. Values applied for single modifiers varied from 0.1 (modifier: task) to 3.7 (modifier: product concentration), and 0.2–20 (modifiers not specified) for the respective studies. In the study of Armstrong *et al.* (1996), the substance-specific modifier (volatility) was assigned a value of 0.75–1, while the workplace-related modifiers (temperature, task, loading technology) were assigned values of 0.63–1, 0.1–2, and 1 or 3 respectively.

Retrospective modelling and regression analysis may be hampered by the fact that determinants are interrelated and nested within one another, and because regression models are not easily interpreted in the presence of multi-collinearity (Burstyn and Teschke, 1999). Although dermal modifiers in this toolkit are not directly comparable with those applied for inhalation exposure purposes, the magnitude of quantitative 'adjustments' gives a more objective view of the implications of exposure modifiers in general. In Table 2, the postulated minimum and maximum values are given for each modifier group (MG) and the total value of the groups combined (MT). As values assigned for modifiers are intended for generic applications in different types of industries, a provisional overall range of values are proposed (e.g. 0.001–50).

Implementation

To illustrate the implementation of modifiers in the toolkit, a brief description is included of the calculations required to apply values assigned to modifiers. First, it seems appropriate to define an additional component of the toolkit, i.e. the route weight fraction (RWF). The contribution and relevance of the exposure routes (DC, SC, DEP) are not only relevant for modifiers, but also for different tasks and operations (or DEO unit). For example, for the DEO unit 'immersion tasks', the exposure routes DC and SC receive priority, whereas 'spray dispersion' tasks may emphasize the importance of all three routes. In order to address this discrepancy, a RWF has been proposed for each DEO unit. These weighting factors therefore account for the percentage contribution of each exposure route of a given DEO unit (Warren *et al.*, 2003).

Table 1. A summary of the proposed dermal modifiers and values assigned to each variable

Modifier	Description	Generic value			Rationale	Supplementary literature
		DC	SC	DEP		
Substance specific modifiers						
Volatility/viscosity (liquid)	*Like water*	1	1	1	Dermal exposure via surface contact is expected to decrease for volatile products due to evaporation from surfaces/skin. It is assumed that high volatility results in an increased transfer (DEP), e.g. application of solvent-like formulations. A high viscosity or stickiness results in an increased skin retention.	Garrod *et al.* (1999), Cinalli *et al.* (1992), Roff (1997)
	Like solvent	1	0.3	3		
	Like oil, grease	3	3	0.3		
	Like solvent suspension	3	3	3		
Particle size (solid)	*Like (dry) coarse sand*	1	1	1	Skin adherence correlates inversely with particle size. Smaller particles become easily airborne; deposition of aerosol increases with particle size.	Driver *et al.* (1989), Kissel *et al.* (1996), Fogh *et al.* (1999)
	Like (dry) flour	3	3	3		
	Like (dry) granules/pellets	0.3	0.3	0.3		
Wetness/contamination of objects[a]	*Damp/moderate to extensive areas of contamination (20–80%)*	1	1	1	Correlation exists for surface contamination and hand exposure. Handling of contaminated objects is expected to increase dermal exposure.	Fenske and Horstman (1987), Lansink *et al.* (1996), Brouwer *et al.* (1992), Brouwer *et al.* (1999), McArthur (1995)
	Touch dry/small areas of contamination (<20%)	1	0.1	1		
	Saturated/complete contamination (>80%)	1	10	1		
Moistness/adherence (solid)	*Like dry solids*	1	1	1	It is assumed that moist solids can increase skin adherence.	Kissel *et al.* (1996)
	Like moist solids	3	3	1		
General workplace modifiers						
Temperature of process/substance (liquid)	*Substance/process at normal and elevated temperatures*	1	1	1	An increase in processing temperature (above normal for scenario) is expected to increase dermal exposure.	–
	Liquids are heated	1	3	3		
Temperature of process/substance (solid)	*Substance/process at normal and elevated temperatures*	1	1	1	See above.	–
	Solids are melted	1	3	3		
Spraying of liquids (droplet size)[b]	*'Normal' spraying or fogging of liquids*	1	1	1	The relationship between spray pressure and dermal exposure is inconsistent. A significant difference in dermal exposure is expected for spraying processes that produce airborne and non-airborne fractions.	Garrod *et al.* (1998), Preller and Schipper (1999), Methmer and Fenske (1996)
	Little (very low) pressure causing large droplets	1	0.3	0.1		
Spraying of solids (particle size)[b]	*Spraying/fogging of powder*	1	1	1	See above.	–
	Strewing of course solids/granules/pellets	1	0.3	0.1		
Restricted workspace	*Unrestricted workspace*	1	1	1	Confined or restricted workplaces expected to increase dermal exposure.	Van Drooge *et al.* (2000)
	Restricted workspace	3	3	3		
Orientation of worker	*Work positioned at or below waist level*	1	1	1	Orientation of the worker may increase dermal exposure.	HSE (1999)
	Work positioned above waist level	3	1	3		

Table 1. Continued

Modifier	Description	Generic value			Rationale	Supplementary literature
		DC	SC	DEP		
Amount of product	*Normal*	1	1	1	A substantial increase in the amount of product used is associated with a higher dermal exposure level.	De Cock *et al.* (1998), De Pater *et al.* (2000), Brouwer *et al.* (2000a,b)
	Small amounts (<1 fifth of normal)	0.3	0.3	0.3		
	Large amounts (>5 times of normal)	3	3	3		
Control measure modifiers						
Level of automation	*No automation (fully manual)*	1	1	1	Manual tasks are normally related to an increased dermal exposure compared to automated processes.	Brouwer *et al.* (1994), Lansink *et al.* (1996)
	Partially automated, partially manual	0.3	0.3	0.3		
	Fully automated	0.1	0.1	0.1		
Ventilation	*Natural/general ventilation*	1	1	1	The use of local exhaust ventilation generally decreases dermal exposure, in particular through surface contact and deposition.	Van Drooge *et al.* (2000), Methmer and Fenske (1996)
	Local exhaust ventilation	1	0.3	0.3		
Segregation	*No segregation*	1	1	1	Segregation of the worker or the process is associated with a decrease in dermal exposure, particularly for the DC and SC routes of exposure.	De Cock *et al.* (1998), De Vreede and van Amelsfort (1997)
	Complete segregation	0.1	0.1	0.3		
Containment	*No containment*	1	1	1	Control at the source is expected to reduce dermal exposure significantly or altogether.	–
	Complete containment	0.001	0.001	0.001		

Note: DC, direct contact; SC, surface contact; DEP, deposition.
[a]Only used for scenarios classed under handling of objects.
[b]Only used for scenarios classed under spray dispersion.

Table 2. Proposed minimum and maximum values for different modifiers groups (MG) and the total modifier value (MT)

Modifier group (MG)	Proposed minimum value	Proposed maximum value
Substance-specific modifiers	0.3	3
Workplace-related modifiers	0.3	30
Control measure modifiers	0.001	1
Total modifier value (MT)	0.001	50

Note: values are open for review.

For the implementation of modifiers the following conditions are suggested:

1. Only one modifier of the 'control measure' group can be assessed by the toolkit, provided that the modifier is chosen with the highest impact.
2. If the modifier 'complete containment' is applied, all other modifiers are excluded.

In Table A3 an example is given to illustrate how modifier values are introduced and the modified default value is estimated using some basic calculations. Below, a summary of the main steps and calculations are presented.

- Selection of the DEO unit and modifiers.
- Per modifier: the contribution of different exposure routes is calculated by multiplying the modifier factor ($MF_{DC,SC,DEP}$) with the route weight fraction ($RWF_{DC,SC,DEP}$) of a given DEO unit. Then the modifier value (MV) for hand and whole-body exposure is calculated by summation of the three routes of exposure:

$$MF_{hand,whole\ body} = (MV_{DC} \cdot RF_{DC}) + (MV_{SC} \cdot RF_{SC}) + (MV_{DEP} \cdot RF_{DEP}) \quad (1)$$

- Multiple modifiers: modifier factors (MF) are multiplied with each other to obtain a value per modifier group (MG) and for all groups combined (MT):

$$MG_{hand,whole\ body} = MF_{modifier\ 1} \cdot MF_{modifier\ 2} \cdot MF_{modifier\ n} \quad (2)$$

$$MT_{hand,whole\ body} = MG_{substance} \cdot MG_{workplace} \cdot MG_{control} \quad (3)$$

Values obtained with formulae (2) and (3) are not allowed to exceed the (provisional) minimum and maximum values as specified in Table 2.

- The total modifier value (MT) calculated above is subsequently multiplied by the default value of the designated DEO unit (DEO_{DV}) to obtain the modified default value (DV_M). Modified default values (DV_M) can be translated to a qualitative exposure estimate by using Table A2.

$$DV_{M\ hand,\ whole\ body} = MT \cdot DEO_{DV} \Rightarrow \text{qualitative exposure class} \quad (4)$$

Effects of values assigned to modifiers

The actual effect of a modifier on default values can be evaluated by observing the shift in the qualitative exposure bands. Table 3 shows the effect of the minimum and maximum total modifier value (MT) on the qualitative exposure bands.

Three examples are given of default values for the hand and whole body, respectively. The first example shows how the default value of 0.03 mg/cm^2/h (low exposure class) for hand exposure is adjusted by the minimum and maximum modifier value to <0.005 mg/cm^2/h (very low) and 1.5 mg/cm^2/h (high), respectively. These shifts in exposure estimates and qualitative exposure classes give a more concrete illustration of the effect of the selected modifiers on default values. However, from a practical point of view, it would be uncommon for a toolkit user to apply a large number of modifiers that result in values that exceed the minimum and maximum range. In general, default values are adjusted to such an extent that the qualitative exposure class is altered with a shift of one or two exposure bands, e.g. from a medium band exposure class (0.05–0.5 mg/cm^2/h) to a very low band (<0.005 mg/cm^2/h) or a very high band (≥5 mg/cm^2/h). Setting of an appropriate range remains dependent on future research and field studies.

CONCLUSIONS AND FUTURE DEVELOPMENT

With the support of a comprehensive literature review (Marquart *et al.*, 2003), it was possible to select and group some of the principle modifiers that are responsible for variation in dermal exposure. A number of essential modifiers are not addressed in this paper because some determinants form an intrinsic part of the toolkit itself, e.g. in-use concentration. It is important to note that the toolkit user selects a DEO unit with a fixed derivative default value, and that this value also captures some intrinsic determinants of the task or operation (e.g. the technology/equipment). The principal modifiers related to inconsistent personal and work environment characteristics were excluded in an attempt to simplify the 'user-level' application of the toolkit in SMEs. This toolkit should therefore not be mistaken for a comprehensive regulatory risk assessment tool.

The general framework of the toolkit assumes an evidence-based approach that uses quantitative and qualitative exposure data obtained from field studies. At this point in time, however, exposure data of dermal exposure are still insufficient to derive meaningful generic values for modifiers that are solely based on empirical data. Values assigned to modifiers as presented in this paper were derived semi-quanti-

Table 3. Effects of minimum and maximum modifier values

Dermal exposure of	Example of default (mg/cm^2/h)	Exposure class	Modifier value	Effect of adjustment	
				Modified default (mg/cm^2/h)	Modified exposure class
Hand	0.03	Low	[a]	<0.005	Very low
			[b]	1.5	High
	0.27	Medium	[a]	<0.005	Very low
			[b]	>5	Very high
	2.5	High	[a]	<0.005	Very low
			[b]	>5	Very high
Body	0.005	Low	[a]	<0.001	Very low
			[b]	0.25	High
	0.06	Medium	[a]	<0.001	Very low
			[b]	>1	Very high
	0.5	High	[a]	<0.001	Very low
			[b]	>1	Very high

[a]Minimum total modifier value (0.001).
[b]Maximum total modifier value (50).

tatively by means of references to the literature and educated assumptions. Hence, a limitation of this proposal is that values assigned to modifiers are not data driven, and this implies that the choice of generic modifiers and their assigned values need to be thoroughly evaluated and validated.

We acknowledge that the presented values do not capture the exact variance of the exposure estimate. However, the advantage of an underlying quantitative model is that its transparent structure allows for revision as new evidence becomes available. For this purpose, field studies are currently being conducted in various industries as part of the RISKOFDERM project.

Table A1. Default exposure values by task group (Warren *et al*., 2003)

Task group	Qualitative body exposure ($mg/cm^2/h$)	Qualitative hand exposure ($mg/cm^2/h$)
Handling contaminated objects (solid)	0.50 (high)	21.63 (very high)
Handling contaminated objects (liquid)	0.2 (high)	4.09 (high)
Manual dispersion of solids	0.05 (medium)	0.50 (high)
Manual dispersion of liquids	0.05 (medium)	0.117 (medium)
Hand tool dispersion of solids	0.05 (medium)	0.50 (high)
Hand tool dispersion of liquids	0.016 (medium)	0.738 (high)
Spray dispersion of solids	0.064 (medium)	1.386 (high)
Spray dispersion of liquids	0.459 (high)	1.067 (high)
Immersion (solids)	0.50 (high)	2.50 (high)
Immersion (liquids)	0.61 (high)	2.50 (high)
Mechanical treatment (exposure to solid)	0.05 (medium)	0.25 (medium)

APPENDIX

Tables A1 and A2 give the default exposure values, and Table A3 shows an example of the calculation.

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Table A2. Qualitative default dermal exposure values (Warren *et al*., 2003)

Qualification	Potential body exposure rate ($mg/cm^2/h$)	Potential hands exposure rate ($mg/cm^2/h$)
Very low	0–0.001	0–0.005
Low	0.001–0.01	0.005–0.05
Medium	0.01–0.1	0.05–0.5
High	0.1–1	0.5–5
Very high	1 and higher	5 and higher

Table A3. Example of calculations[a]

DEO unit/task group:	Manual dispersion (e.g. wiping)		
Physical property:	Liquids		
Route weight fraction:	Body	= DC (50%); SC (50%); DEP (0%)	
	Hands	= DC (50%); SC (50%); DEP (0%)	
Default value of			
DEO unit:	body	= 0.05 $mg/cm^2/h$ (medium)	
	hands	= 0.117 $mg/cm^2/h$ (medium)	
Modifiers selected			
by user:	volatility:	like solvent	(DC = 1; SC = 0.3; DEP = 3)
	amount of product:	large amounts	(DC = 3; SC = 3; DEP = 3)
	restricted workspace:	restricted/confined	(DC = 3; SC = 3; DEP = 3)

Firstly, the correction factor per modifier and modifier group is calculated:

volatility (modifier group: substance-specific) = $(1 \times 0.5) + (0.3 \times 0.5) + (3 \times 0) = 0.65$

amount (modifier group: workplace-related) = $(3 \times 0.5) + (3 \times 0.5) + (3 \times 0) = 3$

restricted workspace (modifier group: workplace-related) = $(3 \times 0.5) + (3 \times 0.5) + (3 \times 0) = 3$

To keep values within the ranges proposed in Table 2, the minimum and maximum values are adopted if these are exceeded. Subsequently the modifier group values (MG) are multiplied by each other to obtain the total modifier value (MT), thus $0.65 \times 3 \times 3 = 5.9$. The total modifier value (MT) is multiplied by the default value to attain the modified default value:

Modified default		
value:	body	= $0.05 \times 5.9 = 0.3$ $mg/cm^2/h$ (high)
	hands	= $0.117 \times 5.9 = 0.7$ $mg/cm^2/h$ (high)

[a]See Methodology section for an explanation of the terminology, and the Results section (implementation) for the main steps and calculations.

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