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# Deriving Default Dermal Exposure Values for Use in a Risk Assessment Toolkit for Small and Medium-sized Enterprises

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**This paper describes the derivation of default task-based dermal exposure values for use in a risk assessment toolkit for small and medium-sized enterprises (SMEs). A set of separately determined dermal exposure modifiers have been applied to published studies of dermal exposure to obtain 'normalized' dermal exposure data sets. These data sets are grouped according to task and then further subdivided by making a distinction between processes involving solid and liquid products. For each of the resulting 12 groups, two default exposure rates are required: potential exposure rate to the hands and potential exposure rate to the body. Default values for risk assessment are then derived by taking a weighted average of the 75th percentiles of these normalized exposure distributions. In addition, a measure of peak surface concentration is required to take into account the risk of local skin effects. The higher of the (modified) hand and body exposure rates after applying the relevant penetration factors for clothing and gloves is used. Usually this will be the hand exposure rate. These default values serve as robust initial exposure estimates in a risk assessment toolkit for SMEs.**

*Keywords:* dermal; exposure; risk assessment; task-based

## INTRODUCTION

This publication is the fourth in a series of four describing a dermal risk assessment toolkit developed as part of the EU funded project RISKOFDERM (QLK4-CT-1999-01107) (Goede *et al.*, 2003; Marquart *et al.*, 2003; Oppl *et al.*, 2003). This toolkit is aimed at addressing the need of small and medium-sized enterprises (SMEs) for a practical aid to assess and manage the occupational health risks posed through dermal exposure to chemical agents. At present, dermal exposure models are either over-simplifications (EASE, 1996) or specific to certain circumstances. The most developed models are for pesticides (EUROPOEM, 1996; Van Veen, 2001). Few, if any, of these existing approaches link the exposure assessment to hazard and make an actual assessment of risk. The toolkit being developed within the RISKOFDERM project aims to provide robust assessments of exposure and hazard while stopping short of the complexity of a full regulatory risk assessment. An additional output of the toolkit will be a suggested regime of control measures to reduce the risk (if necessary) to more tolerable levels.

The toolkit is designed to assess both exposure and hazard each on a qualitative scale of five categories of severity. Dermal exposure is considered in three stages:

1. Determining the dermal exposure to the outer envelope of the body, commonly referred to as potential dermal exposure.
2. A calculation of actual dermal exposure to the skin after considering the mitigating effects of clothing.
3. An assessment of either uptake through the skin to give internal dermal exposure (for systemic effects) or the peak local concentration on the skin (for local skin effects).

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Thus for local and systemic effects, the initial process of determining the exposure to the outer envelope of the body is the same for both, while at the later stages of the risk assessment their treatment diverges. Oppl *et al.* (2003) present the main framework of the toolkit, while other complementary work is described in Marquart *et al.* (2003) and Goede *et al.* (2003).

This paper contributes to the first stage of the exposure assessment—estimating potential dermal exposure to the outer envelope of the body—through the derivation of default dermal exposure values that form the basis of a multiplicative model of exposure. An important feature of the toolkit is that it provides risk assessments only for in-use preparations and not for specific chemicals. Accordingly, throughout this paper, exposure refers exclusively to in-use preparations and not to individual chemical agents or analytes.

## OUTLINE OF THE EXPOSURE MODEL

Although the risk characterization stage of the toolkit compares a qualitative assessment of exposure (assigned to one of five exposure categories) with a qualitative hazard assessment, a quantitative model for exposure has been chosen to underpin the toolkit. The premise of this model is that operator exposures are determined mainly by task. In order to keep the model manageable, tasks have been grouped into six generic categories termed dermal exposure operation (DEO) units (RISKOFDERM, 2001, 2002). Briefly these are: handling of contaminated objects, manual dispersion of substance, hand tool dispersion of a substance, spray dispersion, immersion and mechanical treatments.

Dermal exposure can differ significantly for similar applications but using different liquid and solid formulations (Popendorf *et al.*, 1995a,b). Therefore within each DEO unit there are four default exposure values: two for potential dermal exposure rate to the body for liquids and solids (mg/cm$^2$/h); similarly, two for potential dermal exposure rate to the hands (mg/cm$^2$/h). These values are adjusted to account for clothing and the (possible) protective qualities of gloves, and are scaled in accordance to the surface areas they represent. To assess the risk from systemic effects, this total exposure rate is multiplied by the duration of the task to give a total actual skin exposure. Accounting for uptake through the skin gives the correct category for the qualitative assessment of dermal exposure for systemic effects.

For risk assessment for local skin effects, a peak local exposure in mg/cm$^2$ is obtained by taking the higher of the two default values (again after adjustment for the effects of clothing and gloves—if worn). This value is supposed to represent the highest exposure occurring over an area large enough to cause local skin effects such as irritation or sensitization. This peak dermal exposure is not scaled according to duration, as longer periods of exposure are likely to increase only the surface area exposed and not the highest local skin concentration. A complete description of the risk assessment framework represented by the toolkit is given by Oppl *et al.* (2003).

To account for the wide variation in exposure that can occur within each grouping of tasks, a set of exposure modifiers has been determined. A total of 15 modifiers have been adopted, arranged into three non-overlapping groups representing separate aspects of the exposure scenario. These groupings are:

- Substance-specific modifiers: these relate to the physical properties of the product that affect the levels of exposure, e.g. particle size.
- Workplace-related modifiers: modifiers representing the process, task and environment, e.g. confined spaces.
- Control measures: generic workplace control measures that lead to a reduction in exposure, e.g. local exhaust ventilation. This category does not include control measures such as protective clothing or gloves, as the exposure part of the toolkit estimates potential rather than actual exposure. A separate part of the toolkit provides a comprehensive treatment of control measures for the purpose of risk management.

Each modifier has two or three categorical levels with one level assigned as the default and assumed to have no effect on exposure. The other levels have, through a combination of an analysis of the literature and expert judgement, been assigned modification factors. These exposure modifiers are then supposed to increase or decrease exposure by these factors and the default exposure value is altered accordingly.

The effect of exposure modifiers can be quite different depending upon the mechanism by which dermal exposure occurs. To allow for this, each modifier was assigned three separate scaling factors—one for each of three main mechanisms of dermal exposure: direct contact, surface contact and deposition from an aerosol. These three routes of exposure represent a simplification of the conceptual model for dermal exposure assessment developed by Schneider *et al.* (1999). Direct contact refers to the transport of substances directly from the source to the outer envelope of the body, e.g. exposures through splashes or immersion. In contrast, surface contact represents exposure through contact with intermediate contaminated surfaces, while deposition is the transfer from an aerosol or airborne particles. The chosen exposure modifiers, their categorical levels and the assigned scaling factors, and a full justification for their particular values, is given in Goede *et al.* (2003). For completeness, the modifiers are summarized in the accompanying Appendix.

Table 1. Data sets for spray dispersion of liquids

| Study | Body part | Routes of exposure | | | Modifiers of exposure | Data points | GM[a] (mg/cm$^2$/h) | GSD | 75th percentile[a] (mg/cm$^2$/h) |
|---|---|---|---|---|---|---|---|---|---|
| | | DC | SC | DEP | | | | | |
| Antifoulant spraying (HSE, 1999b) | Body | 0 | 30 | 70 | Solvent suspension | 27 | 0.108 | 4.15 | 0.282 |
| | Hands | 0 | 60 | 40 | Solvent suspension | 7 | 1.24 | 1.76 | 1.818 |
| Uncabbed orchard spraying (HSE, 1999a) | Body | 0 | 30 | 70 | Large quantities | 7 | 0.069 | 6.77 | 0.249 |
| Cabbed orchard spraying (HSE, 1999a) | Body | 0 | 30 | 70 | Segregation | 22 | 0.078 | 3.24 | 0.173 |
| Cleaning (Preller and Schipper, 1999) | Body | 0 | 30 | 70 | None | 15 | 1.68 | 9.19 | 7.48 |
| | Hands | 0 | 60 | 40 | | 9 | 3.40 | 7.57 | 13.31 |
| Public hygiene (Llewellyn *et al.*, 1996) | Hands | 0 | 60 | 40 | Small quantities | 8 | 1.59 | 13.28 | 9.08 |
| | Body | 0 | 30 | 70 | | 64 | 1.33 | 6.4 | 0.464 |
| Tree nurseries—boom (De Vreede and Van Amelsfort, 1997a) | Body | 0 | 30 | 70 | None | 6 | 0.155 | 2.62 | 0.338 |
| | Hands | 0 | 60 | 40 | None | 6 | 0.741 | 4.34 | 2.00 |
| Tree nurseries—lance (De Vreede and Van Amelsfort, 1997a) | Body | 0 | 30 | 70 | None | 6 | 0.841 | 3.18 | 1.61 |
| | Hands | 0 | 60 | 40 | None | 6 | 0.284 | 2.10 | 0.468 |
| Tree nurseries (De Vreede and Van Amelsfort, 1997b) | Body | 0 | 30 | 70 | Large quantities, partial automation, segregation | 9 | 0.665 | 6.16 | 2.27 |
| | Hands | 0 | 60 | 40 | | 9 | 7.43 | 2.66 | 14.37 |
| Remedial biocides (Garrod *et al.*, 1998) | Body | 0 | 30 | 70 | None | 67 | 0.195 | 7.85 | 0.783 |
| | Hands | 0 | 60 | 40 | | 20 | 0.180 | 18.22 | 1.27 |
| De Pater *et al.* (2000) | Body | 0 | 30 | 70 | Small quantities | 58 | 0.042 | 2.67 | 0.082 |
| Spraying outside of container (Brouwer *et al.*, 2000) | Body | 0 | 30 | 70 | Solvent suspsension | 21 | 0.133 | 3.88 | 0.331 |
| | Hands | 0 | 60 | 40 | | 22 | 0.010 | 9.50 | 0.047 |
| Spraying inside of container (Brouwer *et al.*, 2000) | Body | 0 | 30 | 70 | Solvent suspension, constricted workplace | 5 | 0.383 | 2.35 | 0.682 |
| | Hands | 0 | 60 | 40 | | 5 | 0.059 | 3.55 | 0.139 |
| Low pressure disinfectant spraying (Popendorf *et al.*, 1995a,b) | Hands | 0 | 60 | 40 | None | 8 | 0.099 | 4.42 | 0.269 |

[a]Denotes normalized geometric mean and 75th percentile.

This underlying quantitative model of dermal exposure is more transparent than a completely qualitative one. In particular, the supposed effects of modifiers on levels of exposure are properly set out and documented, and as a result are fully open to review, criticism and validation. With a completely qualitative structure, this would not be possible. For example, if it were claimed that a fine particle size increases exposures from medium to high, then this statement is more difficult to assess than a claim that exposures will on average be three times higher. Furthermore the quantitative model may be readily updated in the light of new evidence—both the default exposure values and the modifying factors can easily be revised as new research into dermal exposure becomes available.

## METHODOLOGY FOR DERIVING DEFAULT EXPOSURES

Where possible, each default value has been derived from published exposure studies. In comparison to inhalation exposure data, published dermal exposure data is relatively scarce. Additionally, except where data has been collected for generic modelling purposes, it is common to express expos-

Table 2. Data sets for spray dispersion of solids

| Study | Body part | Routes of exposure | | | Modifiers of exposure | Data points | GM[a] (mg/cm$^2$/h) | GSD | 75th percentile[a] (mg/cm$^2$/h) |
|---|---|---|---|---|---|---|---|---|---|
| | | DC | SC | DEP | | | | | |
| Public hygiene (Llewellyn *et al.*, 1996) | Body | 0 | 30 | 70 | None | 21 | 0.018 | 6.61 | 0.064 |
| | Hands | 0 | 60 | 40 | None | 3 | 0.320 | 8.79 | 1.39 |

[a]Denotes normalized geometric mean and 75th percentile.

Table 3. Data sets for manual dispersion of liquids

| Study | Body part | Routes of exposure | | | Modifiers of exposure | Data points | GM[a] (mg/cm$^2$/h) | GSD | 75th percentile[a] (mg/cm$^2$/h) |
|---|---|---|---|---|---|---|---|---|---|
| | | DC | SC | DEP | | | | | |
| Disinfectant wiping (Popendorf *et al.*, 1995b) | Hands | 50 | 50 | 0 | None | 6 | 0.062 | 2.39 | 0.117 |

[a]Denotes normalized geometric mean and 75th percentile.

ure in terms of the mass of active chemical. In these cases, unless the concentration, duration of task and exposed body area are also given for each measurement, it is not possible to express the exposures in the form chosen for the toolkit (mg/min/h). Having identified suitable studies, these are then grouped under the relevant DEO units (RISKOFDERM, 2001, 2002) ready for the next stage in the derivation process.

*Normalization*

The exposures represented by each literature data set will reflect the specific conditions for that exposure scenario. These conditions can be described through the toolkit's generic modifiers of exposure. For each scenario, all the non-default classifications of modifiers are noted, and from these an overall modifying factor (MF) is calculated. A normalized data set is then obtained by dividing each exposure by this modifying factor. The following example illustrates the calculation of the overall modifying factor (MF).

*Study: Amateur application of antifoulant paint to leisure boats (Guiver et al., 1997)*

DEO unit: hand tool dispersion of liquids.

Modifiers of exposure taking non-standard values identified in this study:

Volatility: like solvent suspension (DC 3, SC 3, DEP 3).

Restricted workplace: restricted (DC 3, SC 3, DEP 3).

Supposed contribution to total exposure by routes of exposure:

DC 20%, SC 40%, DEP 40% (body)
DC 40%, SC 40%, DEP 20% (hands)

First the modifying factors for each modifier are calculated:

Volatility:

$$(3 \times 0.2 + 3 \times 0.4 + 3 \times 0.4) = 3 \text{ (body)}$$
$$(3 \times 0.4 + 3 \times 0.4 + 3 \times 0.2) = 3 \text{ (hands)}$$

Restricted workplace:

$$(3 \times 0.2 + 3 \times 0.4 + 3 \times 0.4) = 3 \text{ (body)}$$
$$(3 \times 0.4 + 3 \times 0.4 + 3 \times 0.2) = 3 \text{ (hands)}$$
$$3 \times 3 = 9 \text{ (body)}$$

Overall modifying factors:

$$3 \times 2 = 9 \text{ (hands)}$$

Next obtain a normalized data set by dividing each exposure by the appropriate modifying factor. Writing $W_i = X_i/MF$, we assume that the (raw) data are log normally distributed implying that $Y_i = \ln(X_i/MF)$ are normally distributed. Let μ and σ be standard estimates of the mean and standard deviation of this normal distribution. It is worth noting that the geometric mean of the raw data is $MF \times \exp(\mu)$ and that the geometric mean is exp(σ)—the same as the normalized data. It is now possible to calculate any percentile from the normalized exposure distribution expressed as $\exp(z\alpha)$ where

$$z_\alpha = \mu + \Phi^{-1}(\alpha) \times \sigma$$

If the toolkit user were to supply the same non-default values (as were observed in the study), then the default value would be scaled by *MF*. Also, $MF \times \exp(z\alpha)$ gives the equivalent percentile fitted directly to the raw data, so using $\exp(z\alpha)$ as the default exposure value would ensure that the toolkit correctly predicts the chosen percentile for this literature data set. As there are multiple data sets available within a DEO, the default value should be based upon all of the normalized percentiles.

Table 4. Data sets for hand tool dispersion of liquids

| Study | Body part | Routes of exposure | | | Modifiers of exposure | Data points | GM[a] (mg/cm²/h) | GSD | 75th percentile[a] (mg/cm²/h) |
|---|---|---|---|---|---|---|---|---|---|
| | | DC | SC | DEP | | | | | |
| Roff (1997) (water) | Body | 20 | 40 | 40 | None | 8 | 0.002 | 4.31 | 0.005 |
| | Hands | 40 | 40 | 20 | None | 12 | 0.124 | 5.86 | 0.409 |
| Roff (1997) (solvent) | Body | 20 | 40 | 40 | Solvent | 7 | 0.015 | 2.96 | 0.031 |
| | Hands | 40 | 40 | 20 | Solvent | 12 | 2.41 | 10.14 | 1.15 |
| Guiver *et al.* (2000) | Body | 20 | 40 | 40 | Solvent suspension, constricted workplace | 10 | 0.006 | 2.91 | 0.012 |
| | Hands | 40 | 40 | 20 | | 2 | 0.488 | 1.06 | 0.509 |
| Garrod *et al.* (2000) | Body | 20 | 40 | 40 | Solvent | 15 | 0.009 | 6.03 | 0.029 |
| | Hands | 40 | 40 | 20 | Solvent | 10 | 3.23 | 5.23 | 1.023 |

[a]Denotes normalized geometric mean and 75th percentile.

Table 5. Data sets for handling of contaminated objects (solids)

| Study | Body part | Routes of exposure | | | Modifiers of exposure | Data points | GM[a] (mg/cm²/h) | GSD | 75th percentile[a] (mg/cm²/h) |
|---|---|---|---|---|---|---|---|---|---|
| | | DC | SC | DEP | | | | | |
| Weighing (Lansink *et al.*, 1996) | Hands | 30 | 70 | 0 | Fine particle size, segregation, partial automation | 6 | 11.676 | 2.72 | 22.94 |
| Dumping (Lansink *et al.*, 1996) | Hands | 20 | 40 | 40 | Fine particle size, segregation, partial automation | 22 | 12.87 | 3.94 | 32.43 |
| Collecting (Lansink *et al.*, 1996) | Hands | 0 | 80 | 20 | Fine particle size, segregation, partial automation | 13 | 8.19 | 2.73 | 16.11 |

[a]Denotes normalized geometric mean and 75th percentile.

*Choice of statistic from the normalized distributions*

In selecting a percentile from the exposure distributions on which the default exposure value will be based it is important to recognize that the process of integrating exposure and hazard to obtain an estimate risk is non-quantitative. While the exposure assessment side of the toolkit is quantitative, this is only to provide a rigorous and transparent structure for the model of exposure. The numerical estimates of systemic exposure are converted to a qualitative ranking of dose exposure prior to their combination with hazard. Nonetheless, the chosen percentile should provide a reasonable estimate of the long-term exposure that would arise through continual working with the formulation. The value chosen for the toolkit is the 75th percentile, this being consistent with other risk assessment frameworks (EUROPOEM, 1996; HSE, 1999b; TnG, 2002).

*Obtaining a default value from the normalized distributions*

As there are multiple data sets within a particular grouping of exposure scenarios, denote the mean, standard deviation and 75th percentile of the *i*th log-transformed, normalized data set by $\mu_i$, $\sigma_i$ and $z_i$. To obtain a default value from the normalized 75th percentiles it is worth noting that $z_i = \mu_i + 0.6745\sigma_i$ has standard error that is approximately proportional to $1/\sqrt{n}$. This suggests taking a weighted average of the $z_i$ with each $z_i$ having weight $\sqrt{n_i}$. That is, taking weights that are approximately inversely proportional to their standard error. Thus

$$z_{\text{default}} = \frac{\sum \sqrt{n_i} z_i}{\sum \sqrt{n_i}}$$

The final default exposure value is then given by $\exp(z_{\text{default}})$. This is equivalent to

$$\text{default value} = \left( \prod \exp(z_i)^{\sqrt{n_i}} \right)^{1/\Sigma\sqrt{n_i}}$$

This may be recognized as a weighted geometric mean. Intuitively, a weighting of $\sqrt{n}$ seems reasonable. It is obvious that for a reliable default value more emphasis should be placed upon the 75th percentiles, which are based upon larger datasets, as there is less uncertainty associated with these. Equally, two separate exposure scenarios each with (say) 10 measurements are more valuable than 20 data points from just one scenario. An example of

Table 6. Data sets for handling of contaminated objects (liquids)

| Study | Body part | Routes of exposure | | | Modifiers of exposure | Data points | GM[a] (mg/cm²/h) | GSD | 75th percentile[a] (mg/cm²/h) |
|---|---|---|---|---|---|---|---|---|---|
| | | DC | SC | DEP | | | | | |
| Solvent based timber pre-treatment (Garrod *et al.*, 1999) | Body | 0 | 100 | 0 | Solvent, objects touch dry | 17 | 0.163 | 4.33 | 0.439 |
| Water based timber pre-treatment (Garrod *et al.*, 1999) | Body | 0 | 100 | 0 | None | 45 | 0.119 | 4.44 | 0.321 |
| De Vreede and Van Amelsfort (1997b) | Hands | 30 | 70 | 0 | None | 12 | 4.45 | 6.95 | 16.46 |
| Guiver *et al.* (2000) | Body | 0 | 100 | 0 | None | 9 | 0.069 | 2.16 | 0.209 |
| Ancillary antifoulant spraying tasks (HSE, 1999b) | Hands | 30 | 70 | 0 | Solvent suspension | 7 | 0.321 | 2.90 | 0.659 |
| | Body | 20 | 50 | 30 | | 30 | 0.020 | 5.16 | 0.059 |

[a]Denotes normalized geometric mean and 75th percentile.

Table 7. Data sets for immersion (liquids)

| Study | Body part | Routes of exposure | | | Modifiers of exposure | Data points | GM[a] (mg/cm²/h) | GSD | 75th percentile[a] (mg/cm²/h) |
|---|---|---|---|---|---|---|---|---|---|
| | | DC | SC | DEP | | | | | |
| Mariculture—solvent (Guiver *et al.*, 1999) | Body | 50 | 50 | 0 | Solvent | 5 | 0.141 | 3.91 | 0.353 |
| Mariculture—water (Guiver *et al.*, 1999) | Body | 50 | 50 | 0 | None | 4 | 0.662 | 3.33 | 1.490 |
| Timber (Guiver *et al.*, 1999) | Body | 50 | 50 | 0 | None | 5 | 0.150 | 5.23 | 0.458 |
| Sheep dipping (Niven *et al.*, 1994) | Body | 50 | 50 | 0 | Saturated objects/complete contamination | 28 | 0.323 | 5.52 | 1.023 |
| Textiles (Guiver *et al.*, 1999) | Body | 50 | 50 | 0 | Partial automation | 5 | 0.047 | 15.88 | 0.303 |
| Leather (Guiver *et al.*, 1999) | Body | 50 | 50 | 0 | None | 5 | 0.046 | 19.09 | 0.334 |

[a]Denotes normalized geometric mean and 75th percentile.

deriving the default value from the normalized 75th percentiles is given in the Appendix.

*Strategy for default values in the absence of quantitative exposure data*

A panel of occupational hygienists independently considered the generic task groupings without quantitative exposure data and assigned them to the qualitative exposure categories. A default exposure value was then derived by averaging the midpoints of the exposure ranges that corresponded to the qualitative exposure assessments.

## RESULTS

The literature data sets used for the derivation of the default values are summarized in Tables 1–7. Each table refers to a particular grouping of tasks—e.g. Table 1 is for spray dispersion of liquids—and gives the number of data, geometric standard deviation, normalized geometric mean and 75th percentiles. Also included are the subjective assessments of the contributions to exposure via each route and the determined modifiers of exposure. There is some variation in the supposed routes of exposure within studies grouped under the same generic task This reflects some subtle differences between the studies that are lost in the groupings of exposure scenarios. Table 8 lists the contributions to total exposure by route of exposure (as used in the toolkit) for each of the generic groupings of tasks.

With the exception of spray dispersion of liquids, there is reasonable agreement between the studies within each DEO unit. The normalized 75th percentiles are within an order of magnitude of one another when comparing the same body parts. As each qualitative exposure band covers one order of magnitude, the literature data provide a consistent basis for deriving default exposure values.

Table 9 gives the quantitative default values for use in the risk assessment toolkit along with their qualitative ranking (Table 10 gives the quantitative exposure ranges that correspond to each exposure banding). The entries in roman type have been derived by taking a weighted average of the 75th percentiles of each normalized literature study (Tables 1–7). Entries in italics denote those where adequate literature data could not be found. These default values have been assigned by the panel of occupational hygienists. In all instances, exposure rates to the

Table 8. Percentage contributions from each route of exposure

| Task group | Body | | | Hands | | |
|---|---|---|---|---|---|---|
| | DC | SC | DEP | DC | SC | DEP |
| Handling contaminated objects (solid) | 0 | 60 | 40 | 20 | 50 | 20 |
| Handling contaminated objects (liquid) | 0 | 100 | 0 | 0 | 100 | 0 |
| Manual dispersion of solids | 40 | 40 | 20 | 50 | 50 | 0 |
| Manual dispersion of liquids | 50 | 50 | 0 | 50 | 50 | 0 |
| Hand tool dispersion | 20 | 50 | 30 | 30 | 40 | 30 |
| Spray dispersion | 0 | 30 | 70 | 0 | 60 | 40 |
| Immersion | 50 | 50 | 0 | 50 | 50 | 0 |
| Mechanical treatment | 0 | 30 | 70 | 0 | 60 | 40 |

Table 9. Default exposure values by task group (mg/cm$^2$/h)

| Task group | (Qualitative) body exposure | (Qualitative) hand exposure |
|---|---|---|
| Handling contaminated objects (solid) | 0.50 *(high)* | 21.63 (very high) |
| Handling contaminated objects (liquid) | 0.20 (high) | 4.09 (high) |
| Manual dispersion of solids | 0.05 *(medium)* | 0.50 *(high)* |
| Manual dispersion of liquids | 0.05 *(medium)* | 0.12 (medium) |
| Hand tool dispersion of solids | 0.05 *(medium)* | 0.50 *(high)* |
| Hand tool dispersion of liquids | 0.02 (medium) | 0.74 (high) |
| Spray dispersion of solids | 0.06 (medium) | 1.40 (high) |
| Spray dispersion of liquids | 0.46 (high) | 1.07 (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)* |

Table 10. Qualitative default values

| 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 |

hands are higher than those to the rest of the body. This holds irrespective of whether the default value has been based upon quantitative exposure data or expert opinion. The qualitative rankings of exposure vary between medium to very high. These only refer to the default values used in the toolkit—lower rates of exposure will be obtained by specifying particular values for some of the exposure modifiers. Also, these default values represent potential exposure; clothing and the use of gloves will frequently result in actual exposure being assigned a lower exposure category. With the exposures for the hands being higher (per unit area) than the body, it follows that the risk assessments for local skin effects will be driven by the default values for the hands, except for occasions where gloves are worn but the worker is wearing only minimal clothing (such as shorts and a T-shirt).

## CONCLUSIONS AND FUTURE DEVELOPMENT

This paper adopts a framework developed in Oppl *et al.* (2003) and Goede *et al.* (2003) that accounts for variation in exposures through a task-based exposure assessment with multiplicative adjustments for particular modifiers of exposure. This methodology has been applied in reverse to obtain default exposure values from quantitative data. These values will inform a risk assessment toolkit developed especially for SMEs.

We believe that the subdivision of exposures into six generic categories of tasks, with a further division to acknowledge the differences in exposure to solid and liquid formulations, represents the best opportunity to derive quantitative default exposure values. Further division of the generic groups of exposure scenarios (DEOs) would lead to default exposure values based upon even smaller numbers of quantitative studies. Our groupings give default exposure values that are more robust to the specific circumstances unique to each individual exposure study.

We envisage that these default values and the modifying factors used in deriving them will be revised as new information becomes available. A major revision should be possible shortly using data from industry collected in the field studies that are being carried within the framework of the RISKOFDERM project. In particular, this data should allow the default values for manual dispersion and mechanical treatment (based upon expert opinion) to be replaced with ones derived from quantitative data.

## APPENDIX

Table A1 shows the correction factors for groups of modifiers.

*Derivation of default body exposure for handling of contaminated objects (liquids)*

Available studies:

Table A1. Correction factors for groups of modifiers

| Modifier | Description | Generic value | | |
|---|---|---|---|---|
| | | DC | SC | DEP |
| Transfer modifiers (source to skin) | | | | |
| Liquid is best described as | *Like water* | 1 | 1 | 1 |
| | *Like solvent* | 1 | 0.3 | 3 |
| | *Like oil, grease* | 3 | 3 | 0.3 |
| | *Like solvent suspension (thick but volatile)* | 3 | 3 | 3 |
| Moistness/adherence (solids only) | *Dry (like dry sand, flour or pellets)* | 1 | 1 | 1 |
| | *Moist (like moist flour or sand)* | 3 | 3 | 1 |
| Wetness/ contamination of objects | *Touch dry/small areas of contamination (<20%)* | 1 | 0.1 | 1 |
| | *Damp/ moderate to extensive areas of contamination (20–80%)* | 1 | 1 | 1 |
| | *Saturated/ complete contamination (>80%)* | 1 | 10 | 1 |
| Particle size(solids only) | *Like (dry) coarse sand* | 1 | 1 | 1 |
| | *Like (dry) flour* | 3 | 3 | 3 |
| | *Like (dry) granules/pellets* | 0.3 | 0.3 | 0.3 |
| General workplace modifiers | | | | |
| Temperature of process/substance (liquid) | *Substance/process at normal and elevated temperatures* | 1 | 1 | 1 |
| | *Liquids are heated* | 1 | 3 | 3 |
| Temperature of process/substance (solid) | *Substance/process at normal and elevated temperatures* | 1 | 1 | 1 |
| | *Metals are melted/welded/gouged* | 1 | 3 | 3 |
| Spraying of liquids (droplet size)[a] | *Little (very low) pressure causing large droplets* | 1 | 0.3 | 0.1 |
| | *'Normal' spraying of liquids* | 1 | 1 | 1 |
| Spraying of solids (particle size)[b] | *Strewing of course solids/granules/pellets* | 1 | 0.3 | 0.1 |
| | *Spraying/fogging of powder* | 1 | 1 | 1 |
| Restricted workspace | *Unrestricted workspace* | 1 | 1 | 1 |
| | *Restricted workspace* | 3 | 3 | 3 |
| Orientation of worker | *Work positioned at or below waist level* | 1 | 1 | 1 |
| | *Work positioned above waist level* | 3 | 1 | 3 |
| Amount of product | *Normal* | 1 | 1 | 1 |
| | *Small amounts (<1 fifth of normal)* | 0.3 | 0.3 | 0.3 |
| | *Large amounts (>5 times of normal)* | 3 | 3 | 3 |
| Control measure modifiers | | | | |
| Degree of automation | *No automation (fully manual)* | 1 | 1 | 1 |
| | *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 |
| | *Local exhaust ventilation* | 1 | 0.3 | 0.3 |
| Segregation | *No segregation* | 1 | 1 | 1 |
| | *Segregation* | 0.1 | 0.1 | 0.3 |
| Containment | *No containment* | 1 | 1 | 1 |
| | *Complete containment* | 0.001 | 0.001 | 0.001 |

[a]Only used for exposure scenarios classed under spray dispersion.
[b]Where more than one of automation, containment and segregation is present then the lowest (per route) of applicable correction factors is used.

Solvent-based timber pre-treatment (Garrod *et al.*, 1999). Normalized 75th percentile 0.223 mg/cm$^2$/h, 17 data.

Water-based timber pre-treatment (Garrod *et al.*, 1999). Normalized 75th percentile 0.321 mg/cm$^2$/h, 45 data.

Ancillary antifoulant spraying tasks (HSE, 1999b). Normalized 75$^{th}$ percentile 0.059 mg/cm$^2$/h, 30 data.

Antifoulant during net deployment (Guiver *et al.*, 2000). Normalized 75th percentile 0.209 mg/cm$^2$/h, 9 data.

$$\text{default value} = (0.223^{\sqrt{17}} \times 0.321^{\sqrt{45}} \times 0.059^{\sqrt{30}} \times 0.209^{\sqrt{9}})^{1/\sqrt{17}+\sqrt{45}+\sqrt{30}+\sqrt{9}} = 0.172\,\text{mg/cm}^2/\text{h}$$

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