TNO Nutrition and Food Research Institute
Occupational Toxicology

Lange Kleiweg 139
2288 GJ Rijswijk
Postbus 5815
2280 HV Rijswijk
Fax 015 284 39 72
Telefoon 015 284 28 42

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Skin exposure to calcium carbonate in the paint industry
Preliminary modelling of skin exposure levels to powders based on field data

Authors:
C.J.M. Lansink, M.S.C. Beelen,
J. Marquart and J.J. van Hemmen

Drafted by:
C.J.M. Lansink, M.S.C. Beelen

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1 Samenvatting

In deze studie is onderzoek gedaan in de verfindustrie naar huidblootstelling aan poedervormige stoffen. Het belangrijkste doel van deze studie was het vinden van de spreiding waarin huidblootstelling aan de handen voorkomt. Deze gegevens zouden een bijdrage kunnen leveren aan het nuanceren van de huidige modellen en aan het formuleren van defaultwaarden voor huidblootstelling. Op dit moment worden voor de beoordeling blootstelling aan bestaande en nieuwe stoffen 2 blootstellingsmodellen gebruikt, te weten: Het EASE model en het US EPA dermale blootstellingsmodel. Naast het vinden van de spreiding in de huidblootstelling, is een aantal andere onderzoeksvragen geformuleerd:

- is er een relatie tussen het blootstellingsniveau en het aantal contacten, blootstellingsduur of de hoeveelheid produkt die gehanteerd of verwerkt wordt?
- hoe groot is het blootgestelde oppervlak van het lichaam tijdens die handelingen?
- welke blootstellingsbeïnvloedende factoren kunnen daarnaast nog onderscheiden worden?

Op basis van een aantal criteria is besloten het onderzoek in de verfindustrie plaats te laten vinden en calciumcarbonaat als modelstof te gebruiken. Bij de verffabrikanten zijn de volgende handelingen bemeten:

- het ophalen van grondstoffen uit het grondstoffen magazijn;
- het handmatig afwegen van hoeveelheden poedervormig calciumcarbonaat;
- het handmatig toevoegen van het poedervormige calciumcarbonaat;
- het verzamelen van de lege zakken;

Het doel van het onderzoek was deze handelingen 20 keer te bemeten bij 10 verschillende verffabrikanten. Dit doel is uiteindelijk alleen gehaald voor het handmatig toevoegen. De huidblootstelling varieerde voor de verschillende handelingen als volgt: ophalen van grondstoffen: 138-1090 mg; handmatig wegen: 247-2411 mg; handmatig toevoegen: 123-4214 mg; verzamelen van lege zakken: 52-1042 mg. Het handmatig wegen is vanwege het kleine aantal metingen niet meegenomen in de analyse van de blootstellingsbeïnvloedende factoren.

De variatie in de huidblootstelling tijdens het verzamelen van de ruwe materialen kan waarschijnlijk volledig worden verklaard uit verschillen in procesvariabelen als werkhandelingen en hygiëne op de werkplek. Bij de statistische analyse kon geen verband worden aangetoond tussen blootstelling en de variabelen duur, aantal gehanteerde zakken en totaal aantal contacten.
De variatie tijdens het handmatig toevoegen lijkt voor een groot deel bepaald te worden door het aantal gehanteerde zakken. Uit de lineaire regressie kwam deze variabele als sterkste naar voren (R^2=0.76). De variabelen duur, totale hoeveelheid gehanteerde calciumcarbonaat en totaal aantal contacten konden eveneens als blootstellingsbeïnvloedende factoren worden aangemerkt. Deze relaties waren echter niet zo sterk, en werden bovendien beïnvloed door het aantal gehanteerde

zakken. De factoren afzuiging en diameter van de mengkuip konden niet als blootstellingsbeïnvloedende factoren worden aangemerkt.
De variatie tijdens het verzamelen van de lege zakken werd eveneens beïnvloed door het aantal gehanteerde zakken. Aangezien deze relatie niet zo sterk bleek, zijn er mogelijk ook andere blootstellingsbeïnvloedende factoren aan te wijzen. Hierbij kan gedacht worden aan proces variabelen als werkmethode en hygiëne op de werkplek. Duur en aanwezigheid van afzuiging konden niet worden aangemerkt als blootstellingsbeïnvloedende factoren.

Op dit moment is het maken van een vergelijking met de bestaande huidblootstellingsmodellen niet goed mogelijk, want:
- het effect van herhaalde contacten is niet meegenomen in het onderzoek;
- het is niet zeker of en wanneer verzadiging van de huid of de handschoenen optreedt, waarschijnlijk wordt na verloop van tijd een steeds groter deel van de huid blootgesteld;
- het is niet duidelijk of de opnamecapaciteit van de handschoenen groter of kleiner is dan die van de huid, de verwachting is dat deze groter zal zijn;
- in EASE is niet duidelijk wat wordt bedoeld met een enkel contact en hoe de blootstelling verandert met een toenemend aantal contacten.

Bovenstaande punten zouden in vervolg onderzoek uitgezocht dienen te worden.

Het EPA model lijkt de blootstelling bij het storten echter in belangrijke mate te overschatten.

1 Summary

In this study skin exposure to powdered agents in the paint industry is investigated. The main target of this project was to establish the range in which skin exposure to powders exists by gathering skin exposure data and related data in the field. This information could be used to validate the present skin exposure models and to construct modified or new approaches. At the moment two models are used to assess the dermal exposure to new or existing substances: the EASE model and the US EPA dermal exposure model. Next to the search for the range in which skin exposure exists, some other questions were formulated:

- is there a clear relation between the exposure level and the number of contacts, duration of exposure or quantity of a product handled or processed?
- what is the area of the exposed skin in the different activities?
- which other exposure modifiers could be distinguished and what is their relation to the exposure level?

Based on some criteria a choice was made for the study to take place in the paint industry and the guidance substance to be calciumcarbonate ($CaCO_3$). The following activities were measured during this study:

- collection of the raw material;
- manual weighing;
- manual dumping of the $CaCO_3$;
- collection and removal of empty bags.

The target was to take 20 measurements per activity in 10 different paint factories. This target was only reached for the manual dumping.
The skin exposure ranged for the different activities as follows: collection of the raw material: 138-1090 mg; manual weighing: 247-2411 mg; manual dumping: 123-4214 mg; collection and removal of empty bags: 52-1042 mg. Since the manual weighing was measured only 6 times, it was not taken along in the analysis of the exposure modifying factors.

The variation in the measured values during the collection of the raw material is probably caused by personal workplace methods and workplace hygiene. No correlation could be found between the exposure and duration, number of bags handled and frequency of total contacts.
The greatest part of the variation in the measurements of the manual dumping could be explained by the number of bags handled (R^2=0.76). Duration, total amount of $CaCO_3$ handled, and frequency of total contacts were also exposure modifiers, their relation was however not so strong and they were probably influenced by number of bags handled. Factors such as LEV and diameter of the dumping opening, could not be classified as exposure modifiers.
The variation in the measured values during the collecting of empty bags could partly be explained

by number of bags handled. Since this relation is not so strong (R^2=0.44), process variables such as workplace hygiene and working methods are probably also important exposure modifiers. Duration and LEV could not be classified as exposure modifiers.

At this stage of investigation it is very hard to compare the measured values to the values derived from the dermal exposure models (EASE and US EPA model). The following reasons can be given:

- in this investigation the effect of repeated contact is not measured;
- it is not certain if or when saturation of the skin and the gloves occurs, probably the exposed area of the hands will increase with increasing duration;
- It is not certain if the capacity to retain the powder for the gloves is bigger or smaller than that of the skin, it is expected that the capacity to retain the powder for the gloves is bigger than for the skin of the hands;
- in the EASE model it is not transparent what is meant with one contact and how the exposure changes with increasing number of contacts.

Above mentioned factors should be examined in following research.

The EPA model, however, appears to overestimate the exposure level during manual dumping severely.

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1 Introduction

In the assessment of risks for workers from exposure to chemicals the assessment of occupational exposure on a screening level is an important element. The aim of the assessment of occupational exposure and resulting risk in the scope of Commission Directive 93/67/EEC and Council Regulation [EEC] No. 793/93 is to establish the category into which a "new substance" or "existing substance" according to the Directive has to be assigned, based upon potential occupational exposure and the hazards of the substance.
Screening level assessment of skin exposure is possible using a skin exposure model that exists in two versions. The model presented by US Environmental Protection Agency [US EPA] [Versar, 1984] can be used for calculating skin exposure to liquids and powders. It is based on the idea that exposure is a function of the area of the hands that comes into contact with a substance and the amount of substance that adheres to the skin (per cm^2 of skin). The exposure level due to one contact is assumed to be the exposure level per day, unless specific information (e.g. rapid uptake through the skin) leads to modification of this value. The amount of product adhering to the skin is derived from experimental studies with a number of liquids with different viscosities. For more detailed information see appendix 1.
The UK Health and Safety Executive [UK HSE] has modified this model to include the effect of multiple contacts (EASE model = Estimation and Assessment of Substance Exposure) [Versar, 1984]. The number of contact was categorized into a small number of categories and the exposure per cm^2 was made dependent on the category. This dependency was constructed on the bases of expert judgement. The HSE has excluded the area exposed from its version, so the end result of the HSE version is $mg/cm^2/day$. For more detailed information see appendix 2.
Furthermore the usefulness of both the EPA-model and its modification are based on experiments and not on knowledge of actual occupational skin exposure. Therefore, validation by measurements of exposure levels in a typical industrial situation is required.
Because skin exposure largely depends on the physical nature of the substance and the type of work being done and less on the chemical or toxicological nature of the substance, it is assumed that data regarding a powder of a substance can be used to assess skin exposure of various powdery substances used under the same conditions. Thus the substance studied is regarded as a model substance for exposure to any powder in the situations studied.

1.1 Review of literature

Skin exposure to chemical substances can contribute significantly to total absorbed or systemic dose in many workplace situations. The relative importance of the skin exposure route will increase

when airborne occupational exposure limits are reduced [Fenske, 1993].
Almost all data reported about exposure to powders regard levels of exposure via inhalation of airborne dust. Some of these data are given below. Cooper (1989) studied the control of dust exposures associated with packaging operations (filling of bags with dry material and subsequent handling operations). At a manual packaging station the personal exposure level to a crystalline silica material was 0.19 mg/m^3 (arithmetic mean, standard deviation of 0.18). In another study of Cooper and Gressel (1992) it was found that pushing empty bags into barrels for subsequent disposal was the major dust source; cutting open bags and lifting them to the emptying shelf of the dump station also were significant dust sources, but less important.
Heitbrink et al. (1989) investigated the correlation between a test for material dustiness with worker exposure for the bagging of different powders. Therefore air sampling data from a bag packing operation were gathered. The geometric mean of exposure levels to the different substances varied from 1.1 mg/m^3 to 16 mg/m^3. In another publication of Heitbrink et al. (1990) dustiness tests are applied for prediction of worker's dust exposure. It is concluded that variables such as work-practice, equipment maintenance and process leakage may have a greater effect upon dust exposure than "dustiness", since there was no apparent relationship between dustiness test results and dust exposure levels. Heitbrink and McKinnery (1986) also reported that bag opening, emptying and disposal can be done without a statistically significant elevation of the workers air contaminant exposure; however, when the exterior surfaces of unopened bags were contaminated, the handling of such bags increased dust concentrations (from a background below 0.1 mg/m^3 to about 1 mg/m^3).
Almost all skin exposure data reported regard exposure to pesticides. For registration purposes in the Netherlands estimates of 90th percentile for the potential skin exposure to pesticides are made by Van Hemmen (1992) for mixing and loading of solid formulations. The level of exposure is estimated as 2 g per hour.
Skin exposure can be distinguished in potential and actual skin exposure. Potential skin exposure is the total exposure of an individual, including the exposure of the clothing. The actual skin exposure is the amount on the skin, either directly or after penetration of clothing. In the remainder of this report the term skin exposure will be used, meaning potential skin exposure.

1.2 Aim of the study

The main target of this project is to establish the range in which skin exposure to powders exists by gathering skin exposure data and related data in the field. This information can be used to validate both versions of the skin exposure model and to construct modified or new approaches.

The study will try to answer the following questions.

1 What are the statistical distribution parameters (e.g. range, arithmetic and/or geometric mean) of the (potential) skin exposure of the hands and wrists for a number of predefined exposure scenarios?

2 Is there a clear relation between the exposure level and the number of contacts, duration of exposure or quantity of a product handled or processed?

3 What is the area potentially exposed in these exposure scenarios?

4 Which other exposure modifiers can be distinguished and what is their relation to the exposure level?

Since quantitative assessment of skin exposure in industrial situations has hardly ever been performed, except for pesticides, a very important goal of this study also was to show that this is practicable with existing methodology. It was intended to illustrate that useful quantitative data can be gathered and that such data can play an important role in the improvement of risk assessment for chemical agents.

2 Study design

The selection of a model substance and of the industry in which the study would be done depended on the following conditions. The approach of the study was to follow the "life cycle" of one model substance from production to end use. First of all, the study had to be in an industry were "new substances" or "existing substances" in the scope of the notification requirement (Dangerous Environmental Substances Act) were considered. Secondly, in the processes used there had to be moments of possible skin exposure. Thirdly, there had to be enough companies in the Netherlands to ensure sufficient cooperation. The chosen substance had to be suitable as a model for various substances with variable toxicity. This is assumed to be possible if the exposure is more related to the physical nature of the compound, the type of work and type of activity performed with the substance than to the chemical or toxicological nature of the compound. Finally there had to be a relatively simple analytical way to measure the substance in the appropriate media.

2.1 Exposure situation

Based on the above mentioned criteria a choice was made for the paint industry and the manufacturer of the raw material. In this industry "new substances" or "existing substances" are regularly applied and in the process of paint production different activities can potentially lead to skin exposure. In the Netherlands a sufficient number of paint producers is available. A small number of manufacturers of the raw material is present as well as a multitude of end users.
The chosen substance is calcium carbonate. It is a frequently used substance (powder) in the paint industry, non toxic when skin contact occurs and analytically simple to measure. Unfortunately, the few manufacturers of the raw material were not willing to cooperate. Measurements of exposure of end users were not feasible in the scope of this study.

Based on inquiries and visits of different factories the most important activities in the paint industry where skin exposure might occur are the following.

1 *Collection of the raw material.*
Manual collecting raw material (in bags), including bags of calciumcarbonate, on a pallet or (flat) car in the storehouse of raw material and transportation of the raw material to the place of production.

2 *Manual weighing.*
Manual weighing of amounts of calciumcarbonate (powder) out of bags, tons or cans on a balance and collecting the weighed amount in a bag or a can on e.g. a pallet.

3 *Manual dumping.*
Lifting the bag or the weighed amount of raw material (calciumcarbonate) from the pallet or (flat) car to the dump-shelf, cutting the bag and manual dumping the bag or cans in a tub or vessel;

5 *Collection and removal of empty bags.*
Collection and transportation of the empty bags to (e.g.) a container or bale-press and compacting the bags by pushing them in the container or placing them in the bale-press.

6. *Manual dumping and collection and removal of empty bags.*
Combination of bag dumping and collection and removal of empty bags.

7. *Drumming of powdered paint.*
Drumming of powdered paint in 25 or 50 pound bags, whereby the bags are closed by sewing them together.

2.2 Exposure modifiers

During the different activities skin exposure is influenced by exposure modifiers. Therefore information regarding the following presumed modifiers is gathered in the paint-factories:

1 duration of activity/exposure;
2 number of contacts with contaminated surfaces (bags or other contaminated surfaces);
3 amount of product handled in the exposure period;
4 fraction of the substance in the product;
5 registration of potential part of the body exposed (qualitatively);
6 sizes of packaging;
7 type of packaging;
8 diameter of tub or vessel or size of dumping-opening;
9 relative humidity of the workplace air in the vicinity of the worker sampled;
10 use of personal protective equipment;
11 control measures (such as local exhaust ventilation (LEV)).

2.3 Methods

2.3.1 Sampling

Skin exposure is monitored with 100% cotton gloves (200 g/cm², v.d. Wee, Riel, the Netherlands) with a cap of 28 cm to cover the forearm. The gloves were first washed in a launderette according to a normal procedure. This was followed by washing them twice with warm demi-water, rinse out with demi-water and shaking them twice in 1.2 N HCl to avoid contamination of the gloves with calciumcarbonate from washing water. This was followed by rinsing three times with demi-water. The gloves were dried at least 24 hours in a stove at 70 °C (SOP: DATV/AT/019 Cleaning of textile matrices for measuring dermal exposure).

During the different activities (activity 1 to 7) the workers wore the cotton gloves till the activity finished. When the activity took longer than 30 minutes, new sampling gloves were supplied. During dumping of the raw material (activities 3 or 4) only sampling gloves were worn when calcium carbonate was dumped. After the activity (e.g. collection and removal of empty bags) was finished gloves were carefully removed from the hands of the workers by the investigator and stored by pair in a polyethylene 1-litre bottle (SOP: DATV/AT/006 Monitoring dermal exposure of the hands with cotton gloves).

2.3.2 Chemical Analysis

The chemical analysis of the field samples was developed and performed by our own laboratory. The gloves were analyzed directly or stored in the refrigerator. In the refrigerator the samples are stable for 2 months.
The measuring of calcium carbonate was performed with the atomary absorption spectrometry (AAS) flame technique, because with the help of this method calcium carbonate can be determined relatively simple. On basis of the Ca concentration the concentration calcium carbonate can be calculated. (0.4 g Ca corresponds with 1 g calcium carbonate). To prevent interaction with other metals, 1% lanthanum chloride was added to all samples.
The samples were extracted with 1.2 N HCl and then analyzed with the help of the AAS Perkin Elmer, type 5000, with background correction, at a wavelength of 422.7 nm. The detection limit is 0.1 mg calcium carbonate.
The background of the gloves after rinsing with HCl and demi-water became less than 0.1 mg. The recovery for the extraction of the gloves is between 95 and 103%.
The within-day variation for this method is less than 5%.

2.3.3 Exposure modifiers

Most information about exposure modifiers was sampled by observations. Registration of the duration of the different activities (in minutes) took place, as well as of the amount of product handled in the exposure period (counting of bags of calcium carbonate multiplied by weight per bag) and type of packaging (paper or other). The potential part of the body exposed was indicated on a standard form by encircling the part of the body which was potentially exposed. The number of contacts of the hands with contaminated surfaces (bags or other) was scored once during each activity, for a period of at least 5 minutes. Diameter of tub or vessel or size of dumping-opening (in cm) was registered. Use of personal protective equipment and control measures were registered. A subjective judgement was made of the effectiveness of the local exhaust ventilation at the dumping-opening (if present). The relative humidity of the air was measured with the Humidity and Temperature Probe HMP 32UT (Vaisala, Helsinki, Finland).
A sample of the calcium carbonate handled was taken and analyzed to determine the fraction of the substance in the product. In appendix 4 a sample of the standard registration form (in Dutch) is given.

2.4 Sampling strategy

2.4.1 The paint industry

Per activity 20 measurements would be taken to provide a more or less accurate estimation of distribution parameters of exposure levels. To include sufficient possible variation between workers, facilities and possible exposure modifiers, the measurements were done in 10 different paint factories (two different workers per factory).

During the fieldstudy fieldblanks and fieldspikes were taken to study contamination and stability under influence of moisture, temperature and light of the model substance during fieldwork, transport of the samples en storage of the samples. Every sampling day one field blank and two field spikes was taken (SOP: DATV/AT/017 Taking samples in fieldstudies to determine the source strength).

2.5 Statistical processing of data

The software used during the study were Lotus 123 (version 2.4) for making the database and Solo 4.0 for statistical analysis.

Limits of detection

The limit of detection is based on the fieldblanks. The limit of detection is calculated on the average of the fieldblanks summed with three times the standard deviation of the field blanks.

Recovery

Stability of calcium carbonate during the fieldwork, the transport and storage is based on the fieldspikes. Percentages of recovery are calculated, based on the amount spiked on the glove and amount analytically recovered.

Statistical distribution parameters

The statistical distribution parameters (e.g. range, arithmetic and/or geometric mean, standard deviation, minimum and maximum, 90-percentile values) of the (potential) skin exposure of the hands for the exposure scenarios are calculated.

Influence of the exposure modifiers

Before the exposure modifiers were analyzed, outliers were classified. Outliers are measurements which exceed the distribution extremely and therefore have a unwanted large influence on the results of the analysis, leading to unstable estimation of parameters. Outliers might occur when an activity is performed under different circumstances than normal. To study influences of specific factors, outliers are excluded from the analysis. For a proper use of the (multiple) linear regression analysis, it is essential that the analyzed values belong to the same group (outliers do not belong to the group because the activity is performed differently than normal).

By (multiple) linear regression analyses the influence of variation in exposure modifiers on the variation in exposure level is studied. The main condition for the (multiple) linear regression analysis is that the residues are distributed normally.
The following relation between the dependent and the independent variable exists in a statistical regression-model:

$$Skin\ exposure\ (mg/activity) = c + \beta_1 * var_1 + \beta_2 * var_2 + ... \beta_n * var_n$$

in which

c : constant;

ß : regression coefficient;

var : independent variables.

The square of the correlation coefficient (R^2) indicates the amount of variation in the dependent variable (skin exposure) explained by the independent variables (exposure modifiers). This procedure can be performed for the following continuous and dichotomous variables.

1 *Continuous variables.*
duration of exposure (minutes),
amount of calciumcarbonate handled (kg),
number of contacts (number),
relative humidity (%) (added moisture might build a liquid layer in particle surfaces, increasing this layer should increase the capillary binding force. Though this may not be relevant for calcium carbonate, it may be influential for hygroscopic substances, this factor was considered in case a very high relative humidity would be observed);
diameter or size of the vessel (cm or cm^2).

2 *Dichotomous variables.*
Size of package (25 kg or more),
type of package (cardboard bag or other),
presence or absence of control measures;
type of local exhaust ventilation (point ventilation or other ventilation);
effectiveness of local exhaust ventilation (good or bad);

Dichotomous variables were also analyzed by multiple linear regression. For this analysis dummy variables were used.

The (multiple) linear regression analysis was done as follow:
First, the variables duration, bag count and amount of calcium carbonate handled, are analyzed on their correlation with exposure. When it turns out that these variables are mutually correlated, then they have to be analyzed separately with linear regression (a condition for the multiple regression is that the independent variables should not be too strongly correlated). When there is a correlation between exposure and one of above-mentioned factors duration, bag count or amount of calcium carbonate handled, the exposure values can be adjusted for the correlated factor. This value may

give a better picture of the exposure, some sort of standardization exists. This will be outlined later in this paragraph.

The next step is that the multiple regression will be performed on the remaining variables (LEV, size packaging etc.) and one of the above mentioned factors (duration, bag count or amount of calcium carbonate handled), which has the best correlation with the exposure (only if it is a significant correlation), as the independent variables (one variable at the time). When it turns out that the independent variables (remaining variable and the variable duration, bag count or amount of calcium carbonate handled) are correlated, linear regression is performed with the remaining variable as independent and the exposure as the dependent variable. The reason for above mentioned method of analysis and the adjustment of the exposure with one of the exposure modifiers is the fact that the activities in general are not performed 'standardized'. By analysing the way just described this sort of standardisation is artificially created.

An example for the not 'standardized' method is the following. The manual dumping for example will not always be performed with the same number of bags during the same time. When the dumping of bags in the presence of LEV, for example, is always performed with less bags than the dumping of bags without LEV, it is expected that a significantly relation will always be found between exposure and exhaust ventilation, this may be an artifact because of the relation between the number of bags handled and the presence of LEV.

3 Results

3.1 Introduction

Skin exposure was measured in 10 factories of the paint industry. Measurements were done during the collection of raw material, manual weighing, manual dumping, collection and removal of empty bags, manual dumping and collection of empty bags at once, and drumming of powdered paint.
In table 1 the number of measurements are reported.

Table 1: Number of measurements on skin exposure during different scenarios in the paint industry.

Activity	Number of measurements
Collection of raw material	13
Manual weighing	6
Manual dumping	22
Collection and removal of empty bags	17
Drumming of powdered paint	2
Manual dumping and collection of empty bags	3

As can be seen from the above table, the investigation was not successful in reaching 20 measurements for each activity. This especially regards manual weighing of calcium carbonate (n=6). For this activity only the distribution parameters will be determined.
The manual dumping and collection of empty bags at once and drumming of powdered paint will not be further discussed, because of the very small number of measurements. The small number of measurements were due to the fact that these activities were performed only occasionally in the paint factories.

Blanks
On each day of sampling 1 blank was taken. The mean of the blank samples was 0.17 mg. The limit of detection is the mean of the blanks plus 3 times the SD of the blank samples. The limit of detection based on 10 blanks was calculated as 0.86 mg.

Spikes

On each day of sampling two spikes were taken to determine the stability of the calcium carbonate during transport and storage. The recoveries varied for the high concentrations from 92% to 100% and for the lower concentrations from 24% to 100%; 24% is very low, but can be considered as an outlier, since the range of the other spikes was 84% to 100%.

3.2 Descriptive statistics

The following items of the different activities are described:

- manner in which the activity is performed;
- distribution parameters (geometric mean (GM), geometric standard deviation (GSD) (the measurements were more or less lognormally distributed), minimum (min) and maximum (max), 10th and 90th percentile).

In this study, the exposure to the body was investigated by observation. During the different activities was scored which part of the body, next to the hands, was exposed. Table 3 gives for the different activities the numbers in which a certain part of the body was observed to be exposed. The same holds for the use of protective equipment. Table 3 gives for the different activities the numbers in which dust control was available.

Below the results for the different activities are further described.

Collection of raw material

All workers in general performed this activity in the same way. Bags containing calcium carbonate were displaced from the storage to a pallet and then transported to the production.

The exposure during the collection of raw material ranged from 139 to 1090 mg with a 10th and 90th percentile of 243 mg and 1064 mg respectively. The geometric mean (GM) and geometric standard deviation (GSD) were 476 mg and 1.8, respectively.

Table 2: Score numbers for the part of the body exposed during the different activities

Scenario	n	Score numbers from the part of the body exposed					
		head	forearm hands	upper arm	torso stomach	upper legs	lower leg
Manual weighing	6	0	5	0	4	1	0
Collecting raw material	13	0	12	0	6	1	2
Manual dumping	22	1	20	0	17	3	6
Collecting empty bags	17	3	15	2	4	2	3
Dumping and collecting	3	1	3	0	3	1	0
Drumming	2	1	2	0	0	0	1

n: number of measurements

Table 3: Use of personal protective equipment for the different activities

Scenario	n	Scores of personal protective equipment used						
		gloves latex, vinyl	work-ing gloves	dispos-able mask	apron	safety goggles	half face mask	cap
Manual weighing	6	2	0	1	0	0	0	1
Collecting raw material	13	2	0	2	0	0	0	1
Manual dumping	22	4	4	13	1	2	1	1
Collecting empty bags	17	1	1	5	0	0	0	1
Dumping and collecting	3	2	0	1	0	0	0	0
Drumming	2	0	0	0	0	0	0	0

n: number of measurements

Manual weighing

All workers in general performed this activity in the same way. An opened bag was put on the weigher, the calcium carbonate was scooped from the bag into another bag and then the weighed calcium carbonate was placed on the ground or a pallet.

Exposure during manual weighing ranged from 247 to 2511 mg, with a GM and GSD of 685 mg and 2.5 respectively. Since only 6 measurements were available, no 10th and 90th percentile were calculated.

Manual dumping

Manual dumping of calcium carbonate was performed in different ways:

1 cutting the bag open, removing the top of the bag, lifting the bag to the dumping shelf, emptying bag into mixer, laying empty bag to the floor, or pushing it into an barrel;

2 lifting the bag to the dumping shelf, cutting the bag open, dumping the bag into the mixer, laying the empty bag to the ground, or pushing it into a barrel.

Three outliers were classified:

- During one dumping operation, bags contained only 53% calcium carbonate; furthermore it concerned the dumping of a granule, while during all other measurements it concerned powder;
- During another dumping operation the calcium carbonate was dumped out of 100 pound bags, furthermore the calcium carbonate was swept away from the dumping shelf into the mixer with the hands. This resulted in a very high exposure;
- During one dumping operation calcium carbonate was dumped out of 100 pound bags, whereby granules of calcium carbonate were pulverized with the hands and the spilled calcium carbonate was swept away from the dumping shelf into the mixer. These factors led to an extreme high exposure.

Above-mentioned values were not considered in the calculation of the GM and the GSD.

Exposure of the hands ranged from 123 to 4214 mg, with a GM and GSD of 888 mg and 2.5 respectively. The 10th and 90th percentile were 216 and 3046 mg.

Collection and removal of empty bags

During this activity empty bags were brought into a barrel or to a bale press; the exposure occurred by pushing the bags together.

Three outliers were classified:

- One sample was taken while a closed box was brought to the balepress. This resulted in hardly any contact with the empty bags, and so in an extremely low exposure;

- Two samples were taken while empty bags contained calcium carbonate with a purity of only 53%.

Above-mentioned values are not considered in the calculation of the distribution parameters.

Exposure of the hands ranged from 53 to 1042 mg, with a GM and GSD of 215 mg and 2.7 respectively. The 10th and 90th percentile were 55 mg and 1039 mg respectively.

In table 4 the distribution parameters for the different activities are given.

Table 4: Statistical distribution parameters of dermal exposure to calcium carbonate during the different activities

Activity		**mg**				
	n	**GM**	**GSD**	**Min**	**Max**	**10th-90th perc.**
Collecting raw material	12	476	1.83	139	1090	243-1064
Manual weighing	6	685	2.5	247	2511	n.d.
Manual dumping	19	888	2.5	123	4214	216-3046
Collecting empty bags	14	215	2.7	53	1042	55-1039

Min: Minimum
Max: Maximum
10th-90th perc.: 10th to 90th percentile
n.d.: Not determined

3.3 (Multiple) linear regression analysis

The following factors were examined (the activities for which the factors were analyzed are put in brackets):

- duration (collection of raw material, manual dumping, collection and removal of empty bags);
- number of bags handled (collection of raw material, manual dumping, collection and removal of empty bags);
- amount of calcium carbonate handled (manual dumping);
- LEV (collection and removal of empty bags);
- effectiveness of LEV (manual dumping; in all cases manual dumping was performed in the presence of LEV);
- diameter of the dumping opening (manual dumping);

- bag size, 25 or 50 kg bags (manual dumping);
- frequency of contacts (collection of the raw material and manual dumping);
- manner in which the empty bags are collected (collection and removal of empty bags).

The results of the above mentioned continuous factors are given below in table 5.

Table 5: Measured or observed values of the continuous variables.

Activity / Modifying factor	Duration (min)	Number of bags	Amount of $CaCO_3$ handled (kg)	Relative humidity (%)	Frequency of total contacts	Diameter of dump-opening (cm)
Collecting raw material	1-7 (2.5)	2-11 (7.5)	n.d.	36-74 (57)	2-33 (12)	n.d.
Manual weighing	2-5 (3)	n.d.	3-38 (16)	36-84 (65)	3-13 (9)	n.d.
Manual dumping	1-15 (6)	2-24 (8)	10-1000 (234)	36-77 (54)	4-42 (17)	25-100 (53)
Collecting empty bags	1-3 (1.5)	1-24 (10)	n.d.	36-77 (51)	n.d.	n.d.

( ): mean values.
n.d.: not determined

As can be seen, the potential exposure modifiers were not analyzed for all activities. When the factors were not analyzed they were of no concern for that activity; for some of them this is outlined below:
- during collection of raw material and collection of empty bags there was no contact with a known amount of calcium carbonate;
- during the collection of the raw material no local exhaust ventilation was present;
- number of contacts was not screened during the collection of empty bags.

The following factors were not analyzed at all:
- relative humidity of air; a small range was observed, so this could in the observed situations not be an exposure modifier;
- type of packaging: only paper bags were used.

Collection of the raw material

None of examined exposure modifiers had a significant correlation with exposure (number of bags handled R^2<0.001, p=0.93, duration R^2<0.001, p=0.98 and frequency of contacts R^2=0.22, p=0.15). The results are summarized in appendix 4.

Manual weighing

Since only 6 measurements were taken during the manual weighing, modifiers were not analyzed.

Manual dumping

When the multiple regression was performed, it turned out that another outlier could be classified, this value had a great impact on the regression. The reason why it concerned an outlier is not certain; during the measurements no abnormalities were observed.

A significant correlation was observed between exposure and the 'main' modifiers duration, number of bags handled and amount of calcium carbonate handled; put in brackets are the p-value and the square of the correlation coefficient:

- exposure and duration (R^2=0.45, p=0.002);
- exposure and number of bags handled (R^2=0.76, $p < 0.001$);
- exposure and amount of calcium carbonate handled (R^2=0.65, $p < 0.001$).

Above-mentioned R^2 and p-values are values derived from the linear regression, not from the multiple linear regression. The overall R^2 in the multiple regression was 0.77, which means that 77% of the variation in the values could be explained by duration, number of bags handled and total amount of calcium carbonate handled. Above-mentioned means that the exposure can be adjusted for duration number of bags handled and amount of calcium carbonate handled.

When these factors were analyzed together with multiple linear regression, it turned out that they are all related to each other. This can be illustrated by the correlations between the different modifying factors (table 6).

Table 6: Correlation among the exposure modifiers duration, number of bags handled and total amount of calcium carbonate handled

Modifying factor	Duration	Number of bags	Total amount of calcium carbonate handled
Duration	1.0000	0.7887	0.8366
Number of bags handled	0.7887	1.0000	0.8748
Total calcium carbonate handled	0.8366	0.8748	1.0000

Therefore it was concluded that the equation derived from the multiple linear regression analysis is not very useful, because the independent variables are correlated.

'Number of bags' had the highest regression coefficient, so the remaining modifiers (diameter of the tub or vessel, total number of contacts, LEV and bag size) were analyzed with exposure and number of bags handled. Number of bags handled and the remaining potential factors were the independent variables.

Frequency of total contacts was analyzed with linear regression, since there was a strong correlation between frequency of total contacts and number of bags handled.
Frequency of total contacts was the only factor, from the remaining potential modifying factors, which could be classified as a modifying factor based on regression analysis. The results of the regression analysis are given below, put in brackets are the p-values for the multiple (diameter of dumping opening, presence of LEV and bag size) and linear (frequency of total contacts) regression analysis and the square of the correlation coefficient of the multiple and linear regression analysis:

- frequency of total contacts (R^2=0.32, p=0.04)
- diameter of the dumping opening (R^2=0.01, p=0.8)
- presence of LEV (R^2=0.03, p=0.9)
- bag size (50 or 100 pound bags) (R^2=0.13, p=0.58)

The results are summarized in appendix 4.

Collection and removal of empty bags
From the linear regression it seemed that only number of bags handled explained a part of the variance in the measured values (R^2=0.44, p=0.01). Duration was not correlated to the exposure (R^2=0.06, p=0.40).
The influence of LEV and the manner in which the bags were collected were analyzed with multiple regression in which number of bags handled and the separate factors LEV and manner of collecting were the independent variables.
The results are given below:

- LEV (R^2=0.11, p=0.78);
- way in which the bags were collected (R^2=0.02, p=0.82).

None of the above-mentioned factors had a correlation with exposure.
The results are summarized in appendix 4.

The results of the statistical distribution parameters for the rightly adusted exposure values (in case possible) are summarized in table 7. Manual weighing is not entered in the table, because multiple regression analaysis is not performed on this activity.

Table 7: Statistical distribution parameters of the adjusted dermal exposure concentrations to calcium carbonate during the different activities

7a

Activity		mg/hour				
	n	GM	GSD	Min	Max	10th-90th perc.
Collecting raw material	12	n.a.	n.a.	n.a.	n.a.	n.a.
Manual dumping	19	10829	1.9	2893	32709	4317-26419
Collecting empty bags	14	n.a.	n.a.	n.a.	n.a.	n.a.

7b

Activity		mg/bag				
	n	GM	GSD	Min	Max	10th-90th perc.
Collecting raw material	12	n.a.	n.a.	n.a.	n.a.	n.a.
Manual dumping	19	126	1.7	39	527	47-217
Collecting empty bags	14	24	2.6	5.8	117	6.1-86.6

7c

Activity		mg/kg calcium carbonate				
	n	GM	GSD	Min	Max	10th-90th perc.
Collection raw material	12	n.a.	n.a.	n.a.	n.a.	n.a.
Manual dumping	19	5.0	1.7	1.6	19.2	1.9-8.7
Collecting empty bags	14	n.a.	n.a.	n.a.	n.a.	n.a.

Min: Minimum
Max: Maximum
10th-90th perc.: 10th to 90th percentile
n.a.: Not applicable

4 Discussion

4.1 Introduction

The results of the study clearly show that it is feasible to sample skin exposure (of hands and forearms) using pseudo-skin methodology in field studies. The results may not precisely represent the amount available for absorption through the skin. They are, however, meaningful for comparison with and improvement of empirically based exposure models. Analysis of relations with exposure modifiers indicate that the results can also be used to give guidance for control of skin exposure. The knowledge of skin exposure to powders is definitively increased by this study. Results from field studies such as this one will enable exposure assessors to reach more realistic and valid estimates of relevant skin exposure levels, either by direct comparison or through improved models.
The study reported here is only a small scale study of a certain type of activity to a certain type of chemical agent. More field studies will be needed to build a growing knowledge base on skin exposure. This is necessary to acheive - in the future - risk assessment regarding skin exposure of a quality that is more or less equivalent to the quality that is already possible for assessment of risks due to respiratory exposure to chemical agents.

The main target of this project was to find the range in which skin exposure exists by gathering skin exposure data and related data in the field. Next to this was analyzed if there exists a relation between exposure and some modifiers, such as duration, number of bags handled and total amount of calcium carbonate handled.
Furthermore some other modifiers were examined such as frequency of total contacts during the handling and diameter of the tub or vessel. Since there were not many measurements taken it is hard to determine a significant correlation between the exposure and the latter modifiers.
The exposure of other parts of the body than the hands was only observed, not qualified. It appears that contact of skin or clothing, apart form hands and forearms, mainly occurs with the torso/stomach and to a lesser extent with the legs. Since this observation was subjective it will not be discussed furthermore. For more detailed information it is necessary to investigate this item more detailed, for example with the whole body surrogate skin exposure monitoring. The use of protective equipment was generally very limited, apart from the use of disposable dust masks that was encountered in several cases. The use of protective equipment was only described, no qualification took place. It was not examined in what way the exposure was diminished by the use of protective equipment. This item will also not be discussed furthermore.

Below the different activities will be discussed.

4.2 Collecting raw material

The variation of the measurements for the skin exposure during the collection of the raw material is relatively low (138-1090 mg, GSD=1.8). This variation can not be explained by duration or number of bags handled, since no correlation exists between exposure and those factors. There is also no correlation between frequency of contacts and exposure.
The explanation could be that the most important factor for exposure during collection of raw material is the existing amount of dust on unopened bags. As seen in the literature contamination of exterior surfaces at unopened bags can lead to an increased dust concentration [Heitbrink and McKinnery, 1986], and an increased dermal exposure is also likely. Exposure also strongly depends on the hygiene in the workplace, the manner in which the bags are handled (breakage of the package probably leads to an extreme increase of the exposure) and the manner in which the bags have been packed (this determines the amount of dust on the bags).
In further research observation of the hygiene of the workplace is recommended.

4.3 Manual weighing

Since there are only 6 measurements taken, only the distribution parameters were determined. The range of the exposure during the manual weighing was: 247-2511 mg.

4.3 Manual dumping

The variation in the exposure data is relatively low (133-4214 mg, GSD=1.5). About 77% of the variation can be explained by duration, number of bags handled and total amount of calcium carbonate handled. From these exposure modifiers number of bags handled is the most important one (R^2=0.76). According to the linear regression, frequency of total contacts is also an exposure modifier. This is however debatable, because the screening is rather subjective, the factor may have a large error and it is related to number of bags handled.
The not-explained fraction of the variation is probably caused by factors, such as process variables and worker habits. After analysing diameter of the tub, LEV and bag size with multiple regression, it turned out that these variables were no exposure modifiers. The possible explanations for this are given below:

- non-standardized procedures; every worker performed the dumping in a different way; this may make it difficult to determine the effect of other modifiers: possibly the influence of personal working methods are more important;

- dumping openings are not very different for the different workplaces. In most cases the dumping opening is covered;
- local exhaust ventilation; the goal of LEV is generally prevention of inhalation exposure, during dumping of calcium carbonate; the hands are between the LEV and the dust emission source;
- bag size; dumping of 100 pound bags was observed only 3 times, the rest of the bags were 50 pound bags; this makes it difficult to determine a significant correlation between the bag size and exposure.

Comparison of the measured data with the dermal exposure models

Because manual dumping was measured most of all activities, the exposure data derived from the manual dumping were compared with the values derived from the EPA model and EASE.

For the comparison with the dermal exposure models the following factors were to be determined:

- what can be considered as one contact;
- what happens during repeated contact;
- contact level over the day;
- area exposed.

It has to be noticed that the method used in this investigation is one of a surrogate skin with a large adherence capacity (gloves probably retain a larger amount of calcium carbonate than the hands). The exposure measured with the help of the gloves could so result in an over-estimation of the real exposure. The following assumptions are made:

- one dumping operation is comparable with one contact;
- because it is unknown what the effect of repeated contact is, it is chosen to examine one contact, namely one bag dumping operation;

To consider a reasonable worst case situation the 90th percentile value is used to make an assessment. The assessed exposure per day is thus calculated to be 1063 mg. This assessed exposure holds for two hands and a part of the forearms.

In the US EPA dermal exposure model is defined that the area of two hands and a part of the forearm is about 1300 cm^2. The exposure assessed by the EASE and the EPA dermal exposure model is the following:

- EASE; wide dispersive use, direct handling and incidental contact (1 contact) leads to an exposure of 0.1-1 $mg/cm^2/day$. When the area of two hands is assumed to be 1300 cm^2, the assessed exposure becomes 130-1300 mg/day.
- EPA dermal exposure model; filling or dumping containers of powders, flakes or granules; 5-14 $mg/cm^2/day$, this leads to an exposure of 8000-22400 mg/day (the assessed exposure holds

for a single contact).

The assessment made by EASE and the calculation derived from the measured data do not differ very much, but some points are important to notice.

Both the EPA dermal exposure model as EASE are not based on actual exposure data, but on a small number of experiments whereby the hands are immersed in a liquid. The EPA considered one immersion as one contact; this however gives very high exposure levels. EASE tried to bring a correction in the model by introducing different contact levels. A disadvantage of this is that the incorporated influence of contact level is not based on theoretical or empirical data, but purely on expert judgment.
Furthermore, the fact that the workers may wash their hands between two exposure periods is probably not taken into account in the assessments made by EASE and the EPA dermal exposure model.

The exposure, based on present study, can not be assessed for repeated contacts, since it is uncertain how the exposure increases with increasing contact level. It is plausible to assume that the exposure will increase linearly to some extent and from a certain point increases less than linearly. It is even plausible to assume that from a certain point the surface of the hands (gloves) may be saturated with calcium carbonate, which means that there may be a balance between the product reaching the skin and the product leaving the skin. This balance also depends on the possibility of the product to penetrate through the skin. In the present investigation can be assumed that no penetration through the skin occurs.

4.4 Collection and removal of empty bags

There is a relatively large variation in the measured values during this activity (52-1042 mg GSD=2.7). A part of this variation could be explained by number of bags handled (44%), The explanation for this is the fact that the more bags are collected, the more dust may escape.
Duration is not an important factor during the collecting of empty bags, because the duration of the collection of 10, 20 or 30 empty bags is not very different. The bags are brought to the balepress or the box all together.
Variation in plant conditions, process variables, and work habits might also be important exposure modifiers.
No other exposure modifiers were classified, this could be explained as follow:

- manner of collecting the bags; in both cases (bringing the bags to the balepress or bringing the bags to a box) the exposure variability is probably caused by picking the bags up from the ground, whereby the bags are pushed together;

- LEV; LEV is only present at the bale press, the highest exposure, however, probably occurs when the bags are picked up to bring them to the bale press.

5 Conclusions and recommendations

Field studies regarding skin exposure are possible and necessary to improve and modify existing assessment methods. This study resulted in useful data regarding skin exposure to powders.
The exposure of the hands during the different activities are summarized in table 4, and range from 52 to 4214 mg. Below the ranges for the different activities are given:

- collection of the raw material: 138-1090 mg;
- manual weighing: 247-2511 mg;
- manual dumping: 123-4214 mg;
- collection and removal of empty bags: 52-1042 mg.

The largest part of the variation in the collection of the raw material is probably caused by personal working methods or workplace hygiene.
The most important exposure modifier for the manual dumping is probably the number of bags handled. From the linear regression it turned that exposure and number of bags handled are strongly related (R^2=0.76).
For the collection and removal of empty bags, the number of bags was classified as an exposure modifier. Since this relation was not very strong (R^2=0.44) workpractice and hygiene are probably, next to the number of bags handled, also important exposure modifiers.

At this stage of the investigation it is hard to compare the measured values to the values derived from the dermal exposure models. The following reasons can be given:

- in this investigation the effect of repeated contacts is not measured;
- it is not certain if or when saturation of the skin and the gloves occurs and if or when penetration through the skin occurs;
- in EASE is not transparent what is meant with one contact and how the exposure changes with increasing amount of contacts;
- gloves may retain more powder than the skin does, this is however not examined.

A tentative conclusion is, that the EPA model appears to overestimates the exposure level severely. In future research the above-mentioned factors, effect of repeated contact, the possibility of the skin to saturate, and the difference between gloves and skin in retaining powder should be studied. Furthermore, factors as plant conditions, work practice and hygiene should be considered in further research. Finally from, the dermal, exposure models a better insight is required on what is meant by one contact and how the exposure increases with increasing number of contacts.

Apart from the factors already mentioned, it is recommended to enlarge the scope of the skin exposure field studies to other powders, other activities (e.g. bagging) as well as to several types of liquids and aerosols (mists) in relevant situations. International cooperation, within Europe, as well as with other countries, is recommended for an efficient gathering of data.

Aknowledgement

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Justification

Authors:

Drs. C.J.M. Lansink
Occupational hygienist

Date: 6-5-1996

Drs. M.S.C. Beelen
Occupational hygienist

Date: 5-6-1996

Ir. J.Marquart, RAH
Senior Occupational hygienist

Date: 5-6-1996

Dr. J.J. van Hemmen
Head, Department Occupational Toxicology

Date: . . - . . -1996

Appendix A: US EPA model for skin exposure

Introduction

The EPA skin exposure model, developed by US EPA, is a model for estimating skin exposure from direct contact of the hands with contamination. Exposure is calculated as mg/day for the hands.

Model

The model is a simple model that multiplies the surface area of contact (one or two hands) with the quantity typically remaining on the skin. Once it has been determined that skin contact is likely and no monitoring data are available, the contact may be quantified by using the following equation:

$$D = S * Q * C$$

where: D = Skin exposure in mg

S = Surface area of contact in cm^2

Q = Quantity typically remaining on the skin in mg/cm^2

C = Concentration of chemical of concern in percent

The time of exposure is estimated qualitatively and the skin exposure calculated is then expressed as mg/day. The area exposed has to be derived from specific data or from a table of default values (table 1.1) provided by US EPA. The amount of substance adhering to the skin has been established in experimental research with liquids.

Default values

US EPA provides default values (see table 1.1) for estimating the amount of skin contact that may occur in particular situation, if such contact is not ruled out by factors such as temperature or corrosivity.

When using the default values in table 1.1, the exposure estimate should be adjusted by the following factors when applicable:

- concentration of the chemical in a mixture;
- percent of the hands exposed if less than what would be typically expected for the activity;
- rapid evaporation of the chemical (lessening exposure time);
- effect of an industrial hygiene programme(s).

Powders

For powders the exposure level is calculated as if the substance or preparation is a liquid substance or preparation. The result has to be presented with a warning statement regarding the unknown applicability of the results of the studies with liquids for powders.

Result: upper bound or reasonable worst case estimates

The result of the model using the default values is an upper bound estimate of the exposure level. It always presents the maximum amount on the skin of one or two hands. This should always be clearly stated. In practice exposure will often be limited to parts of the hand, lowering the total skin exposure compared to the model.

The result will be a reasonable worst case estimate if from specific information regarding the area exposed a reasonable worst case area is derived.

Table 1.1 Default values for the EPA skin exposure model

Type of contact	Typical example	Area exposed (S; cm^2)	Amount adhering to skin (Q; mg/cm^2)
Routine immersion, two hands	Handling wet surfaces Filling/dumping containers of powders, flakes, granules Spray painting	1300	5 - 14
Routine contact, two hands	Maintenance / manual cleaning of equipment Unloading filter cake Changing filter Filling drums with liquid	1300	1 - 3
Routine contact, one hand		650	1 - 3
Incidental contact, two hands	Connecting transfer line Weighing powder / scooping / mixing (e.g. dye weighing)	1300	1 - 3
Incidental contact, one hand	Sampling Ladling liquid / bench scale liquid transfer	650	1 - 3

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Appendix B: EASE model for skin exposure

Introduction

The EASE model, developed by the UK Health and Safety Executive, can partly be seen as an extension of the ad hoc analogy approach. The UK HSE has modified the model of US EPA, that is supported by empirical studies with liquids, to include the effect of multiple contacts (Versar, 1984).

Model

From the UK National Exposure Data Base and studies and ideas reported by the US Environmental Protection Agency (EPA) data for combinations of substances and situations, assigned to categories for the same aspects, have been studied by experts from the HSE. These experts have derived generic exposure values for relevant combinations of these aspects.

The number of contacts of the skin with the contaminant is an important parameter in the assessment of skin exposure. For the assessment of skin exposure to solid substances no theoretical or empirical supporting data are provided.

Table 2.1 is derived for assessment of potential skin exposure.

Table 2.1 Determination of skin exposure

Physical state	Pattern of use	Pattern of control	Contact level (mg/cm²/day)			
			None	Incidental	Intermittent	Extensive
gas, vapour or not dusty solid			very low	very low	very low	very low
liquid, aerosol (solid or liquid) or solid	closed system		very low	very low	very low	very low
	inclusion on to matrix or non-dispersive use	not direct handling	very low	very low	very low	very low
		direct handling	very low	0 - 0.1	0.1 - 1	1 - 5
	wide dispersive use	not direct handling	very low	very low	very low	very low
		direct handling	very low	0.1 - 1	1 - 5	5 - 15

Powder

The value of empirical data from liquids for exposure to powders has not been evaluated.

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Appendix C: Standard registration form

Page 1/2

No:

Bedrijfsnaam :
Bedrijfsnummer :

Naam werknemer :
Nummer werknemer :

Meetgegevens dermale blootstelling:

Handeling : Ophalen / Afwegen / Toevoegen / Verzamelen*
Starttijd : . uur Eindtijd : . uur
Aantal zakken : à kg merknaam: korrelgrootte:
zakmonsternummer:
à kg merknaam: korrelgrootte:
zakmonsternummer:
à kg merknaam: korrelgrootte:
zakmonsternummer:
Afgewogen : * kg merknaam: korrelgrootte:
zakmonsternummer:
* kg merknaam: korrelgrootte:
zakmonsternummer:
* kg merknaam: korrelgrootte:
zakmonsternummer:

Monsternummer HS :
RV-lucht (%) :
Diameter mengkuip of grootte stortgat bij toevoegen:

Beheersmaatregelen en PBM:

Afzuiging aanwezig : Ja/Nee*
Type afzuiging : Punt/Anders
Wordt de afzuiging gebruikt : Ja/Nee
Hoe is de effectiviteit : Goed/ /Slecht
Welke PBM worden gebruikt of anders n.l.: : Latex of vinyl handschoenen / Werkhandschoenen / Snuitje / Bedrijfskleding / Coverall / Voorschoot / Veiligheidsbril

Aantal kontakten gedurende observatieperiode van 5-10 minuten:

Starttijd periode: . uur Eindtijd periode: . uur

Gecontamineerde oppervlak/voorwerp:	Kontakten per periode:
Zak(ken) (alleen indien $CaCO_3$)...............	
Andere gec. oppervlakken of voorwerpen.......	

Blanco monster:

Starttijd : . uur Eindtijd : . uur
Monsternummer :

Spike monsters (Hoog en Laag):

Belading spike 1 : mg Belading spike 2 : mg
Monsternummer : Monsternummer :

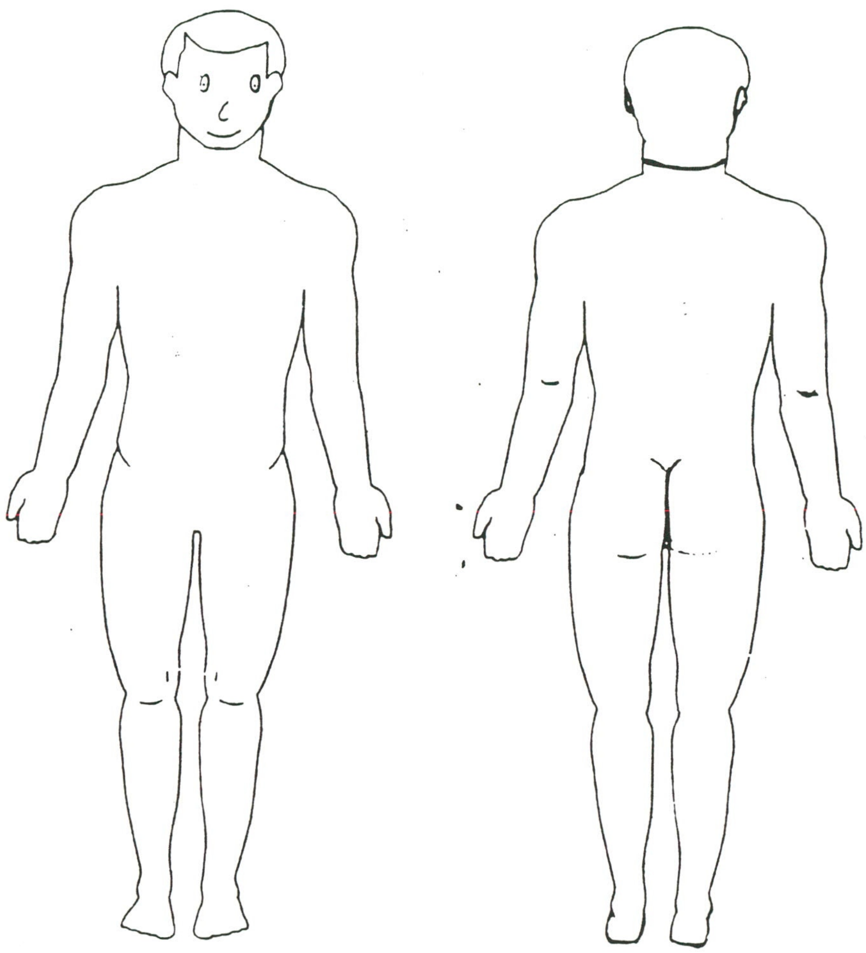
Onderzoeker(s): Para(a)f(en):

* Omcirkelen wat van toepassing is

Page 2/2 Standard registration form No:

Zichtbare blootstelling en/of kontakten:

Verontreinigingen inkleuren in de onderstaande figuren



Bijzonderheden gedurende de meting:

Onderzoeker(s):	Para(a)f(en):

Appendix D: Square of the correlation coefficients for the factors which at the begin of the study were remarked as exposure modifiers

Table 3.1: Square of the correlation coefficients for the most important exposure modifiers

Activity		Duration		Number of bags		Amount $CaCO^3$ handled	
	n	R^2	p-value	R^2	p-value	R^2	p-value
Collection of raw material	12	<0.001	0.98	<0.001	0.93	n.a.	n.a.
Manual dumping	19	0.45	0.002*	0.76	<0.001*	0.65	<0.001*
Collection of empty bags	14	0.06	0.40	0.44	0.01*	n.d.	n.d.

*: Significant correlation between exposure and modifying factor
n.d.: Not determined

Table 3.2: Square of the correlation coefficients for the remaining modifiers

Activity		LEV		Dump opening		Frequency of total contacts		bag size		Manner of collect-ing bags	
	n	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value	R^2-level	p-value
Collection raw material[a]	12	n.a.	n.a.	n.a.	n.a.	0.22	0.15	n.a.	n.a.	n.a.	n.a.
Manual dumping[b]	19	0.03	0.90	0.01	0.80	0.32	0.04*	0.13	0.58	n.a.	n.a.
Collection of empty bags[b]	14	0.11	0.78	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.02	0.82

a Compared to the total exposure
b Compared to the exposure/bag
* Significant relation with exposure
n.a. Not applicable
n.d. Not determined