POST-APPLICATION EXPOSURE OF WORKERS TO PESTICIDES IN AGRICULTURE

REPORT OF THE RE-ENTRY WORKING GROUP

Joop J. van Hemmen
Graham Chester
Paul Hamey
Juhani Kangas
Erik Kirknel
Wolfgang Maasfeld
John Perkins
John Phillips
Corina Schulze-Rosario

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SUMMARY

In this report, the results of an analysis of the available documents and publications relevant for assessing post-application exposure are presented. A generic model for dermal exposure with a tiered approach is proposed that can be used for risk assessment purposes in registration procedures for agricultural pesticides under Directive 91/414/EEC. Inhalation exposure is generally less important for post-application exposure, especially for outdoor scenarios. There is no generic model for inhalation exposure available. Preliminary approaches are presented for indoor inhalation exposures.

The first step in the assessment for *dermal exposure* makes use of a generic model with the following structure. The basis for the dermal exposure assessment related to the relevant scenario is formed by a multiplication of DFR (dislodgeable foliar residue), TC (transfer coefficient) and T (duration of the work). If no DFR data for the specific compound are available, DFR may be calculated from the application rate, divided by a reasonable estimate of the leaf area index (a possible default value for this is no larger than 2). In other cases, a highly conservative default value for the DFR may be taken as 3 $\mu g/cm^2$ for a standardised application rate of 1 kg/ha.

A database is developed containing transfer coefficients related to specific scenarios. If this database does not give appropriate surrogate values for the TC (scenario), it is possible to extract relevant TCs from other indicated sources. These latter values are presently unsubstantiated.

However, the size and quality of the databases in the present report are such that no robust values can be derived. There is therefore a strong need for collection of appropriate data in field studies.

The following **indicative** TC values are proposed for four different harvesting scenarios with bare hands:

Vegetables:	2,500 cm^2/hr
Fruits (from trees):	4,500 cm^2/hr
Strawberries:	3,000 cm^2/hr
Ornamentals:	5,000 cm^2/hr

The calculated potential dermal exposure data using these values may be used in the first tier of the risk assessment. In the higher tiers more and more experimental information is required as presented in the table and the graph on pages 15 and 16, respectively.

For *inhalation exposure* the database with exposure values is even smaller than for dermal exposure. Some indicative values can be proposed for specific indoor, glasshouse scenarios with the following algorithm:

mg as/hr inhaled = kg/as/ha applied x Task Specific Factor

The Task Specific Factors, that can be used in the first tier of the exposure and risk assessment, have been estimated for a small set of exposure data for harvesting of ornamentals and re-entry of greenhouses about 8-16 hours after specific applications. The **indicative** Task Specific Factors are:

- 0.1 for cutting ornamentals;
- 0.01 for sorting and bundling of ornamentals;
- 0.03 for re-entering geenhouses after low-volume-mist application (8 hours after application);
- 0.15 for re-entering greenhouses after roof fogger application (16 hours after application).

Overall it is absolutely clear that there is an urgent need for more field data on post-application (re-entry) scenarios from which relevant data for predictive modelling can be extracted.

Contents

All databases (Annex 8, 10 and 13) in this report are available to readers from the Europoem co-ordinator. They are not included in this report as hard copies due to their size.

1. Introduction

Plant protection products are used in agriculture, horticulture and elsewhere in order to prevent major yield and quality losses. They are an integral part of various types of crop maintenance measures. This means that other maintenance activities may make it necessary to re-enter treated areas relatively shortly after application, i.e. within the normal time window for major plant protection activities. The type of work to be done and the point of time for re-entering relative to the time of application of a plant protection product may vary from crop to crop. Moreover, other activities (e.g. packaging, sorting, bundling, and dipping) are performed which may lead to exposure but which are not directly related to re-entry.

Plant protection products are biocidal active substances and are by nature toxic to target organisms and potentially so to humans that come into contact with them. Therefore, the safe use of plant protection products presupposes, among other things, an evaluation of worker exposure during re-entry and other post-application tasks, an adequate risk assessment on the basis of the various practical scenarios and, if necessary, specific instructions for worker protection on the label.

Those activities are generally conducted during the course of official registration of a plant protection product. As, according to Council Directive 91/414/EEC, the registration procedures and the evaluation criteria are currently harmonised between the Member States of the European Union, the objective of this paper is to contribute to the discussion about a future Union-wide evaluation and an assessment scheme for the so-called "re-entry exposure assessment". As there are many different crops and a lot of different activities the description of these various aspects, as well as the approach for assessing exposure, needs some structure.

In this report, an overview will first be given of the scenarios in which post-application exposure may occur and after that, a generic model will be described with which in principle post-application exposure can be assessed if sufficient information is available. The general structure of this model assumes that during application, the foliage of a crop is covered with pesticide residue that may be transferred to clothing and skin of worker, when activities involving contact with the crop, such as harvesting, are carried out. Important factors in the model are the application rate, the foliage density, the time of activities after application, the transfer from foliage to worker and the duration of the work. These various factors, and some others that are relevant for the generic model, will be described with some detail, as well as available information from re-entry exposure studies as could be obtained from public places (published reports, literature studies and some other literature sources). No relevant material, sufficiently documented, was obtained from proprietary sources.

2. Scenarios

A first distinction must be made between crops grown *indoors* or *outdoors*.
Within these two main scenarios individual crop groups can be identified depending on the way of cultivation and related activities.
These crop groups can be sub-divided further in terms of how comparable work patterns are and in which way a further categorisation can be made.

In the following, indoor and outdoor scenarios are described in more detail with respect to work tasks, clothing and possible contact with foliage.

2.1. Outdoor crops

Outdoors, many different crops are cultivated. Main activities which lead to at least some contact between crop and worker are harvesting, pruning, thinning, and also inspection (e.g. for control of diseases or the special case of wild oat). The type of crops to consider varies widely over Europe from North to South and possibly from West to East. Differentiation may be made in crops that need to be harvested regularly or from time to time (e.g. apples, pears, grapes, olives, etc.), and in crops that need not to be harvested (at all or hardly at all). In the latter case, examples are the greens of golf links and the culture of conifers.

For vegetables and ornamentals grown outdoors, conditions with respect to dermal exposure are largely comparable to the same crops growing indoors, and need therefore no further consideration.

Although there may be exposure of some kind to pesticides with field crops where harvesting is highly mechanised, it will be considerably less than for the above mentioned scenarios. This applies especially to crops such as cereals, maize or sugar beets.
Further consideration should be given to inspection of crops for diseases and, possibly, hoeing activities.
It is not possible to consider all crops, but some important categories will be described in the following.

Fruit trees
Various pesticides are applied to the crops in a regularly and frequent way throughout the period February to October. During that period various activities may take place, which of course depend to some extent on the crop under consideration. The most important activities for apples and pears are the pruning of the tree, the harvesting of the fruits and the fruit thinning. The harvesting activities and the thinning are done with bare hands. For pruning, occasionally, gloves are used not to protect against pesticide exposure but against skin damage. Depending on the weather and on the region in Europe, the clothing might vary for the same activities.

Hop
Activities connected with the foliage wall in hops are confined to training the shoots as soon as they are able to bind (from mid-April to end of July). Superfluous ground shoots are removed during the cultivation period either manually or mechanically, depending on the resources available. During the cultivation period the bottom 2 meters are defoliated either manually or chemically (stripping). Other cultivation measures (e.g. tilling) and harvesting are performed mechanically.
As a rule jobs are carried out with gloves, which helps to prevent injury since the bines have small hooked hairs with needlepoints. There is a potential for exposure during harvesting, particularly when collecting bines for transport to static picking machines.

Vines (grapes)
During spring and summertime, pesticides are applied to the vines. During this period the crop-activities are pruning (minor activity), foliage work and of course harvesting of the grapes. Harvesting and foliage work is usually done with bare hands and under conditions that light clothing is required. Under conditions of good agricultural practice, exposure of the workers can be reduced by doing the foliage work before and not after a pesticide application. The degree of exposure largely depends on the structure of the vine.

Tree nurseries
The variation in trees that are cultured is quite large. Culture may take place both indoors and outdoors in trays, containers or in the soil. Exposure to pesticides may occur during the handling of the soil containing pesticides, the handling of cuttings and inoculation activities. During growth, exposure may occur during pruning and soil activities such as weed control, and the mechanical removal of the tree and the pulling from the soil, and the sorting and bundling of especially the smaller trees and cuttings.
Many of these activities are comparable to activities in other crops. Apart from possibly the potting and planting activities, there does not appear to be relatively high-exposure handling activities.

Berries

The culture of berries will lead to exposure during the pruning and thinning activities and during harvesting. In general, exposure is highest with crops that have a high foliage density and with which there is extensive physical contact in the conduct of any activity. It should be noted that pesticides, generally, will not be applied after blossoming. This indicates a relative low potential for dermal exposure.

Lawns/greens/playgrounds
With respect to the level of re-entry exposure in comparison with the crops mentioned above these scenarios are not considered important. Possible exceptions might be children playing or sporting activities with much contact between body and grass.

All post-application scenarios described, which are regarded as being relevant for Europe, are summarised in Table 1.

As the work activity “thinning” is only relevant for pome and stone fruit, it is not mentioned explicitly in the table.

2.2. Indoor crops

For indoor crops a distinction may be made between ornamentals (especially ornamentals) and vegetables grown in greenhouses (glass or plastic). Exposure during re-entry tasks can happen in both cases.
The most important crops (with respect to exposure) are the higher ones from which the ornamentals or fruits are picked or cut and for which there is extensive physical contact with the foliage of the crop. Important flower types are roses and carnations and some pot-ornamentals; important vegetables are tomatoes, cucumbers and sweet peppers.
In cultures of ornamentals pesticide application is very frequent, so that accumulation of residue may occur. Generally, all activities are done with bare hands, with possible exceptions for roses with thorns (skin damage!) and crop activities, which lead to 'greenish' hands (especially for women). In some crops there is an almost daily contact with the crop, indicating that the time between application and harvest is necessarily short (e.g. roses).

Next to harvesting the sorting and bundling of ornamentals (which also includes stripping of bottom leaves) may be important for consideration. The contact zone with the body is generally formed by hands and forearms. In hot periods there may also be extra contact with the body due to very light clothing.

Exposure duration may be up to 6 hours for a normal day of harvesting, sorting and bundling, and occasionally even longer. The exposure may be over several days a week in view of the continued presence of pesticides on the crop depending upon the stability of the particular pesticide (or even mixture of pesticides).
Other probably less important activities include picking of cuttings, thinning of the central flower, other thinning procedures, planting of cuttings, pulling up the grids in which the ornamentals are grown, training of plants, visual control for diseases, making bundles at the auctions or in florist shops, and bagging of ornamentals.

The vegetables or other edible commodities are less frequently treated with pesticides (biological control!). Activities to be considered are training and thinning (tomatoes, cucumbers) as well as harvesting. However, whereas training and thinning are carried out at intervals of one or several weeks, harvesting usually takes place at a 2-to-3-day interval. The use of gloves is fairly common with all work tasks in tomatoes.

2.3. Grouping of scenarios

The crop groups, which are listed in Table 1, may be further sub-divided with respect to the anticipated contact with foliage:

- Thinning activities are considered to involve lower or similarly intensive contact with foliage in comparison with pruning. In addition, the same body parts of the worker will be exposed to the foliage

during both types of activities. Therefore, exposure assessments for pruning will also cover the worst case exposure assumptions for thinning.
- Pruning of pome fruit crops will lead to comparably intensive contacts with foliage as for stone fruit crops. Therefore both crop groups (for tree fruits) should be combined. Further combinations may be developed for fruit vegetables, grapes and ornamentals.
- Harvesting activities may contain common elements of handling practices, which are similar for the various crops.

Bearing this in mind in a first approach the following groups of crops can be assumed:
- citrus, pome fruits and stone fruits with large fruits, e.g. peaches
- fruit vegetables, bushberries and stone fruits with small fruits
- grapes
- strawberries
- head cabbage, head lettuce and ornamentals, incl. pot flowers
- tobacco

According to Table 1 dermal exposure during post-harvest activities results primarily from sorting and packaging (bundling). Especially in the case of sorting, workers have to handle the harvested commodity with their hands, most often in a similar way as during harvesting but without any contact to foliage. Therefore, in a first attempt these post-harvest exposures could be considered at the most as comparable to exposure during harvesting.

3. Exposure

The routes of exposure during post-application activities are the same as in operator exposure, i.e. dermal and inhalation. However, the sources are different: foliage, surfaces, soil, and also dust may contribute.

3.1 Dermal exposure

Most maintenance activities include frequent contacts with the foliage of the crop. Therefore, dermal exposure is considered to be by far the most important exposure route during re-entry activities. The amount of resulting exposure (for a certain activity) depends on one hand on the amount of residue on foliage and for different activities on the intensity of contact to the foliage. On the other hand, time of contact is also an important issue.

3.2. Inhalation exposure

Inhalation exposure potentially may occur to residual vapour and airborne aerosols, which in turn are restricted to a relatively short period after application, e.g. in outdoor crops only during the time when the spray is drying or in greenhouses within a few hours after application. Also resuspended aerosols through the movements of the crop as well as some dust during re-entry activities may result in inhalation exposure. Outdoors there will be rapid dissipation of vapour and aerosols, leading to much lower inhalation potential than indoors (for example in glasshouses). Further, for many cases the current appreciation is that inhalation exposure is less important than dermal exposure.

Table 1: Post-application scenarios in Europe

No.	Crop/Crop group (recommended test species for post application investigations)	Indoor/outdoor Cultivation		Type of post-application activity (work task)		
				Pruning	Harvesting	Other post-application activities
1	Citrus (Oranges)		F	-	4	Sorting, packing, handling after post harvest treatment
2	Pome fruit (Apples)		F	-	4	Sorting, packing, handling after post harvest treatment
3	Stone fruit		F	4	4	Sorting, packing
4	Grapes		F	4	4	Packing
5	Strawberries		F	-	4	-
6	Strawberries	G		-	4	-
6a	Fruit vegetables (Tomatoes, Cucumbers, etc.)	G		4	4	Sorting, packing
7	Bush berries (Currants)		F	-	4	-
8	Fruit vegetables (Tomatoes, Cucumbers, etc.)		F	4	4	Sorting, packing
9	Cabbage / Lettuce	G	F	-	4	Weeding, planting
10	Ornamentals/Pot flowers	G	F	4	4	Sorting, packing
11	Tobacco		F		4	Planting
12	Cereals		F			Scouting
13	Cotton		F			Nursing
14	Banana		F		4	Leaf cutting, wrapping?, handling after post harvest treatment
15	Turf		F			Recreation (no worker exposure)

F = field G = greenhouse

Thinning refers only to pome and stone fruit and is not shown in this table

4. Generic dermal exposure model

On the basis of the available data on dermal exposure, attempts have been made to develop a general approach. This approach is based on the following steps in the process of dermal exposure. It starts with the application of the pesticide leading to coverage of the foliage with pesticide residue that may or may not disappear in time due to various reasons, such as uptake in the foliage or hydrolysis of some kind. What remains on the foliage (dislodgeable foliar residue) may be transferred to clothing or skin of a worker that comes into contact with the foliage. The transfer (via the transfer coefficient) will depend on the nature of the contact and the degree of contact between body and foliage, and the duration of the work. The resulting generic model has the following algorithm:

Potential dermal exposure (DE) = DFR x TC x T (1)

where DFR is the dislodgeable foliar residue, TC is the transfer coefficient, and T is the time of contact. The dislodgeable foliar residue can be considered to be the applied amount divided by the leaf area index:

DFR = AR / LAI (2)

where AR is the application rate and LAI is the leaf are index. The leaf area index is the ratio between the (one-sided) foliage surface area and the ground surface area on which it grows. In these formulae one factor is not yet included and that is the dissipation (decay) of the active substance on the foliage. This may be introduced as a factor or as a formula if the exact nature of the dissipation over time is known. If no data are available on the degree of dissipation, the conservative approach is to assume no dissipation at all. In that case DFR0 is used for calculations, i.e. the residue available directly after application (when dry).
In practice this would mean that if no dermal exposure measurements are available, the exposure can be calculated using the relevant application rate and/or data or assumptions on dislodgeable foliar residue, the duration of the work activity and information on TCs. This requires a database on TCs, with special emphasis on the scenario that is relevant.
The various factors are discussed in detail in the annexes to this report, but the major issues involved will be discussed here in short paragraphs (4.1-4.3). Possible exposure to pesticide residues in soil is treated in chapter 6.

4.1. Dislodgeable foliar residue

The amount of residue on foliage depends on several factors, the application rate and droplet sizes but also on the crop type and the amount of foliage (leaf area index). Moreover, dissipation of residues on crop foliage over time depends on the physical and chemical properties of the applied active substance as well as on environmental conditions.
Common methodologies for determination of foliar residues have been described. Usually a diluted surfactant in water is used for rinsing a certain leaf area, resulting (after analysis) in an expression of residue amount per area: the dislodgeable foliar residue. A more detailed discussion of the various issues involved is given in Annex 1. With permission of the ARTF (Agricultural Re-entry Task Force; North-America), the general protocol for the DFR measurements is included in Annex1A.
It is important to note whether the area given refers to one side or to both sides of the leaves.
However, experimentally determined dislodgeable foliar residue data are not available in all cases. In these cases an estimation of the amount of dislodgeable foliar residues immediately after application can be made taking into account the application rate, the crop habitat (LAI) and the (possible) extent of residues remaining on foliage from previous applications. In Annex 2, the available information on leaf area index is compiled, and it appears that conservative approaches are available for using these data to calculate the DFR from the application rate, using formula (1), but one should be careful, since such a calculation implies that the coverage of the foliage is homogeneous. A possible default for LAI

in a first tier approach would generally not be higher than 2. For exposure determinations one should always use the DFR values that are in the contact zone of the foliage with the workers.

4.2. Transfer coefficient

The transfer of residues from the crop foliage to the clothes or skin of the worker can be regarded as more or less independent of the kind of product applied and the level of worker exposure will depend only on the intensity of contact with the foliage.
This again is determined by the nature and duration of the maintenance activity to be carried out during re-entry.
Therefore it is advisable to group the various crop habitats and maintenance activities to "re-entry scenarios". Investigations to this end have been carried out over the last two decades, primarily in the United States. Especially, generic transfer coefficients have been developed for a number of scenarios. This will be discussed later. Since the nature of the transfer coefficient used may depend on the data one has at hand (data for potential or actual exposure, full body or only body parts), it is essential to make clear what sort of TC is meant. This is discussed in more detail in Annex 3.

4.3. Exposure and dermal absorption

Dermal exposure (and concomitantly, inhalation exposure) is by no means the ultimate goal of the assessment, since next to possible local effects on the skin and in the airways, the active substance must enter the body for systemic health effects. This requires absorption through the skin. Although the endpoint for the current report is exposure assessment and not risk assessment, it is worthwhile to indicate the relevance of knowledge on absorption and the possible validation of the use of data on dermal exposure and dermal absorption, in Annexes 4 and 5, some reflections are made on dermal absorption (Annex 4) and the use of biological monitoring (Annex 5).

5. Using the generic model

Equation (1) is applicable, using the database on TCs, when measured DFR values are available.
In most cases, especially when developing a new product, these data are not available at an early stage. For the estimation of worker exposure at that stage an extended version of the above formula together with a tiered approach can be used.

5.1. Tiered approach to risk assessment for re-entry workers

If use conditions are relevant to re-entry exposure, a tiered approach to risk assessment is proposed. Adopting a tiered approach allows flexibility in the assessment procedure. While tier 1 uses only generic data and assumptions, the demand for further and more specified information increases with each successive tier. Accordingly, information and assessments become less general, i.e. more refined and specific to the situations under consideration as described below.
Comparing the estimated exposure value at any tier level with the AOEL (acceptable operator exposure level; which is applicable also to the re-entry worker) may demonstrate an acceptable risk, leading to a regulatory decision to authorise the product. On the other hand, failure to demonstrate an acceptable risk takes the assessment to the next tier, which demands more exact input data. The general form of this tiered approach is depicted in words in the table and in the graph on the next pages.

These tiers, as illustrated, do not constitute a rigid framework, but offer a transparent view of the approach to be taken in matching the availability of specific exposure data with the demands for rigorous risk assessment.

6. Estimation of inhalation exposure

The description of the generic model and the tiered approach reflects only dermal exposure, not inhalation exposure. Although in many cases inhalation exposure will be less important for the risk assessment than dermal exposure, some emphasis is put on inhalation exposure in Annex 6. It describes the small amount of available data and an algorithm is given for some re-entry scenarios:

mg as/hr inhaled = kg/as/ha applied x Task Specific Factor

The Task Specific Factors, that can be used in the first tier of the exposure and risk assessment, have been estimated for a small set of exposure data on harvesting of ornamentals and re-entry of greenhouses about 8-16 hours after specific applications. The **indicative** Task Specific Factors are:

- 0.1 for cutting ornamentals;
- 0.01 for sorting and bundling of ornamentals;
- 0.03 for re-entering greenhouses after low-volume-mist application (8 hours after application);
- 0.15 for re-entering greenhouses after roof fogger application (16 hours after application).

In many cases inhalation exposure is expected to be quite low in comparison with dermal exposures, with of course exceptions for situations where aerosols and volatile pesticides are of concern.

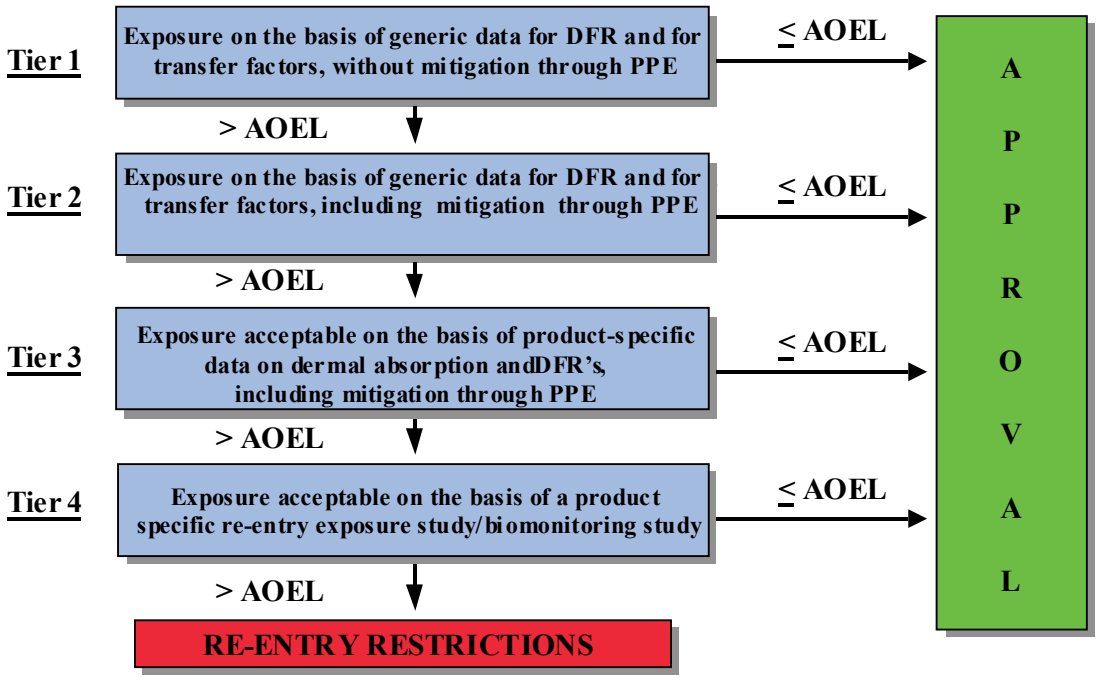
Inhalation exposure may not only be to vapours, but also to dusts. The relevance of soil exposure to inhalation contamination with pesticides is covered in Annex 7, which give a possible approach to estimating this, whenever considered relevant. In the general case it will be relatively low when compared to other exposures. The case of possible dermal exposure to soil containing pesticide residues is treated in Annex 7, using the concept of ‘dermal adherence’.

Tier 1	Uses the generic assumption on initial DFR and database for transfer factors to give single conservative point estimates ("surrogate values") for total potential exposure, fully exploiting the capacity of the database which are applicable to a broad range of re-entry scenarios common to European conditions. If the estimated re-entry exposure is within the AOEL no further action is required and approval can be granted.
Tier 2	Uses the generic database plus additional information relating to exposure mitigating factors (i.e. exposure reduction coefficients for personal protective equipment [PPE]) pertinent to the case. This offers a middle course where supplementary use-specific information is used to refine the exposure estimation, thus reducing uncertainty. If the estimated re-entry exposure including defined specific instructions on worker exposure is within the AOEL no further action is required and approval can be granted.
Tier 3	Uses additionally data on product-specific percutaneous absorption, on dislodgeable foliar residues and their dissipation curves from foliar dislodgeable residue studies under actual conditions of use. If the estimated re-entry exposure including the redefined specific instructions on worker exposure -if necessary-, is within the AOEL, no further action is required and approval can be granted.
Tier 4	Uses product-specific data from biological monitoring studies or re-entry exposure studies on the active substance under consideration and the actual re-entry conditions. This provides absolute exposure data and places the greatest demands upon the quality and relevance of data required. If the measured re-entry exposure including the redefined specific instructions –if necessary- on worker exposure is within the AOEL, no further action is required and approval can be granted. If the measured re-entry exposure exceeds the AOEL, re-entry restrictions have to be established.

Table 2 Tiered approach (see also next page)

FIGURE 1

TIERED REGULATION OF RE-ENTRY EXPOSURE AND RISK ASSESSMENT



7. Development of a database for TCs

For use in the generic model as described above, the scientific and other literature has been compiled in order to extract data on initial DFRs (dislodgeable foliar residue after application, when the deposit is dried-on) and on transfer coefficients related to the scenarios as listed in Table 1. No proprietary studies were obtained that could be used for this last purpose.
A full list of the literature that was used for these purposes is presented in Annex 8. An overview of the data on initial foliar residue is presented in Annex 9. The database, containing the most relevant features of the studies they were extracted from, is given in Annex 10. From the presentation in Figure 2 (next page) it is obvious that there is a large variation in DFR0, even when standardized for the application rate. For a highly conservative assessment of the initial DFR (DFR0), in a first tier assessment, it may be concluded that 3 microgram/square centimeter active substance on foliage, which is about the 90th-percentile of the distribution, can be taken as a source strength for exposure when no relevant/appropriate data on leaf area index can be used to estimate the dermal exposure to the workers.

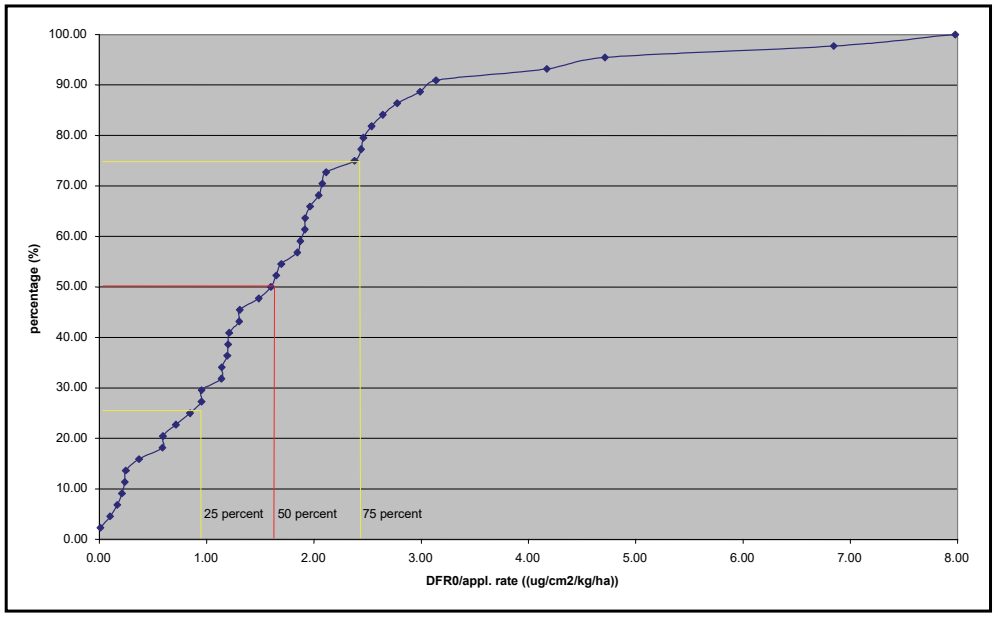


Figure 2 Cumulative initial DFR/Application rate

From the publications listed in Annex 8, the relevant studies were extracted that contain data on dermal exposure and dislodgeable foliar residues from which TCs can be calculated. The table in Annex 8 is not listed in the report, since it is very large.

These relevant studies were thoroughly reviewed for their acceptability of TC data to be included in the database. A summary of the review reports is included in Annex 11. The analysis is presented in Annex 12. In Annex 13, the relevant database containing these data is presented.
Data were observed for four major scenarios, all reflecting mainly harvesting:

- fruit trees (5 studies)
- (straw)berries (1 study)
- ornamentals (3 studies)
- vegetables (1 study).

From these studies all TCs were extracted and given as input to small databases per scenario that are graphically represented in Annex 12 and on the next two pages as Figures 3 and 4.
The potential difficulties in doing so are described in Annex 3. In view of the actual data, various difficulties were encountered, such as low quality description; inconsistencies in tables and text; impossible verification of values; averaging of values before presentation and the like. Several reports were acceptable, but several others were of borderline acceptance to the reviewers (Annex 11). It was concluded, however, to take as much as possible TC data from the publications in order to be able to at least **indicate** the possible levels of relevant exposure.
The main remaining problem after all this, is the nature of the exposure data, which is a mixture of actual dermal exposure data and potential dermal exposure data. It can be seen in Figure 3 that for hand exposure the data reflect actual dermal exposure data, although this could just as well be described as potential dermal exposure data, since all observed workers had bare hands, which is the common case for post- application work. The body exposure (whole body, excluding hands) databases are partially actual and partial potential exposure data (figure 4).

Figure 3 Hand exposure data

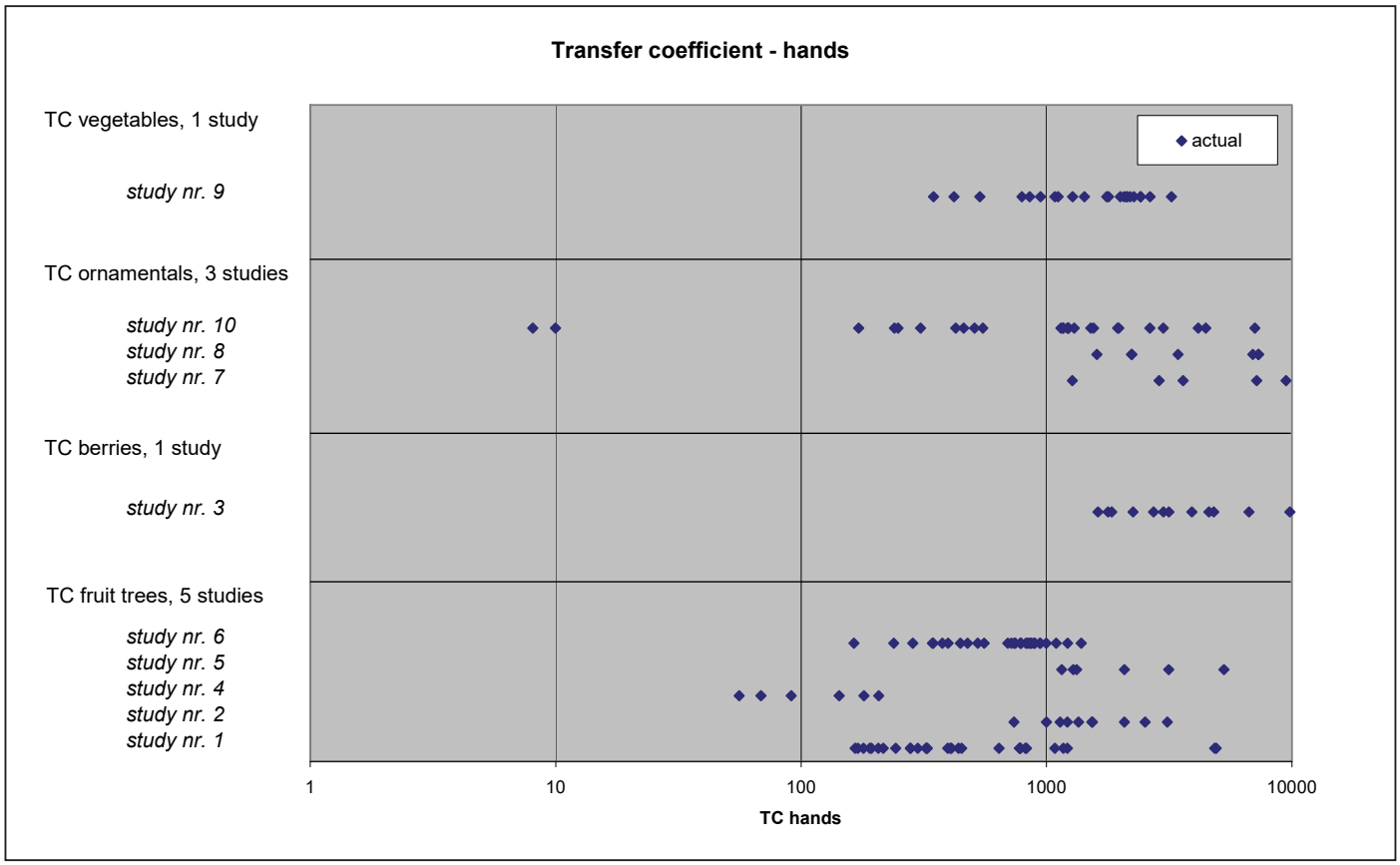
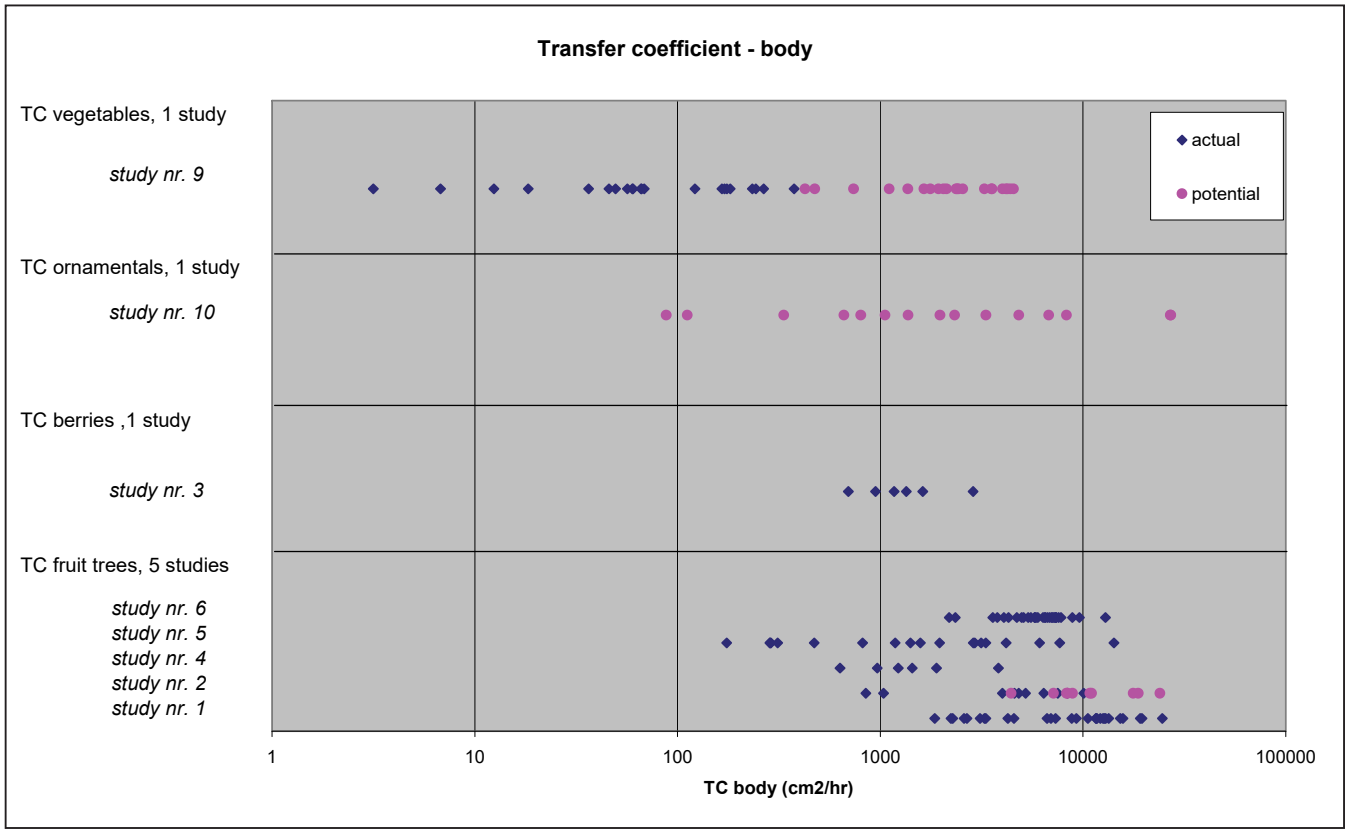


Figure 4 Body exposure data



From these relatively small databases, surrogate transfer coefficients may be deduced as indicated here. Rounded values for the 90th-percentiles are used for the smallest databases and rounded values for the 75th-percentiles for the largest databases. This approach is taken since a small database may not be typical for the scenario, especially when it contains only one single study. Therefore a reasonable worst case estimate (90th-percentile) is taken for the surrogate value. In case of a large database, the data are considered more representative and a more typical estimate for a surrogate value may be the 75th-percentile (as in EUROPOEM I, 1996; Van Hemmen, 2001).

For the **vegetables scenario** the TC for hand exposure amounts to about 2,200 cm^2/hr (75^{th}-percentile) and the potential body exposure amounts to 3,600 cm^2/hr (75^{th}-percentile). Thus the total for potential exposure is 5,800 cm^2/hr. If body exposure were to be reduced by (protective) clothing, with for instance a tenfold reduction of exposure, the total actual exposure would lead to a TC of approx. 2,500 cm^2/hr. These data compare well with the EPA data (US-EPA Policy Paper on Agricultural Transfer Coefficients (Aug. 2001).

For the **ornamentals scenario** the TC for hand exposure amounts to about 4,000 cm^2/hr (75^{th}-percentile) and the potential body exposure amounts to about 10,000 cm^2/hr (90^{th}-percentile), giving a total of 14,000 cm^2/hr for potential exposure. If body exposure were to be reduced by (protective) clothing, with for instance a tenfold reduction of exposure, the total exposure would lead to a TC of 5,000 cm^2/hr (with bare hands). These data also compare well with the EPA data (US-EPA Policy Paper on Agricultural Transfer Coefficients (Aug. 2001).

For the (**straw)berries scenario** the dataset is rather complex, and must be calculated with various assumptions, as has been done for the graphs. For the calculation of the TC values, arithmetic means are used, since the original data in the study are also given as means. The bare hand scenario for berries result in a TC value of 2,500 cm^2/hr for hands. Taking into account the crop height and cropping pattern of strawberries there is likely to be very low exposure to the rest of the body. This is confirmed by findings in the study of residues on lower legs below detection limit (LOD). Adding the forearms, which are described as representing skin as well, a TC value of 3,670 cm^2/hr results. This figure seems to be higher than comparable ones but may be explained by the inexperience of the pickers (see Zweig et al; 1984, p.1234 last paragraph). Therefore, it is proposed to use a TC of 3,000 cm^2/hr**.**
Due to the cropping pattern this TC is not proposed for berry fruit other than strawberry.
These data compare reasonably well with the EPA data (US-EPA Policy Paper on Agricultural Transfer Coefficients (Aug. 2001), although they are slightly higher.

For the **fruit trees scenario** the TC for hand exposure amounts to about 2,500 cm^2/hr (75^{th}-percentile). However, the TC value body exposure is not easy to determine in view of the spread of the data for actual and potential exposures. For actual exposure it may be just below 10,000 cm^2/hr (75^{th}-percentile) and for potential exposure the database is small, but a surrogate value could be up to 20,000 cm^2/hr (90^{th}-percentile). If body exposure were to be reduced by (protective) clothing, with for instance a tenfold reduction of exposure, the total exposure would lead to a TC value of 4,500 cm^2/hr (with bare hands). These data compare reasonably well with the EPA data (US-EPA Policy Paper on Agricultural Transfer Coefficients (Aug. 2001).

For other scenarios, TC data may be extrapolated from these scenarios if they are considered to be comparable. In other cases an approach can be taken as described by Krieger et al. (1992) and of the US-EPA Policy Paper on Agricultural Transfer Coefficients (Aug. 2001). It should be noted, however, that these values couldn't be substantiated by the present working group.

8. Conclusions and recommendations

From an analysis of the data and approaches available in the published literature, a tiered approach for assessing potential dermal exposures during post-application activities is developed, which uses two related algorithms. The basis for the dermal exposure assessment related to the relevant scenario is formed by a multiplication of DFR, TC and duration of the work. If no DFR data for the specific compound are available, DFR may be calculated from the application rate, divided by a reasonable estimate of the leaf area index. In other cases, a reasonably conservative default value for the DFR (standardised for an application rate of 1 kg/ha) may be taken as 3 $\mu g/cm^2$.
If the current database does not give appropriate values for the TC (scenario), it is possible to extract relevant TCs from other unsubstantiated sources.

However, size and quality of the databases in the present report are such that no robust values can be derived. There is therefore a strong need for collection of appropriate data in the field.

The following **indicative** TC values for potential dermal exposure are proposed for four different harvesting scenarios with bare hands:

Vegetables:	2,500 cm^2/hr
Fruits (from trees):	4,500 cm^2/hr
Strawberries:	3,000 cm^2/hr
Ornamentals:	5,000 cm^2/hr

The calculated dermal exposure data may be used in the first tier of the risk assessment. In the higher tiers more experimental information is required as presented in the table and graph (section 7).

For inhalation exposure only a few possible default values can be used specifically for indoor, glasshouse re-entry scenarios. These are presented in the form of an algorithm:

mg as/hr inhaled = kg/as/ha applied x Task Specific Factor

The Task Specific Factors, that can be used in the first tier of the exposure and risk assessment, have been estimated for a small set of exposure data for harvesting of ornamentals and re-entry of greenhouses about 8-16 hours after specific applications. The **indicative** Task Specific Factors are:

- 0.1 for cutting ornamentals;
- 0.01 for sorting and bundling of ornamentals;
- 0.03 for re-entering greenhouses after low-volume-mist application;
- 0.15 for re-entering greenhouses after roof fogger application.

Overall it is absolutely clear that there is a large need for more field data on post-application (re-entry) scenarios from which relevant data for predictive modelling can be extracted.

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Annex 1 Measuring dislodgeable foliar residue. Review of methodology

Several foliar residue sampling methods have been proposed for the estimation of a safe re-entry period. The methods used are 1) organic solvent extraction from leaves (Ware et al., 1974), 2) collection of contaminated foliar particles by vacuum filter apparatus (Popendorf et al., 1975), or 3) aqueous extraction followed by partitioning into an organic solvent (Gunther et al., 1973; Iwata et al., 1977). The last, also called the dislodgeable foliar residue method, is most commonly used and considered even today as the most relevant practical method for estimation of re-entry period.

A method for the collection of the samples with a leaf punch sampling tool, described by Smith and Little (1954), is most often used. This tool was first developed for taking unit area samples of cotton leaves. It has interchangeable cutting dies which vary in diameter from 1 cm to 3.2 cm. The cut leaf sections fall freely into a screw-cup glass jar which can be removed and sealed tightly against dehydration or leakage of fluids, in which the sections are collected and stored. Refinements of the method were published by Gunther et al. (1973) and Iwata et al. (1977), and the method was applied for dislodgeable dust on foliage by Popendorf and Leffingwell (1977).

With the leaf punch technique it is possible to collect leaf punches of different diameters because the dies of the leaf punch tool are interchangeable. In their article Iwata et al. (1977) recommended the use of one inch (2.54 cm) diameter punches, thus for the recommendation of using 40 or more leaf punches, the total surface area for the sample is about 400 cm^2 (two sided). This methodology has been used recently when studying the re-entry exposure of workers (Manninen et al., 1996; Kirknel et al., 1997; Fenske et al., 1999 and Agricultural Reentry Task Force DFR draft protocol).

Leaf punching may not be feasible due to small size or irregular shape of leaves. In these cases entire leaves may be taken for the sample. For example, dislodgeable foliar residue studies on turf grass (Goh et al., 1986b; Black & Fenske., 1996), lawn grass (Goh et al., 1986a), ornamentals (Brouwer et al., 1993; Nigg et al., 1992) and grapes (Dong et al., 1991) have been carried out by collecting whole leaves with scissors and tweezers. The total leaf surface area was in most of these cases measured with a surface area meter on one side and the result multiplied by two to obtain the total leaf area. In the study by Black & Fenske (1996) the dislodgeable foliar residue was calculated by the sampling area, but usually results are calculated as µg pesticide residue / cm^2 area of collected leaves.

The sampling strategy for the leaves is greatly dependent on the type of plants to be studied. It is important to collect samples from the areas where workers are likely to be in contact with the foliage. With tall upright crops, such as cotton, stacked tomato, grape, and sweet corn, leaf samples should be taken from the lower middle and upper part of the canopy and for smaller ones, such as lettuce or cauliflower, the wrapper leaves are representative. Foliage from tree crops, other than citrus, are sampled at the highest level accessible by a sampler standing on the ground (Iwata et al., 1977).

For citrus trees, the portion of the tree about 1.2 – 1.8 m above the ground is sampled. One sampling procedure for obtaining 40 leaf punches is to punch at 45^o intervals around eight trees, with five punches per tree according to the following table (Gunther et al. 1973).

Tree 1	0º	45º	90º	135º	180º
Tree 2	45º	90º	135º	180º	225º
Tree 3	90º	135º	180º	225º	270º
Tree 4	135º	180º	225º	270º	315º
Tree 5	130º	225º	270º	315º	0º
Tree 6	225º	270º	315º	0º	45º
Tree 7	270º	315º	0º	45º	90º
Tree 8	315º	0º	45º	90º	135º

Another method, which simplifies the sample collection procedure and increases the sample size (total area) but decreases the number of trees sampled, is to collect a total of 48 leaf punches from eight points equally spaced around six trees. Any sampling procedure can be used provided that the entire circumference of the tree is represented. Usually at least two replicants of samples are recommended (Iwata et al., 1977; Gunther et al., 1973).

According to the ARTF DFR draft protocol (Annex 1) the study should be conducted at geographical locations representative of the spectrum of climatic and crop growing conditions expected in the intended-use areas. A crop variety commonly grown in each use area will be selected. Each site will consist of two plots, one treated and one untreated. The untreated plot will be positioned upslope (if applicable) and upwind (at application) at least 30 m of the treated plots to reduce the potential for contamination due to drift. Both plots will be uniquely identified, or each site will consist of a single treated plot. All untreated control samples will be collected prior to application of the test substance. For tree crops the recommended plot size is 8 to 12 trees for sampling (e.g., 4 trees x 3 replicates) that are all bordered by other treated trees. For example: 3 rows x 14 trees, 4 rows x 8 trees, or 5 rows x 6 trees. For row crops, plots should be of sufficient size to allow collection of all necessary plant material without sampling the same plants twice or sampling border rows or plot ends, but no smaller than 1,000 square feet. The treated plot will be divided into three subplots for the three replicate samplings.

If collected leaf samples or punches are stored more than 30-60 minutes before being extracted they must be stored cold until further treatment in laboratory or on field. The ARTF DRF draft protocol recommends that the containers with the leaf material will be kept cool by placing them on substitute or wet ice for transport to a field laboratory (if possible). Dislodging of the leaf samples will be performed as soon as possible, but no longer than 12 hours after collection. The foliage will not be frozen prior to processing. If samples must be stored the chemical stability of the residues during storage must be verified (Popendorf and Leffingwell, 1982). Storing samples at - 15^{o}C will in most cases be enough for succesfull preservation of the residues.

Gunther et al. (1973) were the first to suggest the laboratory method for determination of the dislodgeable foliar residue. The method consisted rinsing of collected leaf punches in 50 ml of water and two drops of a 1:50 dilution of Sur-Ten wetting agent. The mixture is shaken vigorously for 60 minutes and decanted thereafter into a separatory funnel. This procedure is repeated with 30 minutes of shaking. The two decantants are combined in the separatory funnel. The leaf punches are then washed with 25 ml of water which, after shaking for five seconds by hand, is combined with the two earlier decantants.

Pesticide residues are extracted from decantants by shaking three times for 20 seconds with 50 ml of organic solvent (hexane or chloroform). The extracts are dried with anhydrous Na_2SO_4 and stored at 4^0C before analysis.

This method was further developed by Iwata et al. (1977). They shaked leaf samples for 20 minutes three times with 100 ml of water and 4 drops 1:50 diluted Sur-Ten wetting agent. The decantants are extracted two times with 50 ml of dichloromethane and then dried with Na_2SO_4. Dichloromethane is

evaporated and the residue is dissolved in acetone or hexane for further analysis. In both cases results are expressed as μg of a pesticide residue per cm^2 of leaf area.

The ARTF DRF draft protocol recommends the following procedure. Samples will be dislodged with 0.01% Aerosol® OT solution [or equivalent aqueous surfactant solution if Aerosol® OT interferes with the analytical procedure] by diluting one milliliter (mL) of a 10% Aerosol® OT 75 solution to 1,000 mL using distilled or deionized water. Next, 100 mL of the 0.01% Aerosol® OT 75 solution will be added to each jar containing the leaf material. The jars will be capped securely and placed on a reciprocating shaker operating at approximately 200 cycles per minute for a period of approximately 10 minutes. The leaf material will be separated from the solution by carefully decanting the solution into clean, labeled containers that are appropriate for the solution containing the active ingredient. Any fallen leaf material will be returned to the original sample jar for the second dislodging. Another 100 mL of the OT solution will be added to the leaf material and the dislodging process repeated. The solution will be decanted into the same container as the first 100 mL of dislodged solution. The leaf material can be discarded at this stage.

These methods have been used extensively with some modifications. The aqueous extraction of dislodgeable residue has been done using water without any surfactant (Kirknel et al., 1997; Berck et al., 1981; Bowman et al., 1982) or using Triton X-100 as wetting agent in water solution (Brouwer et al., 1993; Jongen et al., 1991). Depending on the analytical method used and pesticides analysed the extraction procedure of dislodgeable residue from the water phase has been done with different solvents, e. g. hexane (Berck et al., 1981; Kvalvåg et al., 1977), ethylacetate (Fenske et al., 1999; Spencer et al., 1995; Goh et al., 1986), or toluene (Black et al., 1996). In some cases the final extraction has been filtered (Zweig et al., 1983; de Cock et al., 1998) or preconcentrated with Sep Pak C_{18} cartridge (Jongen et al., 1991) before analysis.

Some studies have been performed to estimate the proportion of dislodgeable foliar residue from the total foliar residue. Several factors, e.g. the pesticide itself, plant material, and the time after the treatment, have strong effect on the dislodgeable portion but it seems to vary between 40 - 100 % (Brady et al., 1991; McEwen et al., 1980).

The foliar dislodgeable method has been discussed by Mc Lean et al., 1977; Popendorf et al., 1982; Dong et al., 1991 and Kirknel et al., 1997. The leaf punch sampler requires special maintenance and some initial investment. The sampling validity depends upon the assumption that small leaf segments are representative of the leaf as a whole. A study by Furness and Newton (1988) suggest that deposition of pesticides sprayed on leaves is far from uniform. According Dong et al. (1991), collecting whole leaf samples is easier than sampling leaf punches. The damage done to the sub-cuticular tissues is one argument against leaf punching. This leads to the extraction of pesticides also beneath the surface layers. The use of wetting agents may also interfere with a waxy foliage. During the aqueous extraction process, the problem in partitioning the foliar residue between the organic leaf structure, and organic or inorganic material and water on the leaf, is of concern for compounds which are either highly water soluble or highly insoluble. When extracting the residue from the decantant, one must not assume that the parent pesticide and its metabolite will behave in a similar fashion; their polarities and differential solubilities may be quite different.

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Annex 1A ARTF Protocol

DISSIPATION OF DISLODGEABLE FOLIAR ACTIVE INGREDIENT RESIDUES FROM PESTICIDE TREATED CROP

I. INTRODUCTION

This protocol was developed by the Agricultural Re-entry Exposure Task Force (ARTF) for use by the Task Force and it's members when conducting dislodgeable foliar residue studies. The protocol was designed with input from the U.S. EPA, CDPR, and Health Canada. The study design and dislodging procedures detailed in this protocol were developed in an attempt to standardize assessment of dislodgeable residues.

II. STUDY PURPOSE

The objective of this study is to determine the levels of [active ingredient] residues that can be dislodged from [crop] foliage. This information will be used with generic worker activity transfer coefficients to calculate potential human exposure while performing [activity] involving contact with treated foliage. The generic transfer coefficients will be developed by the Agricultural Re-entry Task Force (ARTF). Once this information is available, it will be possible to calculate potential re-entry exposure.

This study is designed to fulfill the requirements under Series 875; Occupational and Residential Exposure Test Guidelines, and to respond to the EPA data call-in (DCI) issued October 18, 1995. This study will be conducted in accordance with EPA, FIFRA, Good Laboratory Practice Standards (GLP); 40 CFR, Part 160 (October, 1989).

III. JUSTIFICATION OF TEST SYSTEM

Application of the [formulation type] formulation of [pesticide] to [crop] at [timing] represents a worst-case scenario for potential exposure to workers for all of the registered uses.

NOTE: It may be necessary to provide a justification on why the chosen scenario is worst case.

This study has been designed to conform as closely as possible to all EPA requirements. The test substance is a typical end-use product and application and agronomic practices accurately reflect the label and normal crop culture in the areas where the study will be conducted. Dislodging leaf material with a surfactant in aqueous solution is the accepted convention for measuring the amount of dislodgeable pesticide residues on the leaf surface.

IV. EXPERIMENTAL DESIGN

The study will involve typical commercial practices for [pesticide] use on [crop or crop cluster] used at each location. This includes typical cultural and irrigation practices for the variety and area.

The study will take place at [1, 2, 3, or 4] different geographic locations that represent important climatic conditions and cover the significant climate variations. Each site will consist of one untreated plot and one treated plot. The treatments will be made at a maximum label rate and minimum volume of carrier using commercial application equipment.

V. MATERIAL AND METHODS - FIELD

A. <u>Test Substance</u>

Trade Name:	[pesticide]
Product Formulation:	[formulation type]

Common Name: [active ingredient]
Active Ingredient: [% active ingredient by GLP analysis]
Expiration Date (if applicable):
Chemical Name: (ai):
EPA Registration No.: [end use product]
CAS Number (ai):
Lot Number: Will be recorded in the study file.
Appearance:
Stability and homogeneity: The stability and homogeneity of the active ingredient within the formulated product will be documented before the start of the study, or concurrently.
Field stability: [any pH, photostability or hydrolysis dependence]

The date of test substance shipment, lot number, date of receipt, and method of shipment, as well as the amount and container size, will be documented. The test substance will be stored in an appropriate manner and storage conditions and daily temperature extremes will be recorded.

Purity analysis and characterization of the test substance will be performed for each lot number. Information regarding the stability and homogeneity of the test substance will be part of the study raw data package. A retention sample from each batch of the test substance will be archived. All unused test substance and partially empty containers will be retained until the final report is signed, unless a prior waiver has been obtained from EPA. Product remaining at the completion of the study will either be returned to the supplier or disposed of in accordance with all state and Federal regulations.

Copies of the product label and MSDS are attached as Appendix A.

B. Study Locations

The study will be conducted at [1, 2, 3, or 4] geographical locations representative of the spectrum of climatic and crop growing conditions expected in the intended-use areas. A crop variety commonly grown in each use area will be selected. The site locations will be:

Trial Number	Location
-------a	[state]
-------b	[state]
-------c	[state]
-------d	[state]

NOTE: For the sake of selecting sites for the DFR studies, the regulatory agencies are producing a regional map based on climatic conditions during the growing season. It is suggested that studies be conducted in all of the important regions unless there is justification for choosing fewer sites as worst case environments.

C. Plot Layout

Each site will consist of two plots, one treated and one untreated. The untreated plot will be positioned upslope (if applicable) and upwind (at application) at least 100 feet of the treated plots to reduce the potential for contamination due to drift. Both plots will be uniquely identified.

OR

Each site will consist of a single treated plot. All untreated control samples will be collected prior to application of the test substance.

[for tree crops]

The recommended plot size for tree crops is 8 to 12 trees for sampling (e.g., 4 trees x 3 replicates) that are all bordered by other treated trees. For example: 3 rows x 14 trees, 4 rows x 8 trees, or 5 rows x 6 trees.

[for row crops]

Plots should be of sufficient size to allow collection of all necessary plant material without sampling the same plants twice or sampling border rows or plot ends, but no smaller than 1,000 square feet. The treated plot will be divided into three subplots for the three replicate samplings.

D. Treatment

The crop will be treated using the following application parameters:

Test substance:	[pesticide]
Formulation:	[formulation type]
Carrier:	[water or oil]
Rate:	[maximum labeled rate in lb ai/A]
Spray volume:	[minimum labeled spray volume in gal/A]
Timing:	[time or crop growth stage of initial or only application]
Number of applications:	[one or the maximum labeled number of applications]
Interval between applications:	[not applicable, or the minimum labeled interval between application in days]
Application equipment:	[representative method that represents worst case deposition]

These conditions were selected from the label as those most likely to give representative dislodgeable residues, provide full coverage to the leaves, and satisfy the EPA guidelines.

The pH of the water (where applicable) will be recorded at the time of application. For these applications, [lb product/A] is defined as the "target rate". An acceptable range is defined as 90-110% [or other appropriate values] of the target rate.

The application equipment will be calibrated according to the appropriate SOPs approved prior to each application to ensure a correct application rate. Complete documentation will be recorded in the field logbook.

The true application rate will be calculated based on applicator output, the active ingredient concentration, and the application time or land area covered. Once the plot has been treated, the amount of product or spray volume remaining will be checked as verification of the application rate. The remaining product material will be disposed of appropriately and in accordance with federal and state regulations.

[Tank mix samples are optional and not required if stability and homogeneity are demonstrated in a laboratory study.]

E. Foliage Sampling

1. Sample List

A complete list of the samples to be collected is presented in Appendix B.

2. Sample Collection

[all crops except conifers and fine-leafed crops]

Samples will be collected using a Birkestrand (or equivalent) leaf punch sampler. The leaves will be sampled directly into a pre-labelled glass jar. All leaf punch samples will be taken when foliage is dry. The untreated plot will be sampled prior to the treated plot [or prior to application when an untreated plot is not used].

All samples will consist of 40 leaf discs, or as needed for a sample of 400 cm^2 leaf surface area, counting both sides of the leaf surface. At each time interval, one sample will be collected from a plot left untreated throughout the duration of the study [if an untreated plot is used], and three replicate samples will be collected from the treated plot. Leaf punchers will be cleaned with appropriate solvent(s) after each interval sampling.

[for conifers or fine-leafed crops]

The use of leaf punches is not feasible for [crops], so the foliage sample will consist of numerous whole leaves [or needles] that cumulatively contain about 400 sq cm of plant material. Leaf [needles] samples will be taken when the foliage is dry and placed in appropriate containers for extraction. The untreated plot will be sampled prior to the treated plot [or prior to application when an untreated plot is not used].

The foliar area will be calculated by dividing the weight of each sample by the weight per unit foliage area, determined by measuring the foliage areas of a known weight of material. The procedure used for determining the foliage areas must be approved in advance by the Study Director.

At each time interval, one sample will be collected from a plot left untreated throughout the duration of the study [if an untreated plot is used], and three samples will be collected from the treated plot.

3. Randomization Procedure

[for tree crops]

A specific randomization procedure should be used for sampling throughout each plot. An example would be to collect ten (10) leaf punches, (each 10 square cm in area) from each of four trees. Punches will be taken from high, low and middle areas of the trees and from all four quadrants.

[for row crops]

A specific randomization procedure should be used for sampling throughout each plot. The procedure should ensure that each sample is made up of representative plant material from all areas of the plots, excluding borders and ends.

4. Sample Processing

The containers with the leaf material will be kept cool by placing them on substitute or wet ice for transport to a field laboratory (if possible). Dislodging of the leaf samples will be performed as soon as possible, but no longer than 12 hours after collection. The foliage will not be frozen prior to processing.

Samples will be dislodged with 0.01% Aerosol® OT solution [or equivalent aqueous surfactant solution if Aerosol® OT interferes with the analytical procedure] by diluting one milliliter (mL) of a 10% Aerosol® OT 75 solution to 1,000 mL using distilled or deionized water. The preparation of the OT solution will be documented in the field logbook. The shelf life of the 0.01% Aerosol® OT solution at room temperature is 48 hours.

Next, 100 mL of the 0.01% Aerosol® OT 75 solution will be added to each jar containing the leaf material. The jars will be capped securely and placed on a reciprocating shaker operating at approximately 200 cycles per minute for a period of approximately 10 minutes.

The leaf material will be separated from the solution by carefully decanting the solution into clean, labeled containers that are appropriate for the solution

containing the active ingredient. Any fallen leaf material will be returned to the original sample jar for the second dislodging. Another 100 mL of the OT solution will be added to the leaf material and the dislodging process repeated. The solution will be decanted into the same container as the first 100 mL of dislodged solution. The leaf material can be discarded at this stage. Teflon-lined caps will be loosely screwed onto the sample jar and sample jars placed at an angle in the freezer as outlined in Section IV.I.

NOTE: Some ARTF representatives have noted that extraction of the dislodging solution in the field with an organic solvent rather than in the analytical laboratory will preclude the need for the shipment of frozen aqueous solutions. If done properly, only aliquots of the organic extract need to be shipped for analysis. This optional procedure must be validated prior to initiation of the field study if it is to be implemented. Care must also be taken to ensure safety when handling and shipping the organic solvents.

5. Sampling Schedule

Foliar samples will be collected at the following time intervals: [times]

NOTE: It is recommended that a minimum of one preapplication and six post application sampling times be followed. The total sampling duration should be 35 days, 2 half lives, or until there are at least two consecutive intervals with non-detectable levels; whichever is shorter. The exact schedule and number of sampling intervals will be specific to the active ingredient's stability and it's use pattern as approved by EPA. The following is a suggested schedule of sampling intervals:

Pretreatment (PRE) - Just prior to each application

Posttreatment (POST)- As soon as the spray dries after each application; 12 and 24 hours after the final application; plus 2, 3, 4, 5, 6, 7, 10, 14, 21, 28, and 35 days after the final application

F. Field Fortification

At least one blank control sample and three or more replicates at a minimum of two fortification rates will be prepared at a minimum of 14 day intervals (e.g., day 1, 14, and 28). Seven samples of untreated leaf material (each containing 400 square cm of leaf material) will be collected from the untreated plot. The untreated leaf samples will be handled and dislodged using the same procedures as described in Section IV.E.4. After the leaf disc samples have been decanted a second time, the 200 mL dislodging solution sample will be fortified just prior to placing the cap on the jar. The fortification solutions and instructions for aliquoting will be provided by the analytical laboratory. The labeled fortified samples will then be placed into frozen storage as described in Section IV.I.

It is recommended that the fortification rates be two to five times the Limit of Quantification (LOQ) plus at least one higher level.

G. Plot Maintenance

Plots will be maintained according to normal agricultural practices. Use of any maintenance chemical must be approved in advance by the Study Director to ensure that the chemicals will not interfere with the analytical procedures. Plots will be identified in such a manner that workers and equipment will not enter the treated plot. It is important that the foliage is not mechanically disturbed for the duration of the study.

Sprinkler irrigation should be avoided, if possible, unless it is a typical agricultural practice. Dates of each irrigation event and approximate irrigation amounts will be recorded in the field logbook.

H. Sample Identification

It is recommended that samples be identified with a label containing the following information:

Sponsor Study Number
Contractor Study Number
Replicate Number
Sample Date
Sample Code and/or Matrix
Timing

Sample identification will not be limited to these items. A sample list is attached to this protocol.

I. Sample Storage

Samples will be stored in freezers set to maintain temperatures at or below freezing [at or below 5°F suggested]. Samples must be placed in the freezer immediately following completion of the dislodging operation. Containers will be placed at approximately a 45° angle with the caps loose to avoid breakage. After freezing, the lids will be tightened, and the containers will be wrapped with electrical or other plastic tape [if deemed necessary] and stored in a convenient position until shipment.

J. Sample Shipment

All samples will be packed using bubble-wrap, polyurethane foam or a similar shock insulator and shipped/transferred frozen to the analytical laboratory. All packing and shipping procedures will be documented in the field logbook and a completed chain of custody form will accompany the samples during shipment. The chain of custody shall include an inventory list identifying each sample in the shipment and shall be signed and dated by the person shipping the samples. All samples will be shipped to:

[Analytical Laboratory]

K. Statistical Methods

No statistical analysis is required for the conduct of the field portion of this study.

L. Required Field Data Records

Original documents or legible verified copies of the following information must be furnished to the Study Director:

1. A description of the test substance (including lot number). The date of test substance shipment, receipt and method of shipment as well as the amount and condition upon receipt will be documented. The dates and methods of disposal will be recorded.
2. A description of the test site, including a map of the test plots indicating their location, topography, size, location of the untreated plot in relation to the treated plot [if applicable]. A map of the general area (e.g., a county map) showing the test site in relation to the nearest town or city.
3. Cultural practices during the course of the trial. A detailed description of these practices will be included in the logbook.
4. Crop characteristics such as planting date, variety, stage of growth, size at application, and plant spacing.
5. The date and method of each application including calibration information.
6. Record of use and description of any maintenance fertilizers and pesticides.
7. A description of the type of irrigation, dates and amount applied.
8. Daily weather data from the nearest weather station for the length of the study, including air temperature, relative humidity, and wind speed and direction at application. Rainfall data must be collected from the test site. State the distance of the test site from the source of the weather data.
9. The date of each sampling and a description of the sampling technique.
10. A record of sample handling, including time from collection to freezer and a copy of the freezer temperature log for the period of time the samples were stored.
11. A copy of the chemical storage temperature log for the critical period of time the test substance was stored (i.e., from receipt through date of final application).
12. Record of test substance receipt, distribution, use at each trial site (test substance use log) and disposal.
13. All correspondence and other miscellaneous raw data needed to reconstruct the trial.

VI. SAMPLE ANALYSIS

The specific procedures for sample analysis will be added by amendment to this protocol.

VII. GOOD LABORATORY PRACTICE

This study must meet all current applicable GLP requirements as outlined in EPA FIFRA 40 CFR, Part 160. All data entries and observations must be signed and dated and kept in a trial-specific logbook or associated raw data file. This study will be monitored by the Sponsor's Quality Assurance (QA) Unit or by the Principle Field Investigator's QA Unit under the direction of the Sponsor's QA Unit. Study techniques and documentation will be audited.

VIII. STANDARD OPERATING PROCEDURE REQUIREMENT

The Principal Field Investigator at each study site will assume responsibility for SOP's used to conduct that trial. Standard Operating Procedures will be in place for all phases and activities of this study and will be adhered to unless superseded by the specific provisions of this protocol. Certifications of SOP adherence will be documented by the signing of the GLP statement provided in the study logbook. Written notification of a deviation from an SOP will be submitted to the Study Director.

IX. PROTOCOL AMENDMENTS AND DEVIATIONS

Intended (planned) changes to the protocol will be made by protocol amendment. Unintended or unexpected divergence from this protocol will be documented in the field raw data as a deviation. The Principal Field Investigator will keep the Study Director informed of

protocol deviations and will discuss protocol amendments with the Study Director prior to implementing them. The Study Director will be notified verbally and/or in writing of all protocol amendments and deviations as soon as possible. All changes in or revisions of the approved protocol and the reasons for the changes will be formally prepared by the Study Director, signed and dated by the Study Director, Principal Field Investigator and Sponsor Representative, and maintained with the protocol.

X. RECORDS TO BE MAINTAINED

A. All original raw data and authorized copies of raw data will be maintained at the Field Testing Laboratories until shipment to the Sponsor.
B. The original protocol and all deviations and amendments (or verified copies).
C. All correspondence that is necessary to reconstruct this study.
D. Training and records of experience of personnel involved in the study.
E. The QA Unit shall maintain a copy of the master schedule and records of all QA inspections.
F. The field report along with any amended field reports that may be issued.
G. All raw data or verified copies of raw data.
H. Photographic records may be helpful, but are not required.

XI. QUALITY ASSURANCE

The field testing laboratory's QA Unit will monitor the project to ensure that the facilities, equipment, personnel, practices, procedures, records and controls are designed and function in compliance with US EPA GLP, Pesticide Program 40 CFR Part 160 (October 1989). The QA Unit will make periodic inspections of procedures, record books, raw data sheets, equipment and facilities at the Field Testing Laboratory and will provide written documentation of findings to management and the Study Director. Appropriate corrective action, if needed, will be instituted immediately. A similar procedure will be used by the QA Unit at the Field Testing Laboratory.

XII. FIELD REPORT

The Field Testing Laboratory will be responsible for submitting completed, audited field logbooks and the associated audited field report to the sponsor. The field report will contain a Quality Assurance statement. It is also suggested that a statement of Compliance with Good Laboratory Practices be signed by the appropriate

Annex 2 A review of leaf area index (LAI) data. Database of reviewed papers

Introduction
Among the factors influencing the re-entry exposure the leaf area index (LAI) is considered as one.
Leaf area index (LAI) is defined as the ratio of the total area of all leaves (one side) of a plant to the area of ground covered by the plant. This means that if a plant had only one layer of leaves all placed next to each other, it would have a leaf area index of exactly 1.0, because the leaf area would equal the ground area covered.

Method
A literature evaluation was carried out on leaf area index data. Additionally non-published data on LAI measurements were also included. Databases consulted were EMBASE, ESBIOBASE, AGRICOLA, BIOSIS, CABA, CROPU, CAPLUS, LIFESCI, TOXLINE, and SCISEARCH. Key words were; leaf area index, agriculture, pesticide, herbicide, fungicide, insecticide, weed control, insect control, disease control, residue, spray, deposit.
From the 149 literature references found, only data with regard to agricultural and horticultural crops were considered. Preference was given to data generated in crops grown in European countries. In cases where results from European countries were available, data from other countries were not considered. If no European data were available, data from any other country were included. Totally 12 literature references were used. Four non-published overviews on LAIs were additionally considered and included.

Results
The results of the data review are given in Table 1.
None of the available studies had the purpose to investigate the LAI in relation to re-entry exposure. In most articles used, the LAIs were determined as one of several parameters of plant development in relation to fertilisation, soil tillage programs or application results in relation to spray equipment used. Therefore data reporting on LAI was rather inhomogeneous. Results were reported as individual results, in ranges, or just presented in a curve. To achieve a more homogenous presentation LAIs are given in Table 1 as ranges between the highest and lowest result reported.

The methods for LAI determination in the articles were often not described in detail and some articles did not report any method. As far as articles report the methods of LAI determination, they are shortly summarised in Table 1.

Discussion
The available database on LAIs is incomplete. The determination methods in most cases are not adequately reported. Therefore it cannot be excluded that different methods lead to different results.
There has been no report available in which correlations between DFR_0 and LAIs have been scientifically established.
Therefore LAI figures that have to be taken as the basis for the DFR_0 calculation still have to be supported by theoretical considerations.

In a theoretical approach the following considerations are made.
In early growth stages where the leaf canopy does not cover the ground completely, or in high crops where the leaf canopy is not yet closed, a corresponding part of the product will not reach the plant surface but reach the soil or will be lost by drift respectively.

This means that for the DFR_0 calculation a default LAI (for one side) of 1 can be assumed. It furthermore can be assumed that if both sides of the leaves are treated, the theoretical LAI for the DFR calculation may be increased to 2.
With progressing plant growth the LAI increases and should be considered in the DFR_0 calculation. This may mean that a default value for the LAI may be up to about 2. Taking into account that both leaf sides are treated, when relevant, the chosen LAI could be multiplied by 2.

Table 1: Leaf Area Index data found in published and no published study reports. (LAI values rounded to one decimal)

Crop	Country	Date	Growth Stage (Code)	Description of growth stage Or time points/time ranges	LAI	Further information a) Purpose of Study b) Method of LAI determination c) Data presented	Reference
Winter wheat	Germany	23.5.84	32 (BBCH)	Stem elongation (node 2 at least 1 cm above node 1)	4.3-5.9	a) Testing of spray equipment b) Counting of plants per m2 (5 times) determination of average leaf surface of at least 100 plants via photometric determination (LICOR area meter (LI-COR Inc.; 4421 Superior St., Lincoln, NE.) c) Individual results	Wolf, 2001
		11.5 98	35-37 (BBCH)	Flag leaf just visible, still rolled	6.4		
		18.5.99	37 (BBCH)	Flag leaf just visible, still rolled	5.8-6.2		
		29.5.84	39 (BBCH)	Flag leaf stage	9.7-10.7		
		2.6.98	49-51 (BBCH)	Beginning of heading	7.5		
		12.6.84	55-59 (BBCH)	Middle - end of heading	12-12.8		
	Switzerland	15.5.91	32 (BBCH)	Stem elongation (node 2 at least 1 cm above node 1)	3.9		
		15.5.91	37 (BBCH)	Flag leaf just visible, still rolled	6.7		
		25.6.91	51-59 (BBCH)	Beginning to end of heading	9.8		
Wheat (Durum and Bread wheat)	France Boigneville, Beauce	29.5.96	59 (Zadoks)	Emergence of inflorescence completed	0.79-2.74	a) Possibilities of hyper spectral imaging observations b) Direct "leaf counting" method c) Figures	Lelong et al. 1998
Winter wheat	Denmark	1996	30 (Zadoks)	Pseudo stem erection	~1	a) Study on fertilizers b) Non destructively by portable device (diffuse light transmission through the canopy, LAI 2000) c) LAIs presented as curve 0 kg N/ha	Gyldenkaerne et al. 1999
			32 (Zadoks)	2nd Node detectable	~1.5		
			33 (Zadoks)	3rd Node detectable	~2		
			53 (Zadoks)	¼ Of inflorescence emerged	~2.2		
			65 (Zadoks)	Anthesis half way	~2		
			85 (Zadoks)	Soft dough	~2		
			30 (Zadoks)	Pseudo stem erection	~1.6	a), b), c) as above 100 kg N/ha	
			32 (Zadoks)	2nd Node detectable	~2.8		
			33 (Zadoks)	3rd Node detectable	~3.8		
			53 (Zadoks)	¼ Of inflorescence emerged	~4.5		
			65 (Zadoks)	Anthesis half way	~4.2		
			85 (Zadoks)	Soft dough	~3.5		
			30 (Zadoks)	Pseudo stem erection	~1.6	a), b), c) as above 200 kg N/ha	
			32 (Zadoks)	2nd Node detectable	~3.8		
			33 (Zadoks)	3rd Node detectable	~5.5		
			53 (Zadoks)	¼ Of inflorescence emerged	~6.5		
			65 (Zadoks)	Anthesis half way	~6.5		
			85 (Zadoks)	Soft dough	~4.2		
Spring barley	Denmark	1996	22 (Zadoks)	Main shoot and 2 tillers	~0.5	a), b), c) as above 80kg N/ha	
			24 (Zadoks)	Main shoot and 4 tillers	~0.7		
			32 (Zadoks)	2nd Node detectable	~3.8		
			33 (Zadoks)	3rd Node detectable	~3.9		
			53 (Zadoks)	¼ Of inflorescence emerged	~4.5		
			75 (Zadoks)	Medium milk	~3.8		
Winter barley	Germany	9.5.84	39 (BBHC)	Flag leaf stage	4-4.9	a) Testing of spray equipment b) Sampling of plants per m^2, photometric determination c) Individual results	Wolf, 2001
Vine (Various pruning forms, e.g. arcade and double-cane pruning)	Germany and CH	1984 to 92				a) Testing of spray equipment b) Determination of total length of planted rows per ha. Counting of leaves of one m row (10 times/plantation randomly selected); determination of average leaf surface of at least 10 shoots plants via photometric determination (LICOR area meter) c) LAIs presented as curve	Raisigl, 2001
		2nd third April incl2nd third June	5-9 (BBHC)	Sprouting (Wool stage to bud burst)	<0.2		
		Mid May to 2nd third June	53-57 (BBCH)	Inflorescence emerge	~0.2-0.5		
		Mid June incl. 1sr third July	69 (BBCH)	End of flowering	~0.4-1.2		
		End July incl. 1st third. August	77-79 (BBCH)	Berry touch (beginning until completed)	~1.4-1.8		
		Mid to end August	81-83 (BBCH)	Ripening of berries (beginning until berries brighting in color)	~0.7-1.8		
Vine (Hedgerow)	N.E. Italy	27.7.94	--	Full foliage development	~1.9	a) Testing of spray equipment b) Sampling of leaves, - photometric leaf area determination (LICOR area	Pergher et al. 1997

Crop	Country	Date	Growth Stage (Code)	Description of growth stage Or time points/time ranges	LAI	Further information a) Purpose of Study b) Method of LAI determination c) Data presented	Reference
						meter) c) Figure (representing mean value)	
Apples	Austria, Italy, Netherlands and Switzerland	1988 - 1996 April incl. 1st third May	10 (BBHC)	Mouse ear stage of first leaves	~0-0.5	a) Testing of spray equipment b) Counting of trees/ha, counting of leaves from 5 randomly selected trees, determination of average leaf surface of at least 300 leaves by photometric determination (LICOR area meter) c) LAIs presented as curve	Raisigl, 2001
		Mai incl. June	65-72 (BBCH)	First petals fallen to fruit size up to 20 mm	~0.4 - 1.8		
		July –August	91 (BBCH)	Shoot growth completed	~1.4-3.9		
Sunflower	Spain (Seville)	21.4.93	--	54 days after sowing	TT:0.53 CT:0.36	a) Traditional tillage (TT), versus conservation tillage (CT): TT : consisting of mouldboard ploughing CT: no mouldboard ploughing; reduced number of tillage operations and leaving crop rests on field as mulch. b) Not specified c) Figures	Moreno et al. 1997
		20.5.93		83	TT:1.23 CT:1.03		
		3.6.93		97	TT:2.19 CT:2.01		
		17.6.93		111	TT:2.25 CT:2.17		
		6.4.95		38	TT:0.17 CT:0.11		
		17.4.95		49	TT:0.58 CT:0.36		
		3.5.95		65	TT:0.72 CT:0.92		
		16.5.95		78	TT:0.67 CT:1.6		
Greenhouse Eggplants	Italy (Sicily)	1987		60 days after transplanting	0.5-0.8	a) Fertiliser test b) Not specified c) Figures	Cosentino et al. 1990
				90	1.1-1.6		
				120	1.4-1.8		
Vicia faba	Spain (Barcelona)	25.01.1988 (sowing)		11 weeks after sowing	~1.	a) Fertiliser study b) Image processing system of sampled leaves c) LAI presented as curve	Vidal et al. 1992
				14	~2-3.5		
				16	~1.5-3.5		
				18	~0.7-1.4		
Potatoes	Germany (Southeast)	13.-17.6.88	35 (BBCH)	Before closing of rows	1.7	a) Testing of spray equipment b) Counting of leaves from at least 10 plants per field followed by determination of average leaf surface of these plants by photometric determination (LICOR area meter), number of plants per ha. c) Figures	Wolf, 2001
		27.6.-1.8.88	49 (BBCH)	Closed rows	2.6		
		11.7.-15.7.88	61-65 (BBCH)	Beginning of flowering	4.9		
		25.7-29.7.88	71-75 (BBCH)	Beginning of berry development	5.9		
Oilseed rape	France (-(Châlons-en Champagne)	9.9.94 (sowing)	-	19 to 40 days after sowing	<0.2	a) Fertiliser study 0 kg N/ha 135 kg N/ha 272 kg N/ha. b) Not specified c) Figures	Leviel et al. 1998
				60	0.93 -- 1.18		
				88	1.47 -- 2.32		
				123	1.3 -- 2.43		
				158	1.24 1.17 2.02		
				172	1.43 1.25 2.64		
				187	1.38 1.85 2.88		
				201	1.29 2.93 3.85		

Crop	Country	Date	Growth Stage (Code)	Description of growth stage Or time points/time ranges	LAI	Further information a) Purpose of Study b) Method of LAI determination c) Data presented	Reference
				214	1.46 4.41 5.40		
				228	1.3 4.56 5.96		
				243	1.79 4.24 5.02		
				256	1.39 4.02 5.98		
				271	1.5 3.56 5.23		
				284	1.0 2.4 4.6		
Processing tomatoes	USA (Calif.)	1994 sowing: 8-.3 transpl.:14.4	-	28.4.94	<0.2	a) Study on fertiliser and crop rotation b) Sampled leaves, photometric determination (LICOR 3000 area meter) c) Figures	Cavero et al. 1996
				12.5.94	0.21-0.52		
				31.5.94	1.19-2.57		
				25.6.94	2.64-5.18		
				15.7.94	2.05-3.4		
				2.8.94	1.6-2.74		
		1995 sowing: 31.3 transpl. 19.4.		11.5.95	<0.2		
				27.5.95	0.41-0.67		
				28.6.95	1.74-3.58		
				17.7.95	2.15-3.53		
				9.8.95	1.56-1.82		
Green beans (Phaseolus vulgaris)	Cameroon	Plantation 17.4.93 Plantation 16.10.93	-	at harvest	1.73-3.24 1.64-3.12	a) Rust control study b) Total leaf area of a plant were measured and divided by the area occupied by the plant. c) Figures	Fontem et al. 1998
White beans (Phaseolus vulgaris) bush type	Canada (Ontario)	1991 Sowing 11.6.1990 1.+5.6.1991 2.6.1992	- -	 at harvest 10.10.1990 10.+15.9.1991 15.+29.9.1992	 -- 1.8-2.3 1-2.4	a) Influence of weed on growth (ragweed b) Sampled plant were measured by leaf area meter (LICOR area meter) c) Figures	Chikoye et al 1995
Dry beans (phaseolus vulgaris)	USA (central Maine)	1990	-	28 days after planting	0.2	a) Fertiliser and tillage systems study b) Measurement by area meter (Delta-T Devices, Cambridge, England) of harvested plants, c) Figures	Liebmann et al. 1995
				56	1.66-2.18		
				84	1.3-3.09		
Corn	USA (Aurora NY)	Medium high hybrid Pioneer 3737	-	June 89	2.3	a) Study of weed control management systems b) Leaf area determined (LI 3100, LI-COR) from 5 randomly selected plants per subplot c) Figures (average over all tillage systems)	Ford et. al. 1994
				June 90	2.5		
		Medium high hybrid Pioneer 37047	-	June 89	2.0		
				June 90	2.4		
		tall hybrid Cargill 3027	-	June 89	2.0		
				June 90	2.7		
		short hybrid Cargill 4227	-	June 89	2.5		
				June 90	3.0		
		large leafy hybrid Fungk G 4309	-	June 89	2.3		
				June 90	2.8		
		floppy-leafed hybrid Fungk G 4324, medium high	-	June 89	1.8		
				June 90	2.6		

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Annex 3 Generation of transfer coefficients

Background to the Concept of Transfer Coefficient

The concept of the Transfer Coefficient has its origins in the United States in the 1970s following cases of pesticide poisoning arising from excessive exposure in harvesters of certain crops such as grapes, tree fruits and other hand-harvested crops. Their exposure was reasonably assumed to have been derived from inadequate decay of foliar residues of the pesticides. Crops such as those mentioned above were seen to present a special problem owing to the acute and chronic exposure potential over an extended growing season. Such problems lead to the idea that safe re-entry intervals could be set based upon the pesticide's residue decay curve and an appropriate toxicological endpoint and NOAEL.

Popendorf and Leffingwell (1982) investigated the relationship between foliar residues and dermal exposure. Their work defined a linear relationship between these variables over a broad range of values, although the ratio may differ between crops and depend upon the work activities.
Dislodgeable foliar residues (DFRs) were used by Nigg et al. (1984) and Zweig et al. (1985) to develop a first approximation of potential dermal exposures for harvesters of several different crops. From plots of exposure (μg/h) as a function of DFR (μg/cm^2) they defined the resulting slope as an empirical 'Transfer Coefficient' (TC), 5000 cm^2/h. This was an average TC for all studies with wide variation from about 800 to 61,000 cm^2/h. The empirical factor was proposed by Nigg et al (1984) for use without the need for actual measurements of re-entry worker exposure. Zweig et al (1985) did recognise the need for further validation using other pesticide/crop activity combinations. Krieger et al. (1990) further elucidated the significance of re-entry worker dermal contact with treated foliage and added weight to the concept of the use of the TC as a generic tool for estimating exposures to workers based upon DFR levels. These authors reported **potential** whole body TCs for a range of crop/work activity combinations from studies done in California.
A 'Transfer Coefficient' is therefore a theoretical estimate of the amount of contact (i.e. area of foliage) that occurs with a pesticide-treated crop during the conduct of a specific work activity. It is the ratio of dermal exposure (DE) to dislodgeable foliar residue (DFR):

$$\text{TC (cm}^2\text{/h)} = \frac{\text{DE (μg/h)}}{\text{DFR (μg/cm}^2\text{)}}$$

The TC is therefore directly proportional to DE and inversely proportional to the DFR.

Transfer Coefficient and the Concepts of Safe Residue Level and Restricted Entry Interval

In the USA it has been accepted for some time that TCs must be applicable to all classes of pesticide regardless of formulation type, method of application and mode of toxicity (US EPA, 1997). This generic approach is clearly valuable and attractive for the regulatory risk assessment process because it enables the estimation of worker exposure at various time intervals based upon the chemical-specific DFR dissipation curve and reduces the need for compound and work activity specific worker exposure studies. Therefore, within the current proposal of a generic model, it is assumed that crop/activity combinations can be created for which it is generally assumed that TCs might be broadly similar. This is also the working hypothesis of the US industry Agricultural Re-entry Taskforce (ARTF), which is conducting re-entry worker exposure studies and incorporating the exposure and associated DFR data into a data base which will derive the associated TCs.

The safe re-entry interval or Restricted-Entry Interval (REI) as it is more commonly referred to nowadays is a standard approach within the risk assessment process in the USA. It is defined as the time at which the DFR has declined to a level that will result in an exposure level equivalent to the toxicological reference dose for the specific pesticide. This residue is known as the safe residue level (SRL) and has the following relationship with the TC:

$$\text{SRL } (\mu g/cm^2) = \frac{\text{RfD } (\mu g/kg/day)}{[\text{TC } (cm^2/h) \times \text{Exposure Time } (h)]}$$

$$\text{where RfD} = \frac{\text{NOAEL } (\mu g/kg/day)}{\text{Safety Factor (unitless)}}$$

Having calculated the SRL it is then possible to determine the REI. This is done by developing a residue dissipation curve for the pesticide and crop of interest and estimating the time (hours or days) required to decline to the SRL.

Re-entry exposure studies that are deemed suitable for inclusion in a database for TCs can be grouped according to the crop/activity groups defined:

1. indoor crops
2. outdoor crops:
   a. fruit trees
   b. hops
   c. vines (grapes)
   d. tree nurseries
   e. berries
   f. lawns/greens/playgrounds

Types of Transfer Coefficient and Database Considerations

Studies considered suitable for inclusion in the database may contain data expressed in terms of both total potential and actual dermal exposure. This raises a complicating factor. Dosimeters, both patch and whole body, may be on the outside of all clothing, under normal clothing, under protective clothing, or under both normal and protective clothing. If one wants an estimate of the amount of foliage contacted to generate a theoretical TC with as few uncertainties as possible, dosimeters located outside of clothing are most suitable. If one wants a realistic estimate of actual dermal exposure, an underclothing location is most suitable. Both types of data can be used to generate TCs provided that the associated DFR data are available.

Relatively speaking, measurements taken outside of all clothing would be less variable than measurements taken from an inside location because the extent to which pesticide penetrates clothing might be expected to vary from worker to worker, from pesticide to pesticide and from formulation type to formulation type. However, a basic tenet of the generic use of exposure data for pesticide operators is that the impact of most of these factors is likely to be minimal and certainly outweighed by other uncertainties. If one uses the potential exposure data to generate a TC then a generic clothing permeation factor must be used to estimate the actual dermal exposure. The literature is somewhat unclear on this matter and not especially helpful. Many of the early studies, including those referred to above, would have included measurements of dermal exposure using the patch method for both clothed and unclothed areas. It is likely that there was no distinction for total and actual exposure. What resulted from these studies were whole body TCs for both covered and directly exposed skin areas such as the hands and forearms.

What is clear is that measurement of exposure across studies potentially suitable for inclusion in a database using different clothing scenarios is unlikely to yield comparable data. Similarly, unless the clothing in studies is identical, one would not necessarily expect the same under-clothing scenario to yield comparable exposure measurements.

Dosimeter location considerations will not have a clear effect upon the distributional form of exposure measurements but must be taken into account, on a case-by-case basis, when evaluating data from multiple studies. Studies involving external dosimetry can be compared because they are measuring the same thing. Similarly, studies involving dosimeters placed under comparable clothing might be combined. However, studies involving external dosimetry and under clothing dosimetry cannot be compared or combined in a database.

It is now apparent that the number and quality of studies available to EUROPOEM for inclusion in a database to enable prediction of re-entry worker exposure for all relevant crop/ work activity combinations across the EU is generally poor. There is a clear need for more studies and data to be generated under typical EU conditions. It is recommended that studies done in future with this in mind should involve measurement of both total potential and actual dermal exposure according to currently accepted guidelines (OECD, 1997). The development of the subsequent data base should take account of the following technical issues:

Field recovery. A standardised form of field recovery correction should be used for all exposure and DFR data that is in accordance with recognised official guidance.

Non-detectable values. A standardised procedure should be developed to deal with the issue of non-detects.

DFR decline curves. The construction of DFR decline curves should be standardised according to an agreed procedure from the possible options available, such as exponential, generalised, log-log, linear or use of the functional form that gives the best fit.

Whole body and body part TCs. The data base should be flexible enough to calculate whole body and body part TCs using both external and internal (under clothing) dosimetry measurements. TCs for the same individual can be aggregated to give a whole body TC provided they are not from overlapping body parts.

Statistical analysis of data. The database must include the following possible options:

- Calculation of percentiles
- Distribution plots
- Geometric and arithmetic means, other central tendency values.

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Annex 4 Use of dermal absorption data

In the tiered approach to re-entry worker risk assessment that is described in the main text of this report, reference is made to the use of relevant dermal absorption data at higher tiers. At these tiers an attempt is made to refine the estimate of the dermally absorbed dose in the worker rather than assume 100% dermal absorption as is done at tier 1 as a highly conservative assumption in the absence of relevant data. The use of percutaneous absorption data in a risk assessment process for any type of agricultural worker, irrespective of whether he is an operator or a re-entry worker, is fraught with uncertainties. There are a large number of potential dermal exposure scenarios that can have a significant impact upon the extent of dermal absorption in the worker, either singly or in isolation:

1. Duration of contact.
2. Extent and frequency of deposition of active substance on the skin over a single day, consecutive days or at irregular intervals over several days.
3. The variation in the physical form of the active substance, e.g. whether present in the form of a liquid or solid formulated product, spray solution or dried on solid deposit.

Measurements of dermal absorption are usually obtained for the formulated product and also for relevant dilutions thereof that represent the in use spray concentrations of the product. With well-designed dermal absorption studies one can usually select appropriate dermal absorption values that can be applied to dermal exposure values to estimate the dermally absorbed dose. The *in vivo* or *in vitro* dermal absorption studies in animals or humans ideally should be designed such that the doses applied to skin are representative of anticipated worker dermal exposure values in terms of dose density, i.e. ug/cm^2 of skin. This is a difficult judgement to make owing to the high degree of variability in field operator exposure levels and the fact that dermal exposure is not uniformly distributed over the skin areas of the individual body parts and the body as a whole.

Another significant confounding factor that is rarely noted is that there is potentially a multitude of use patterns for individual products that can involve single or repeated daily exposure and absorption. Percutaneous absorption studies, whether *in vivo* or *in vitro*, only involve a single application from which absorption is measured over different periods of time, from which a value is selected for the scenario under consideration, typically 24 hours, which is the most relevant period for risk assessment purposes. There is the uncertainty of whether the value determined for a single dermal application is relevant to the repeated daily exposure scenario, which may prevail both for operators and re-entry workers. Absorption may or may not increase following repeated daily exposure, depending upon whether the percutaneous absorption process is saturated by a single exposure, i.e. whether the maximum, steady state absorption rate has been achieved during the single dermal exposure. A degree of flexibility and latitude has therefore to be applied in the assignment of dermal absorption values expressed as percent of applied dose absorbed. The uncertainties in the process must be recognised and taken account of in the overall risk assessment.

For operators, the process of assigning a relevant dermal absorption value for the dermal exposure scenario under consideration is perhaps more straightforward than that for the re-entry worker. The estimation of the dermally absorbed dose in re-entry workers performing a variety of activities that might be conducted at varying intervals post-application is potentially a more complex process. Dermal absorption studies will not have been designed to specifically estimate the dermally absorbed dose following exposure to:

The specific dose densities of re-entry worker dermal exposure levels;

The physical form of the active substance in the matrix in which it is present on foliar surfaces.

This last point deserves special mention and discussion.

Following deposition of a liquid spray solution or solid formulated product on a foliar surface, the active substance will be subjected to a variety of effects, both environmental and physico-chemical in nature. Depending on the ambient conditions the water carrier of a liquid spray solution will gradually evaporate over time to leave a dried deposit on the foliar surface. A solid formulation, although unlikely to be foliar-applied, might be transformed into a liquid form by the presence of dew or rain. This will be subjected to the same effects as the liquid spray. The physical form of these deposits is likely to be concentrated 'hotspots' of active substance rather than an evenly distributed layer of material over the foliar surface. A possible explanation for this is that as the water evaporates, a uniform layer gradually forms discreet droplets that become smaller thus concentrating the active substance. Further, there is a tendency for active substance to concentrate at the tips of the leaves of the foliage under gravity, thereby creating 'hotspots'.

The active substance is also subjected to degradation depending upon its physico-chemical characteristics. Environmental conditions also play a role in this degradation. However, the risk assessment process is concerned solely with the remaining active substance and not with the products of this degradation. In all possible scenarios other than immediately post-application (e.g. up to two to three days) the pesticide is present in concentrated form as the active substance in the absence of its co-formulants. The most suitable dermal absorption value would therefore be one for the technical material rather than the formulated product or its spray solutions. It is uncommon for technical material to have been evaluated for dermal absorption potential in isolation. Data might be available, however, for the material to which manufacturing or formulation workers are exposed. Where *in vitro* studies have been conducted there may be preliminary data available on the active substance in isolation.

It is recommended that, where possible, such data should be used in preference to data on the formulated product. If no such data are available on the active substance it is recommended that the complete dermal absorption database be evaluated to determine if an appropriate, conservative value can be discerned. The approach should be the classic 'tiered approach' to data selection and evaluation and use in the risk assessment process. If there are concerns over the overly conservative nature of the risk assessment using inappropriate dermal absorption data, the option always remains to conduct a new dermal absorption study on the active substance in an appropriate physical form. This study need not be a full study to standard protocol but could be limited in terms of the number of doses and test animals or skin samples used. This is an example of where the *in vitro* technique could have a significant advantage over its *in vivo* counterpart. It would be more straightforward from a technical standpoint to evaluate the impact of the physical variables discussed above on the dermal absorption process *in vitro* than in the *in vivo* animal model counterpart.

Annex 5 Validation of the worker re-entry exposure transfer coefficient concept through biological monitoring

Introduction
The purpose of this Annex is to describe the background and technical issues associated with the proposal to validate the Transfer Coefficient (TC) concept for agricultural crop re-entry activities that underpins the development of a data base of re-entry exposures and generic TCs to enable the calculation of re-entry worker exposure.

Background
The TC concept and the acceptance of its validity is essential for the credibility and acceptance of a data base of re-entry exposure and generic TCs for predicting re-entry worker exposure. The concept has never been validated in terms of its ability to predict dermal exposure when used in conjunction with compound-specific dislodgeable foliar residue (DFR) data. This annex is concerned with the possible use of biological monitoring as a means of validating the TC. Biological monitoring is recognised for giving the most accurate estimate of the absorbed dose of a pesticide, particularly if studies are designed and interpreted with the aid of human metabolism and pharmacokinetic data. A direct comparison of the passive dosimetry and biological monitoring approaches to the estimation of the absorbed dose would go a long way to providing the necessary confidence in the TC concept's validity.

Outline process
The process would be along the lines of the following:

1. Choose cluster group for which there are existing exposure and TC.
2. Conduct re-entry studies with concurrent passive dosimetry and biological monitoring on a suitable surrogate compound that meets the relevant criteria for biological monitoring. This study would give dermal exposure (DE), absorbed daily dose (ADD) and DFR data (to enable the calculation of TCs).
3. Using dermal absorption (DA) data on the surrogate compound the ADD could be calculated with the passive dosimetry approach and a comparison drawn with the ADD determined with biological monitoring.
4. A further comparison could be drawn between the calculated ADD from the generic TC derived from the data within the same cluster and group and the ADDs from the passive dosimetry and biological monitoring approaches.

An additional advantage of the validation project would be to generate generic TCs based upon biological monitoring data in addition to those derived using the conventional approach, if the ADDs estimated by the two approaches are comparable:

$$DE = TC \times DFR$$
$$\text{If } ADD = DE \times DA$$
$$\text{Then } ADD = TC \times DFR \times DA$$
$$\text{If } ADD(biomon) \approx ADD(\text{passive dosimetry}), \text{ then:}$$
$$ADD(biomon) = TC \times DFR \times DA, \text{ thus}$$
$$TC(biomon) = \frac{ADD(biomon)}{DFR \times DA}$$

The TC derived through this process would be a whole body TC and it is recognised that this would not meet any regulatory requirement for regional body part TCs for the purpose of mitigating excessive exposure. However, this limitation could possibly be overcome for many crop/activity combinations on the basis that most of the dermal exposure would involve the hands and forearms.

One other advantage of biological monitoring is that the absorbed dose data could be extrapolated to dermal exposure values if the dermal absorption characteristics of the surrogate compound are well understood, preferably using *in vivo* human skin (although there are substantial uncertainties associated with this procedure. Using the concurrent DFR data, these extrapolated values could be another source of TCs.

The above arguments in favour of doing some biological monitoring would provide the necessary confidence in the TC data that will be used for making regulatory decisions on the acceptability of the risk of the crop re-entry activity for specific products.

Choice of surrogate compound for biological monitoring
On the choice of a suitable surrogate compound, it should meet the following criteria:
availability of human metabolism and pharmacokinetic data;
availability of human in vivo dermal absorption data;
analytical methods available for the principle metabolites that can be refined to the required level of sensitivity.

One such 'generic' compound that meets these criteria is malathion.

There are some significant technical and regulatory issues associated with the proposal to do biological monitoring. These are outlined below.

Issues

1. The proposal made so far has centred on doing one definitive biological monitoring study in the belief that, if the correlation between the ADDs is found to be acceptable, then, as a minimum, no further validation work would be needed. The proposal has so far considered doing the study on a high contact activity/crop combination (e.g. apple harvesting) to hopefully ensure that measurable residues are obtained both in the passive dosimetry measurements and in the urinary metabolite analyses. A valid question that has been posed is whether a single study in a high contact activity, even if good correlation is demonstrated, is adequate to ensure confidence in the TC concept working for activities and crops with lower potential contact. Associated issues are the other activities that should be studied and the influence of formulation type and the different types that might require evaluation.
2. A related issue is whether a single study is likely to be wholly definitive. There will undoubtedly be variance which might be subject to different interpretations. This might lead to the regulatory request and scientific need for further confirmatory validation studies.
3. The validation project outlined above under Background is not only dependant upon the conduct of the study involving the two types of methodology. It also depends upon the input variables to estimate the absorbed dose estimated via these approaches. In the case of the passive dosimetry approach these are:
    - the dermal absorption value used to estimate the absorbed dose from the dermal exposure data; published data indicates a range of 5 to 8% applied dose absorbed in human volunteer studies;
    - method of estimating the actual dermal exposure data.
      In the case of the biological monitoring approach:
    - the fraction of absorbed malathion excreted in the urine as metabolites- 90.2% from a human parenteral dosing study;
    - the choice of urinary metabolites to monitor in the study (eg mono- and dicarboxyllic acid, dimethyl thiophosphate);
    - the fraction of absorbed malathion excreted in the urine as the mono- and dicarboxyllic acid metabolites - 57% from a human dosing study;

- the overall calculation to estimate the malathion absorbed dose equivalent based upon metabolite excretion and analysis.
- sensitivity of the analytical methods for the chosen metabolites.

Annex 6 Re-entry worker exposure to vapour and dusts

The potential exposure to plant protection products via the inhalation route for re-entry workers is governed by a series of factors.

1. Physico-chemical properties of the active substance, i.e. volatility and Henry's law constant.
2. Application technique, e.g. boom sprayers, mist blower, hand held gun and foggers can influence residual air concentration. In addition the position of the application in relation to the crop can influence the atmospheric concentration, e.g., cold foggers can be floor-mounted or suspended above the crop.
3 Physical nature of the post application deposit, i.e. dissolved, suspension, microencapsulated, dust.
4. Post application (re-entry) interval.
5. Environmental conditions, e.g., temperature, wind, open field, and greenhouse.
6 Leaf /canopy density of crop.

Each of these parameters can influence or exclude the potential for inhalation exposure.

Physico-chemical properties
Consideration of the physico-chemical properties of the active substance will indicate if there is any tendency for the molecule to enter the vapour phase either from the dried foliar deposit or from any residual drops remaining on the plant surface. Compounds with a vapour pressure below 100 mPa 20°C can be considered as non-volatile (EU Commission Directive, 1994) and therefore potential exposure can be considered as negligible. Potential exposure from any remaining drops of spray solution can be determined by calculating the Henry's law constant or Henry's coefficient. Values below 10^{-3} are considered to be indicative of non-volatility from water (Lyman et al*.,* 1990). Work undertaken in greenhouses with five compounds with vapour pressures ranging from 1 $x10^{-6}$ to 6 $x10^{-3}$ Pa confirmed that for workers re-entering crops treated with these compounds, inhalation was not a significant route of exposure (Kirknel et al*.,*1997).

Application technique
The initial atmospheric concentration following application can depend on the application technique, e.g. boom versus mist sprayers, or floor versus roof foggers. In a series of studies in greenhouses, both the initial atmospheric concentration and rate of decline was seen to differ between foggers and boom sprayers, furthermore floor-mounted foggers tended to give lower initial concentration and a more rapid decline compared to roof mounted foggers (Kirknel et al., 1997).

Physical Nature of Deposit
Exposure to particulate and aerosols deposits were detected during the first 24 hours in several studies involving applications in greenhouses (Kirknel et al*.*, 1997). These deposits were trapped on glass fibre filters with no size distribution undertaken therefore it is not possible to determine the toxicological significance of this material with certainty.

The particle size controls whether the dust/aerosol is firstly inhalable and secondly respirable. Conventional IOM samplers used to determine exposure to dusts have not resolved the differing size fractions giving a total dust content. Recent developments have allowed new samplers (HSE, 2000) to distinguishing between inhalable and respirable fractions, thus identifying the respirable (i.e. retained particle) fraction which allows a more realistic assessment of inhalation exposure from particles. If a significant proportion of the particles is

below 50 μm diameter then the inhalation route is considered as a potential source of exposure and should be considered (EU Commission Directive, 1994).

The physical nature of the dried deposit or the physical characteristics of the active substance in the spray drop can mediate any tendency that the active substance may have to enter the vapour phase. The presence of a volatile (>100 mPa) active substance in the formulation does not necessary result in significant inhalation exposure. Active substances which are contained by a barrier, i.e., micro-encapsulated formulation, granule/dust, or even particles of undissolved active substance from suspension concentrate spray solutions will decrease the potential for vapour phase inhalation exposure.

Post application (re-entry) exposure
The length of time between end of application and re-entry can have the same impact on inhalation exposure as it can on dermal exposure from foliar dislodgeable residues. Potential exposure from a volatile compound may decrease with time as the concentration of the active ingredient is reduced either by absorption into the plant, degradation or loss to the environment. In a series of measurements after low-volume-mist fogging in greenhouses, Brouwer et al. (1992) studied the disappearance of aerosols and vapour from greenhouse air with closed windows. A 10-100 fold decrease in atmospheric concentration was observed, after about 8 hours, somewhat dependent on the volatility of the compound. The presence of a ventilation system in the greenhouse environment can further reduce the resultant atmospheric concentration.

In a separate series of trials with 5 active substances in greenhouses, Kirknel et al., (1997) also reported that a 10 to 100 fold decrease in atmospheric concentration was observed ca. 16 hours after application. The reduction of atmospheric concentration will impact on the contribution of inhalation to systemic exposure received on re-entry into the treated crop. In a separate greenhouse study with bupirimate, the inhalation exposure was observed to be <1% of the external dose when the cucumbers were harvested 21-28 days after treatment (Schipper *et al*., 1998).

The relationship between inhalation exposure and application rate has been studied in a series of studies on ornamentals grown in greenhouses. These studies have been incorporated in a simple model for inhalation exposure of non-vapour fraction. (van Golstein Brouwers et al., 1995).

The model can be summarised as:

mg as/hr inhaled = kg/as/ha applied x Task Specific Factor

For the following tasks, sorting and bundling, low volume mist application and cutting after dust application there is a certain amount of inhalation exposure (mg/h). This can be estimated from the use rate (kg/ha) using a following Task Specific Factor. The following factors were calculated as the 90-percentile of the observations for specific tasks:

0.1 for cutting ornamentals after application;
0.01 for sorting and bundling of ornamentals;
0.03 for low-volume-mist application (about 8 hours after application).

Additionally, this simple model holds some validity for predicting total atmospheric concentrations for other situations. Review of data reported by Kirknel et al. (1997) indicates for boom and rifle applications the atmospheric concentration at ca. 16 hours after application only exceeded a predicted value based on a Task Specific Factor of 0.02 on only one occasion. Atmospheric concentrations resulting from roof foggers can be modelled using an

empirical constant of 0.15. Under these circumstances the 16 hour concentrations reported by Kirknel et al. (1997) were generally at or below this value.

Using these values (0.01 for sorting and bundling, boom and rifle applications, 0.03 for low-volume-mist application and 0.1 for cutting after dust application, and 0.15 for roof fogger applications) as a first approach it is possible to estimate potential inhalation exposure (mg/h) for non–volatiles (< 100 m Pa). Where the inhalation exposure contributes to toxicologically significant exposure, refinement of the model or the generation of data for the specific GAP can be required which may result in the introduction of a specified re-entry interval.

Environmental conditions
The ability of any vapour/dust to dissipate will impact on potential inhalation exposure. Applications made under cover (i.e. greenhouses) may if there is insufficient ventilation present an enhanced potential for inhalation exposure compared to an application made under open field conditions. Alternatively forced ventilation may also reduce potential build up of concentration compared to an open field with negligible wind. In both scenarios, elevated temperatures can potentially increase the degree of volatilisation and potential exposure. Aerosols and vapours may exist for several days in green houses after low volume spraying (William, 1978, Williams et al., 1980, Lindquist et al., 1987, Liesivuori et al., 1988, Brouwer et al., 1992, Kangas et al., 1993.)

Leaf and tree canopy cover
Leaf and tree canopy cover can similarly impact on the localised atmospheric concentration of a vapour. Applications made to low crops may not result in inhalation exposure. Similar applications made to crops with a high leaf density or dense tree canopy have the potential for localised areas of increased atmospheric concentration. It was been suggested that models for both high and low crops are required (Schipper et al.,1998).

Conclusions
On the basis of a relative small number of data, a model with some indicative default values has been considered useful for use of estimating inhalation exposure during re-entry tasks. These are based only on studies considering work with ornamentals.
The model (algorithm):

mg as/hr inhaled = kg/as/ha applied x Task Specific Factor

The Task Specific Factors, that can be used in the first tier of the exposure and risk assessment, have been estimated for a small set of exposure data for harvesting of ornamentals and re-entry of greenhouses about 8-16 hours after specific applications. The **indicative** Task Specific Factors are:

- 0.1 for cutting ornamentals;
- 0.01 for sorting and bundling of ornamentals;
- 0.03 for low-volume-mist application (8 hours);
- 0.15 for roof fogger application (16 hours).

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Annex 7 Exposure of workers to residues in soil

Some scenarios involving exposure to plant protection products (or relevant metabolites, degradation and reaction products) through dislodgeable foliar residues (DFR) may also entail exposure to soil borne residues. For example harvesting leeks or weeding in a leafy crop may include contact with such residues. In these situations the dermal exposure monitoring data used to either estimate exposure directly or to derive transfer coefficients will include any exposure through soil contact as well as that exposure arsing from contact with foliage.

The contribution of the soil residues to the total exposure is usually expected to be less important than that of the DFR. For example, in a study done in Florida (Stamper *et al*.,1987), measurements of DFR levels on strawberry leaves were 1 to 3 $\mu g/cm^2$, while the concurrent soil residues were from trace levels to 25 ppm. The estimated total potential dermal exposure based on the DFR was 1.44 to 4.33 mg/h. For soil residues to make an equal contribution would require adherence of about 170 g of soil on the hands. This is unlikely to be achieved considering the dermal adherence values discussed below.

However, there may be some re-entry situations where exposure to soil borne residues occurs in the absence of contact with treated foliage, for example using compost treated with an insecticide or during manual harvesting of root crops.

Council Directive 91/414/EEC Annex III (set out in Commission Directive 95/36), point 9.1.3 *Estimation of expected concentrations in soil*, requires predicted estimations of concentrations in soil. These estimations should assume; a soil density of 1.5 g/cm^3 dry weight; a soil layer depth of 5 cm for applications at the soil surface or 20 cm when incorporation is used; where ground cover is present at the time of application a minimum of 50% of the applied dose reaches the soil surface, unless actual experimental data give more specific information. (In the absence of ground cover, 100% of the applied dose is assumed to reach the surface).

Other factors to be considered relate to direct and indirect application to soil, drift, run off, and leaching and include processes such as volatilisation, adsorption, hydrolysis, photolysis, and aerobic and anaerobic degradation. The Directive requires estimates of initial, short, and long term concentrations to be provided where relevant. In some circumstances, field studies on dissipation in soil or residues in soil may be available, in place of the above estimates.

These data on soil residue levels, either estimated or measured, can be used with soil dermal adherence data to estimate potential human exposures, with the actual exposure being estimated on the fraction adsorbed. In this case the exposure is estimated as:

$$\text{Dermal exposure} = \text{Conc.}_{\text{soil}} \times \text{Dermal adherence}_{\text{soil}} \times \text{Skin area contaminated} \times \text{Transfer}_{\text{soil/skin}}$$

and

$$\text{Absorbed dose} = \text{Dermal exposure} \times \text{Percentage absorbed}$$

Of course, not all of the chemical in a layer of soil applied to skin may be bioavailable. However, in the absence of specific information conservative assumptions are typically used.

Field studies investigating dermal exposure to soil by direct gravimetric measurements (Kissel *et al.,* 1996) suggest that an appropriate hand soil loading for a worker would be 0.44 mg/cm^2 (geometric mean peak value for farmers involved in hand weeding). A laboratory study to determine the extent of soil adherence to hands when totally immersed in a range of

dry soil samples (Driver *et al.,* 1989) concluded that the mean hand loading for unsieved soil was 0.58 mg/cm^2 of skin surface. Data for sieved samples suggested that hand loading increased when soil particle size was reduced.

Assuming a surface area of the hands of 820 cm^2, complete coverage, and a soil retention value of 0.44 mg/cm^2, the appropriate daily peak soil hand loading would be 361 mg. Assuming a bulk density for soil of 1.5 g/cm^3, this hand loading value equates to 0.24 cm^3. The dermal exposure to the chemical can be estimated by multiplying by the concentration in soil and assuming that all the chemical contacts the skin.

A refinement of the estimate would be to include a data on the transfer of the active substance from soil to the skin (Duff and Kissel, 1996), but the data to do this are not usually available.

Inhalation exposure can be approximated by using field data on personal exposure levels to soil dust during relevant operations. For example, data from California (Nieuwenhuijsen *et al* 1998), a dry-climate situation likely to give a conservative value, show a worse case total inhalation dust exposure when discing (cultivating) on a vehicle without a cab of 98.6 mg/m^3. Under the same conditions the exposure to respirable dust was 0.58 mg/m^3. A study done in Poland indicated that during plant harvesting personal dust levels were 3.3 to 19.3 mg/m^3 (Molocznik & Zagorski, 2000).

For a chemical distributed evenly in soil at the rate equivalent of 1 kg/ha to a 5 cm depth, assuming the worse case exposure of 98.6 mg/m^3, over an 8 hour day a 60 kg person breathing at 29 litres/minute, would be exposed to 30 ng/kg bw/day. Which is a very low amount indicating that the potential inhalation risk from residues in soil is typically very low.

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Annex 8 Re-entry literature

Not presented due to size.

Annex 9 Initial dislodgeable foliar residue data

Introduction
A literature evaluation was carried out on initial dislodgeable foliar residue (DFR) data. The purpose was to summarize and review knowledge and data on initial DFR data for its applicability for use in generic databases and for exposure modeling. Initial DFR is defined as the DFR samples taken between 0 and 24 hours after application. The purpose of the study was to summarize and review published knowledge and data on initial DFR in relation to the application rate. The results are applicable in generic databases and for exposure modeling.

The 82 selected re-entry publications, included in the 1999 re-entry screening were checked for the presence of initial DFR data. These 82 publication were selected out of 698 publications, based on the presence of DFR data and re-entry exposure data. Next to the 82 selected publications the database was updated using the 1999 re-entry screening search criteria. The search criteria were divided into 3 categories. These categories concentrated upon crop (crop type and used pesticides), dissipation and re-entry respectively. The following databases were screened: RILOH, MHIDAS, HSELINE, CISDOC, MEDLINE, NIOSHTIC and Current Contents. An update concentrated on the publications published from 1999 to June 2000.
The publications containing a re-entry time, an intial DFR value or both were selected for screening. A total of 55 publications is included in the database.

Dataset
The selected references were entered into an Excel spreadsheet (MS-Excel, version 7.0). This Excel file contains information on the publication, feature of the survey, initial DFR data and applications rate. No calculations were performed on the published data, except for conversions to a consistent set of units. No extrapolations of DFR values were made, when only data from figures were available in the references.

Contents of database (Annex 10)
The column A - H (yellow section) includes general information. To be able to compare the initial DFR of the different publications, the following features were recorded: active substance, application rate and corresponding initial DFR (DFR0). The application rate was converted to kg active substance / hectare. The original value as mentioned in the publications (papers) is stored in column J. In column M the converted values are stored. The original initial DFR values are stored in column P. The initial DFR values are converted to $\mu g/cm^2$. The converted initial DFR values are stored in column Q. The original re-entry time as mentioned in the papers is stored in column U. The re-entry time is converted to days. The converted re-entry time is stored in column X. The variables stored in columns are specified in table 1.
The re-entry time could be interpretated in two ways:
1. The legal re-entry time. The time the worker has to wait before re-entry of the field according to the regulatory authorities.
2. The actual re-entry time. The first entry since the last application.

Both interpretations have been included into the database.

Table 1Data stored in DFR0 database

Column	Explanation	Column reference
Article		
Study number	Number of the study	A
Number re-entry study 1999	Study number of publication in the re-entry database of 1999	B
Author	The names of the authors	C
Title	The title of the publication	D
Journal	Journal in which the survey is published	E
Page	Volume and page number of journal	F
Year	The year of publication	G
Reference number	Reference number for TNO documentation	H
Features of the study		
Substance	Active substance measured during re-entry	I
Application rate	Application rate preceeding re-entry	J
Dimension	Dimension of application rate (units given in paper)	K
Conversion rate	Conversion rate of application rate value to SI	L
Application rate calc.	Application rate in kg active substance / hectare	M
Dimension application rate calc.	SI units application rate kg a.i./ ha	N
Crop type	Crop type	O
DFR0	Initial dislodgeable foliar residue	P
Dimension	Dimension of initial dislodgeable foliar residue	Q
Conversion rate	Conversion rate of initial DFR to SI units	R
DFR0 calc.	Initial DFR in $\mu g/cm^2$	S
Dimension DFR0 calc.	SI units initial DFR $\mu g/cm^2$	T
Re-entry time	Legal re-entry time or first re-entry of worker after application	U
Dimension	Dimension of re-entry time	V
Conversion rate	Conversion rate of re-entry time to SI units	W
Re-entry time calc.	Legal re-entry time of first re-entry of worker after application in days	X
Dimension re-entry time calc.	SI legal re-entry time of first re-entry of worker after application in days	Y
Additional information		
Remarks	Additional remarks	Z

Conclusion

The database contains 164 records abstracted from 55 studies. The application rate varies from 0.010 up to 8.98 kg/ha, the DFR0 from 0.0025 up to 10.9 $\mu g/cm^2$ and the re-entry time from 0 up to 65 days. There are 54 records containing application rate values as well as initial DFR (DFR0) values.

The number of records per crop type is not large enough to assess a DFR0-value based on a specific crop type and application rate. Due to the small number of records and the variety in application rates and crop types the database is useful to indicate a approximate relationship between DFR0-values and application rate, leaving the crop type aside. The relationship between DFR0 and application rate is shown in figure 1 and the cumulative distribution of the DFR0 is shown in figure 2. The cumulative distribution of the DFR0 divided by the application rate is shown in figure 3.

Figure 1 contains two outliers. The first outlier (DFR0=10.9 µg/cm^2; Appl. rate=6.6 kg a.i./ha.) is from a study in which bendiocarb was applied to glasshouse ornamentals (azaleas). The second outlier (DFR0=1.87 µg/cm^2; Appl. rate=7.84 kg a.i./ha.) is a study in which a non-specified organophosphate pesticide was applied to oranges.

Summary of database

Description of re-entry database	
Search update	June 2000
Covering studies from	1958 - 1999
Number of studies in Database	55
Number of records	164
Number of active substances (incl. metabolites)	46
Number of crop types	28
Update of database	6 November 2000

Crop type	Number of studies
Hard fruit	25
Small fruit	12
Ornamentals	11
Bushes	1
Vegetables	11
Cotton	4
Corn / Cane	2
Public parks and gardens	3

	Appl. rate (kg/ha)	DFR0 (µg/cm^2)
Minimum	0.010	0.0025
Maximum	8.96	10.9

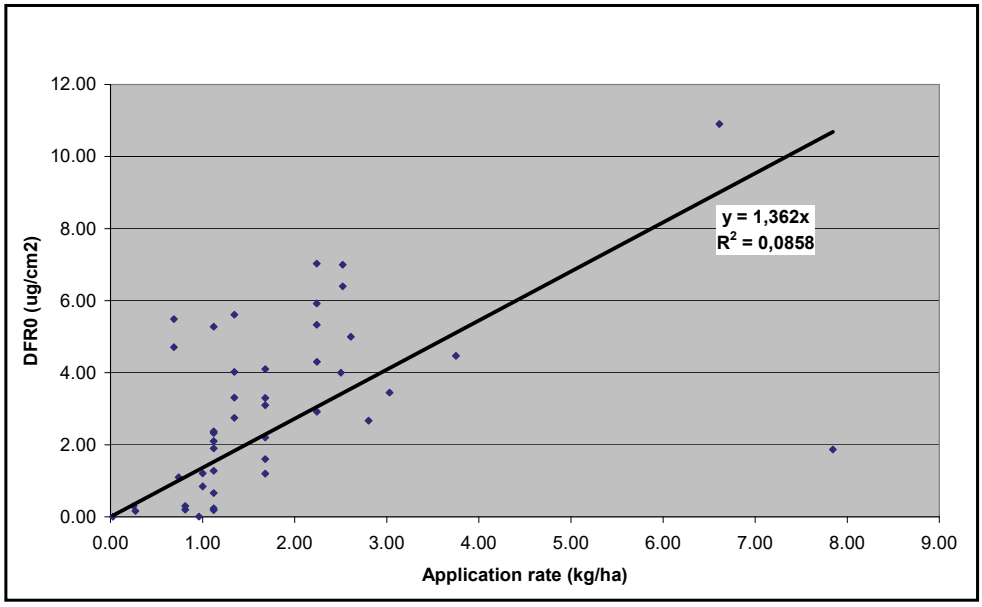


Figure 1 Relationship between initial DFR and application rate

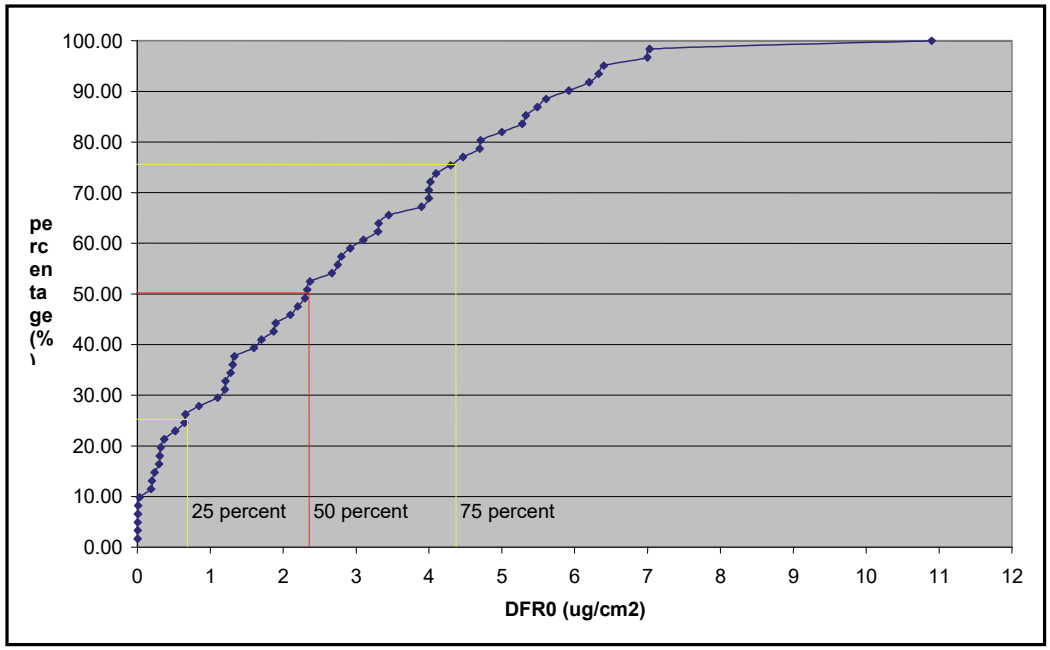


Figure 2 Cumulative initial DFR

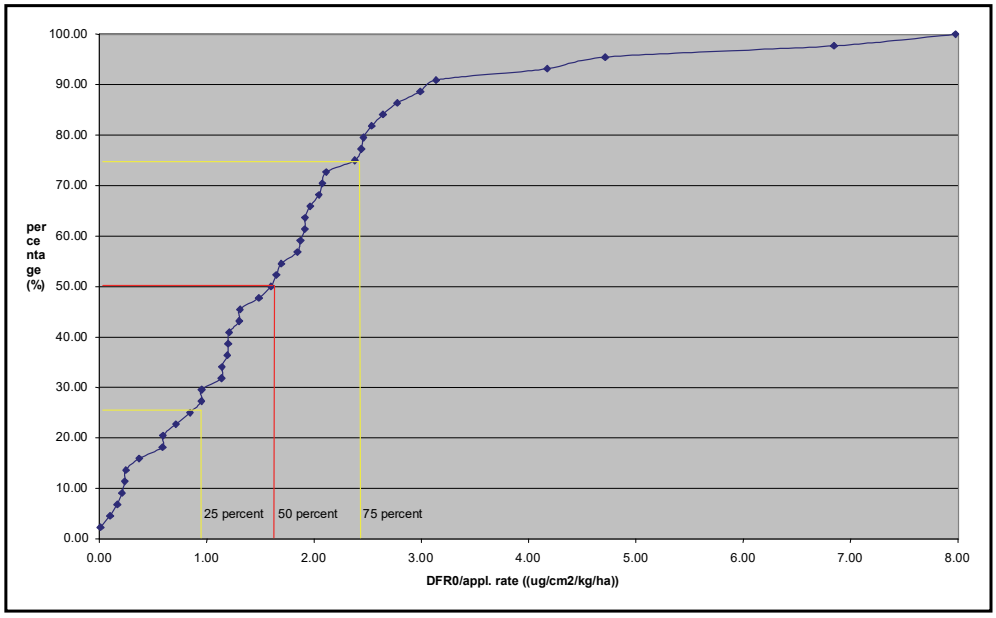


Figure 3 Cumulative initial DFR/Application rate

Annex 10 Database of initial DFR data

Not included due to size.

Annex 11 Summary of study reviews

The studies that were considered to be of value for taking data for transfer coefficients are summarised below. The following studies were considered for this exercise: 6, 7, 21, 36, 44, 45, 51, 53, 55, 57, 68, 70 and 71.

The reviews follow on the next pages.

From the discussions of these reviews it was apparent that all of the data must be considered as indicative value. However it became clear that several studies had appreciable shortcomings, and not all presented data in the publications or reports could be verified. In some cases there were even inconsistencies in the text with respect to relevant data.

The following studies were considered acceptable: 6, 7, 21, 36, 53 and 70, whereas the others were considered of borderline quality or not acceptable. Nevertheless as much data as possible has been used for inclusion in the database, to be able to get indications for relevant indicative values for transfer coefficients linked to specific scenarios. No data were extracted from reports considered unacceptable.

It is clear from this analysis that the database should be updated with good information from new studies. Further research in this area is of extreme importance.

Study 6: Brouwer et al., 1992. Pesticides in the cultivation of carnations in greenhouses: Part II Relationship between residues and exposure (Am. Ind. Hyg. Assoc. J. 53(9):582-587)

Documentation Published conference proceedings. Adequate documentation for review and assessment. No of replicates Dermal exposure of 94 workers, from 18 different farms, as follows: Chlorothalonil (sprayed) 23; thiophanate-methyl (sprayed) 21; chlorothalonil (dusted) 19; thiram (dusted) 17; and zineb (dusted) 14. Duplicate DFR samples of 12 leaves before application and harvesting.
Re-entry conditions Indoor (glass greenhouse) Climate details, (e.g. temperature, humidity, irrigation regime) not reported. Sites situated in the Netherlands.
Work activities Participants: field workers (likely to have been farm workers/owners but not stated) Scenarios: Harvesting carnations (cutting with a knife, collecting in bundles on arm or on cord above crop).
Sampling methodology *Expt details in Am. Ind. Hyg. Assoc. J. 53(9):575-581* Body parts: prewashed cotton gloves covering hand and forearm (one sided surface area 370 cm^2). Respiratory exposure measured with IOM personal air sampler Actual/potential DFR sampled by 2x shaking for 30 min in dist water + Triton-X100 One-sided LAI Concomitant DE and DFR.
Chemical analysis and validation a) chlorothalonil –DFR solutions or methanol extracts of gloves/filters were extracted with hexane, and measured by LC with UV detection. The between day analytical CV was <5% for all matrices; DFR – recovery was 100%; Dermal exposure – analytical recovery from gloves and air filters was >90% b) zineb –converted to soluble form, then derivatised, and derivative measured by reversed-phase HPLC with UV detection. The between day analytical CV was reported to be about 7% for all matrices; DFR – recovery was >90%; Dermal exposure – analytical recovery from gloves and air filters was >90% a) thiophanate-methyl and thiram –in DFR solutions were measured by reversed-phase HPLC with UV detection. Gloves and filters were extracted with acetonitrile first. The between day analytical CV was <5% for all matrices; DFR – recovery was >90%; Dermal exposure – analytical recovery from gloves and air filters was >90%.
Conclusion The quality of this study is study is acceptable for use in the database.

Study 7: Brouwer et al., 1992. Risk assessment of dermal exposure of greenhouse workers to pesticides (Arch. Environ. Contam. Toxicol. 23, 273-280)

Documentation Published conference proceedings. Adequate documentation for review and assessment. No of replicates Dermal exposure of 126 workers, from 32 different farms, as follows: abamectin 12 farms, 48 workers; dodemorph 13 farms, 52 workers; and bupirimate 7 farms and 26 workers. Duplicate DFR samples of 18 leaves before application and during harvesting.
Re-entry conditions Indoor (greenhouse) Climate details, (e.g. temperature, humidity, irrigation regime) not reported. Sites situated in the Netherlands.
Work activities Participants: field workers, i.e. farm employees Three scenarios: harvesting roses (cutting with pruning shears and collecting in bundle on arm); sorting for quality and length; and bundling into bunches of 20 ornamentals. The small flower variety Motrea was used as common and gives high production per unit area and generally no gloves are used because the flower containing branches are almost thornless.
Sampling methodology Body parts: prewashed cotton gloves covering hand and forearm (one sided surface area 370 cm^2). To forestall breakthrough to the hands gloves were worn for a maximum of 1 h. Samples were stored in dark at 4°C until analysed (storage duration not stated) Actual/potential DFR sampled by 2x shaking for 30 min in dist water + Triton-X100 One-sided LAI Concomitant DE and DFR.
Chemical analysis and validation Details published elsewhere a) abamectin –DFR solutions or methanol extracts of gloves were extracted with hexane, and derivatised into a fluorescing compound and hydrolysed before the derivative was measured by HPLC with fluorescence detection. The analytical LOD was1 µg/l for the methanol solutions and 0.25 µg/l for the DFR solutions. The between day analytical CV was <6% for all matrices; DFR – recovery was 100%; Dermal exposure – analytical recovery from gloves was >95% b) dodemorph – DFR solutions were extracted with hexane, dried then dissolved in heptane and measured by GC. The between day analytical CV was reported to be about <7% for the glove extracts; DFR – recovery was 100%; Dermal exposure – analytical recovery from gloves was 100%. a) bupirimate–in DFR solutions was measured by HPLC with UV detection. Gloves and filters were extracted with methanol first. The between day analytical CV was <5% for all gloves; DFR – recovery? Dermal exposure – analytical recovery from gloves was 100%.
Conclusion The quality of this study is study is acceptable for use in the database.

Study 21: Kirknel et al., 1997. Pesticide re-entry exposure of workers in greenhouses. Pesticides Research No. 31. Danish Environmental Protection Agency

Documentation Fairly detailed, published research report describing 16 separate re-entry exposure measurements in 8 commercial glasshouses containing ornamental plants. Five pesticides were included (pirimicarb, paclobutrazol, endosulfan, methomyl and mercaptodimethur) and 12 ornamental species. Some aspects of the report are quite detailed enough for a clear understanding, for example the methodology description. Dermal and inhalation exposure, and dislodgeable foliar residues were monitored. Some experiments only involved air sampling. 21 transfer coefficients were defined.
Re-entry conditions Eight commercial glasshouses typical of Denmark, being relatively small, having flexible work procedures of usually short duration and consequent short exposure times.
Work activities A range of activities was monitored in the study including manual trimming and cutting of ornamentals, removal of buds, making cuttings and manual and machine packing of plants.
Sampling methodology Dermal exposure: whole body dosimetry involving pre-washed, cotton, long-sleeved T-shirt, long trousers, normal underwear and cotton gloves for hand exposure. There is no indication that the underwear formed part of the dosimetry and exposure was therefore a 'total potential' dermal exposure estimate. Further, the derived transfer coefficients are 'potential' and not 'actual' transfer coefficients (with the exception of the hand exposure and transfer coefficients). Inhalation exposure: static and personal air sampling was conducted using SKC sorbent tubes containing XAD-2 resin. Mention is made of a sampling train in which a glass fibre filter is located in front of the sorbent tube with a polyurethane plug as back-up. However, it is unclear as to the nature of the sampling head in which the glass fibre filter is located or what fraction of spray particulate was sampled. It is inferred that the equipment used for static and personal monitoring was identical. DFR: The leaf punch method of Iwata (1977) was used. The areas of foliage sampled were not given although it is stated that at least 20 punches and 4 replicates per sampling were used. Three different sizes of punches were used and the area of these punches is given. Some aspects of the method are different to current guideline recommendations although this does not necessarily detract from their validity. For example, the wash matrix was distilled water and not a water/detergent mix as is usual; the samples were tilted and not shaken and the number of cycles was not as high as usually recommended. There was no 'zero baseline' determination. Assessment of contamination of glass walls, plastic curtains, heating tubes and aluminium tables: Attempts were made to determine the dislodgeable residues by a rinse method. Surfaces were sprayed from a bottle of solvent for two minutes. Plastic curtains were extracted in the same way as the dermal dosimeters.
Chemical analysis and validation This study was not done according to Good Laboratory Practice. Samples were analysed for parent active substance. Laboratory recoveries were generally acceptable. Field recoveries were not determined in any experiment.
Conclusion Despite several shortcomings in terms of methodology and lack of field recovery data, the data from this study can be considered to be of supplementary value since there are few glasshouse data available. For specific work activities in glasshouses the transfer coefficients might be used with caution. The obvious caveat is that the conditions of the individual experiment should be fully understood before deciding to use the data.

Study 36: Nigg et al., 1984. The development and use of a universal model to predict tree crop harvester pesticide exposure (Am. Ind. Hyg. Assoc. J., 45(3):182-186)

Documentation Short literature publication. Study was directed at estimation of transfer of chlorobenzilate in citrus tree (oranges) harvesters. 10 Harvesters were observed. Leaf and fruit samples were taken
Re-entry conditions Climatic data for the study carried out in Florida were not given.
Work activities A professional harvester crew was followed, two to three days after application of the pesticide.
Sampling methodology Experimental detail is presented elsewhere (lit. cited). In brief: pad methodology for the body and hand rinses with ethanol. Leaf punches were obtained and punches and fruits were rinsed according to the Gunther method (lit. cited).
Chemical analysis and validation Not described in the paper (lit. cited)
Conclusion The quality of the data is probably acceptable for inclusion in the database. There is, however, hardly any substantiation possible for the presented data.

Study 44: Schipper et al., 1998. Exposure to pesticides during re-entry activities in greenhouse. Field study in a cucumber crop. TNO report V98.1076

Documentation Publication of internal report, no external review. Inhalation Dermal/passive dosimetry Replicated DFR samples following application and up to 14 days Calculation of Potential and Actual Transfer Factor for re-entry at between 1 and 5 days.
Re-entry conditions Indoor No environmental data reported.
Work activities Application %-butyl-2-ethylamine-6-methylpyrimidine-4-yl dimethylsulfamate. Bupirimate Participants: 22 agricultural workers Tasks Harvesting cucumbers or tying plants (Duration recorded).
Sampling methodology Passive dosimetry Inner and outer dosimeter suits –cotton gloves, head bands, coverall, T shirt, long underpants and socks. DFR samples: minimum of 15 cucumbers per sample 60 Leaf punches/sample Concomitant Dermal/Passive and DFR allow calculation of TC.
Chemical analysis and validation DFR samples washed with soap/methanol solution modified Iwata et al 1977). The wash was extracted with sodium chloride and ethyl acetate. Cotton matrices /cellulose filters were extracted with methanol. Analytical determination of all samples by RP-HPLC with UV detector. LOQ ranged specified.
Remarks DFR for leaf reported. Range 0.12 to 0.33µg as/cm^2 , 2 studies (Greenhouse 4 and 6) should be excluded because of residues present before application. DFR cucumber 6 out of 7 greenhouses 50% of the cucumber had no detectable residue. Therefore cucumbers not considered as significant source of exposure. Hands external exposure (GM) 0.39 mg/hr no significant difference between tasks. Body GM for both tasks 0.54mg/hr. There was some confusion within the report between GM and average values reported in the summary.
Conclusion This is a complex study with a large amount of data. Although not GLP compliant and there is no recovery data reported to confirm the validity of the analytical methods, the work was undertaken by a recognised Institute. The DFR values can be considered acceptable. With the exception of two values which should be excluded. Inhalation was not a significant route of exposure The potential TC are quoted contain the external dose on shirt as well as the dose from hands and face/neck and such are an overestimate of the true dermal dose. Only 1 to 13% of total dermal exposure was found on inner clothes. This distinction should be retained if the data is to be used in database.

Study 45: Schneider et al., 1990. Dermal and urinary monitoring of nectarine harvesters exposed to azinphos-methyl residues in Fresno County California 1988, California Department of Food and Agriculture, HS 1532

Documentation
Publication of a research project; incomplete documentation; some data available for review and assessment but only of indicative character. Dermal and biomonitoring exposure of 26 nectarine harvesters following application of Azinphos-methyl. Cholinesterase measurements of 18 workers Replicated DFR samples following application up to 12 weeks. Calculation of Transfer Factor.

Re-entry conditions
Outdoors. Only max/min temperatures recorded for majority of DFR sampling.

Work activities
Participants: all agricultural workers (age distribution: 17-to 46 years old.
Scenario: Harvesting nectarines for 8 hours (4 days picking)

Sampling methodology
Dermal hands washes, face/neck disposable wipes
Passive dosimetry -long sleeved shirt placed in bag at end of work day.
Biomonitoring with Urine samples 24 hour collection. Blood taken on one occasion (Day 5 of harvesting) from 18 workers and subsequently 14 days later. Red blood cell count and blood cholinesterase (Ellman 1961)
DFR samples: 40 leaves per sample (2.5cm diameter) with a Birkestrand leaf punch
Concomitant Dermal/Passive and DFR allow calculation of TC.

Chemical analysis and validation
DFR samples washed with sodium doctyl sulfosuccinite solution.Gunther *et al*. 1973). The wash was extracted with sodium chloride and ethyl acetate. Shirt/wipes/handwashes extracted with ethyl acetate. Samples were dried with anhydrous sodium sulphate Analytical determination of all samples by GC with nitrogen/ phosphorous detector. Azinphos –methyl and oxon were measured. No recovery data Alkyl phosphates in the urine were determined using a modified Weisskopf and Seiber (1987) method using solid phase extraction and analysis by GC-FPD with a limit of detection of 0.1 ng or 35 µg/L (ppb).

Remarks
Azinphos methyl residues had a half-life of 30 days on the leaves, with DFR value of 0,31 +/- 0.03ug/cm^2 over harvest period. Hand and face/neck wipes constituted 10% of exposure with remaining 90% associated with the shirt (Passive Dosimetry). Cholinesterase inhibition no significant difference between the two sampling times. Biomonitoring showed exposure which may indicate accumulative exposure but significantly less than additive daily exposures over the sampling period with rapid depletion with in 24 hours of cessation of exposure.

Conclusion
This is a complex study with a large amount of data. Although not GLP compliant and there is no recovery data to confirm the a validity of the analytical methods, the work was undertaken by a recognised Government Institute. The DFR values can be considered acceptable. The TC are quoted contain the external dose on shirt as well as the dose from hands and face/neck and such are an overestimate of the true external dermal dose. This distinction should be retained if the data is used in database. The mean transfer factor of 6935cm^2/hr is an excessive overestimate.
Biological monitoring indicates that the actual amount reaching the skin is *ca.* 29%. Therefore the true TC to skin should be lower.

Study 51: Spencer et al., 1993. Dermal and urinary monitoring of peach and apple harvesters exposed to organophosphate residues in Sutter, Stanislas and Madera counties, 1989 and 1990. California EPA, Dept. of Worker Health and Safety Branch, HS-1577.

Documentation Source not indicated. Internal report. No documentation for review. Spray data: only a.i. indicated. No other spray conditions, spray equipment, l water/ha indicated. Physical description of experimental site not available. California. Culture well described.
Re-entry conditions Fruit tree plantations (peach and apple), mainly harvesters Climatic conditions not available.
Work activities Working procedure well described, only is missing the capacity of work performed, daily work hour.
Sampling methodology DFR Available and OK (Gunther et al. 1973). Exposure Potential exposure not available. Actual exposure on parts of the body (not head and thigh), hands covered with nylon knitted gloves. Hands: Wipes followed by wash Clothing dosimeters Transfer factors available, but partly based on actual exposure.
Chemical analysis and validation Chemical analysis Procedure well described, but spiking levels, LOD, LOQ, absent. “Minimum detectable level” is not defined. Recovery OK, but level not defined! Results not adjusted for recovery (bad at hand wash: 53 +/- 34%!) Field recovery In general: method validation not available for DFR and exposure.
Conclusion Potential hand exposure absent. TC’s available, but from actual exposure on hands. A mitigation study. DFR may be used, but the study suffer from lack of quality assurance, validation poor. Before entering the database, data on method validation should be retrieved.

Study 53: Spencer et al., 1991. Long and short intervals of dermal exposure of peach harvesters to foliar azinphos-methyl residues Cal DFA, Worker Health and Safety Branch, HS-1578

Documentation Internal report. Descriptions are reasonable with lit. cited. Details on work duration are not presented, but varied from 100-470 minutes.
Re-entry conditions Peach and apple orchards, treated with azinphos-methyl some 50 or 74 days before harvesting. The harvesting is followed with dermal monitoring and DFR measurements for 29 male professionals.
Work activities No details are given on work conditions.
Sampling methodology DFr measurements with Gunther method (lit. cited) using leaf punches. Dermal monitoring was done with long-sleeved cotton undershirts and outer shirts. Hand exposure was measured with wipes and/or washes
Chemical analysis and validation The methodology for estimating the parent compound and its oxon are described. Quality analysis is not described.
Conclusion The study is acceptable for extraction of exposure data. Despite lack of details, the governmental organisation that carrie dout the study is very capable of doing so.

Study 55: Stamper et al., 1986. Prediction of pesticides dermal exposure and urinary metabolite level of tree crop harvesters from field residues (Bull. Environ. Contam. Toxicol. 36:693-700)

Documentation Physical description of experimental site not available Spray data available Culture not described sufficiently, only citrus harvesters is mentioned Climatic conditions not available.
Re-entry conditions Even in general terms not described.
Work activities Working procedure Not described sufficiently, “harvesters” is not enough. Intensity of work performed not available. This is a general trend in exposure studies: The emphasis is made on the “academic” side, the practical side is forgotten. Very little effort is done in describing the work performed. The variations in the resulting figures have its origin in the working procedures, the practical side.
Sampling methodology DFR Available, (Iwata et al. 1977, Gunther et al. 1977) Exposure pads, actual exposure. Potential exposure not available on body. Hand rinse, 95% ethanol. Transfer factors available. Based on pads and actual exposure. Potential hand exposure is present. But it is not absolutely clear if a TC can be derived!
Chemical analysis and validation Chemical analysis Method validations are not transparent. Maybe the validation is described in Nigg and Stamper 1983, unclear. Only one spiking level indicated. LOD, LOQ not available. Field recovery not done, but samples frozen in field, OK.
Conclusion Overall conclusion It has been concluded there was no reliable linear correlation between DE (actual) and DFR. In general the study is more a PPE/mitigation study, potential exposure not available. The study is not suitable for entering a re-entry database before at least the method validation has been checked. Dermal hand exposure and TC not clear. Maybe a good study, but it is not well documented!!

Study 57: Thongsinthusak et al., 1989. Estimation of exposure of persons in California to pesticide products that contain propargite. CDFA, Worker Health and Safety Report HS-1527

Documentation Published internal report of human exposure assessment. Summarises EPA status, available formulations and uses, dermal absorption and toxicity as well as animal metabolism data. Worker exposure for mixers/loaders and applicators as well as for harvesters, tractor cultivators and cane turners are calculated from referenced studies. The only checkable item is the calculation of transfer factors for peach harvesting.
Re-entry conditions Outdoor No details on climate are given.
Work activities Participants: 10 harvesters Scenario: harvesting peaches.
Sampling methodology Dermal: no details are given except that total dermal exposure refers to a worker wearing long-sleeved shirt and long-legged pants, no gloves Respiratory exposure measured with glass fibre filter and XAD-4 resin tube No methodology given on DFR sampling No concomitant DE and DFR, different studies!
Chemical analysis and validation No details given, unpublished study of registrant is referenced.
Conclusion As this report is issued by CDFA the published data and the transfer factors calculated therefrom should be acceptable. However, it has to be mentioned that only the calculation itself is checkable whereas the reported results for dermal exposure from the same study are not consistent (cf. table 7 and 8).

Study 68: Zweig et al., 1984. Dermal exposure to carbaryl by strawberry harvesters (J. Agric. Food Chem. 32:1232-1236)

Documentation Publication of a research project; incomplete documentation; some data available for review and assessment but only of indicative character. Dermal exposure of 18 strawberry harvesters to carbaryl on three consecutive days Replicate DFR samples before and during harvesting.
Re-entry conditions Outdoor Climate details (temperature, humidity, wind speed, precipitation) during harvesting reported. Site: Corvallis, Oregon, USA.
Work activities Participants: all volunteer workers, mostly less experienced school children (age distribution: 12-year-old: 4, 13-year-old: 3, 14-year-old: 2, 15-year-old: 2, 16-year-old: 2, 18 to 40-year-old: 5) Scenario: Harvesting strawberries (fruits were collected in crates).
Sampling methodology *further details in J. Agric. Food Chem. 31, 1109 (1983)* Light cotton gloves for hands; different pairs for morning and afternoon, monitoring time <2 h; Cotton patches for forearms and lower legs, worn up to 8 h; Actual/potential DFR samples: 48 leaves per sample of outer and inner canopy leaves One-sided LAI Concomitant DE and DFR.
Chemical analysis and validation DFR samples were extracted 3x with aqueous Surten solution, subsequent extraction of the aqueous phase with dichloromethane, Gloves and patches were extracted with acetonitrile by shaking, Analytical determination of all samples by LC with UV detection; Recovery from detergent solution ranged from 85 to 97%; Recovery from dermal dosimeters ranged from 93 to 107%.
Remarks Morning dew caused glove monitors to become quickly saturated with moisture from leaves mixed with fruit juice. Taking into account the water solubility of carbaryl and the sorptive capacity of cotton gloves it is obvious that the given mean DE values overestimate exposure (cf. a.m. vs. p.m.!).
Conclusion The nature of this study is more research like. The results are only of limited use (indicative character) for use in the database.

Study 70: Zweig et al., 1985. The relationship between dermal pesticide exposure by fruit harvesters and dislodgeable foliar residues (J. Environ. Sci. Health B20 (1):27-59)

Documentation Reviewed original scientific publication. No of replicates Dermal exposure of 134 workers from 7 different farms as follows: captan 5 farms, 73 workers, carbaryl 1 farm, 18 workers , vinclozolin 1 farm, 18 workers and methiocarb 1 farm, 25 workers. Crop: strawberries and blueberries.
Re-entry conditions Outdoor field experiments. Details of sites, study dates, pesticides applied, dosage, crops and meteorological information reported. Work has been done in USA.
Work activities Participants: field workers i.e. farm employees. Two scenarios: 1) harvesting strawberries and blueberries (picking berries) 2) weeding strawberries.
Sampling methodology Exposure on 28 cm^2 gauze pad monitors placed at the head, chest, back, upper arms, lower arms and lower legs. Cotton gloves served as hand monitors. Monitors were worn throughout the workday with exception of gloves, which were removed when saturated with moisture and fruitjuice. Foliar samples were randomly collected from outer and inner canopy of the plants each sample consisting 48-leaf disc samples (3 cm diameter).
Chemical analysis and validation Preparation of samples All samples were kept frozen over dry ice or in a deep-freeze until analysis. Dermal monitors were solvent extracted by agitation or a reciprocal shaker. DRF were washed and extracted according wellknown methods by Gunther et al 1973 and Iwata et al 1977. Analysis of pesticide residues. Captan was analysed by GC using EC-detector and OV-1 packed column. Recovery 96 - 103%. Vinclozolin was analysed by GC with OV-1 capillary column and EC-detector. Recovery of residues ranged from 70 - over 100% and RSD was < 5% for standards and < 10% for field samples. Limit of detection 4.3 - 8.7 ng/ml. Carbaryl and methiocarb were analysed by reverse phase HPLC using C-18 column and UV-detector. Recovery for carbaryl was 85.3 - 106.7% and for methiocarb 88.2 - 109.1%.
Conclusion Work was representative for the agricultural population under consideration, also treated area and sampling time were representative as well as equipment and work practices. This study has some weaknesses but results of the study are acceptable for re-entry exposure calculations.

Study 71: Zweig et al., 1985, Exposure of strawberry harvesters to carbaryl in Honeycutt et al., eds. ACS Symposium series 273. American Chemical Society Washington D.C. USA

Documentation Published conference proceedings. Adequate documentation for review and assessment. No of replicants: Dermal exposure of 18 workers to carbaryl residues in strawberry harvesting. One farm near Corvallis, USA.
Re-entry conditions Outdoor. Climate details e.g. temperature, humidity, wind and precipitation recorded. The field had been sprayed with 2.1 lbs a.i./A of carbaryl 15 days prior to the first day of study.
Work activities Participants: field workers (employees). One scenario: harvesting strawberries. Work efficiency recorded (daily production).
Sampling methodology Cotton patch monitors fastened on lower legs and forearms. Hand exposure was measured with cotton gloves. Patches were worn a full working day and gloves 1 - 2 hours before and after noon . DFR were collected on random basis as 48 circular leaf punches starting with the first day post-application of carbaryl and finishing on the last day of the study. Storage of collected samples is not informed.
Chemical analysis and validation Sample extraction Gloves and cotton patches were surface-extracted with acetonitrile and the extracts filtered through Millipore (0.22 u) filters. Foliar pesticide residues and leaf dust were isolated by the wellknown method described by Gunter et al. 1973 and Iwata et al. 1977. Analysis of carbaryl Pesticide residues were analysed by reversed phase HPLC with C-18 column and UV-detector. Recovery of known amounts of added carbaryl ranged from 85 - 107%. Sensitivity was found to be 2 ng.
Conclusion Work was representative for the agricultural population under consideration, also treated area and sampling time representative equipment and work practices were representative. There are several weakness in this study, and obviously methodological overestimation of the exposure. Therefore it is not acceptable.

Annex 12 Analysis of database for transfer coefficients

Introduction
A literature evaluation was carried out on transfer coefficient (TC) data. The purpose was to summarize and review knowledge and data on TC for its applicability for use in generic databases and exposure modelling. The TC is calculated by dividing the dermal exposure (DE) to hands or body by the dislodgeable foliar residue (DFR) sampled the same day. The purpose of the study was to summarize and review published data on TC.

In the screening of the literature (Annex 8) 13 publications were identified containing TC values (table 1). However, of these, two publications contained dermal exposure data but no corresponding DFR data (number 11 and 13) and two publications (numbers 3 and 12) contained identical data. The information contained in publications 1- 10 was entered into a database (Annex 13).

Table 1: Screened TC publications

Number Publication	Author	Title	Year of publication	Journal
1 [36]	Nigg; Stamper and Queen	The development and use of a universal model to predict tree crop harvester pesticide exposure	1984	Am. Ind. Hyg. Assoc. J. 45, 182-186
2 [53]	Spencer; Sanborn; Hernandez; Schneider and Margetich	Long and short intervals of dermal exposure of peach harvesters to foliar azinphos-methyl residues	1991	HS-1578
3 [71]	Zweig; Gao; Witt; Popendorf and Bogen	Dermal exposure to carbaryl by strawberry harvesters	1984	J. Agric. Food Chem. 32,1232-1236.
4 [55]	Stamper; Nigg and Queen	Prediction of pesticide dermal exposure and urinary metabolite level of tree crop harvesters from field residues	1986	Bull. Environ. Contam. Toxicol. 36, 693-700.
5 [51]	Spencer; Hernandez; Schneider; Sanborn; Margetich; Begum and Wilson	Dermal and urinary monitoring of peach and apple harvesters exposed to organophosphate residues in Sutter, Stanislaus and Madera Counties 1989 and 1990	1993	HS-1577
6 [45]	Schneider, Spencer, Sanborn, Alcoser, Garza, Margetich and Del Valle	Dermal and urinary monitoring of nectarine harvesters exposed to azinphos-methyl residues in Fresno County California 1988	1990	HS-1532
7 [6]	Brouwer; Brouwer; Tijssen and Van Hemmen	Pesticides in the cultivation of carnations in greenhouses: part II – relationship between foliar residues and exposures	1992	Am. Ind. Hyg. Assoc. J. 53, 582-587
8 [7]	Brouwer; Marquart; De Mik and Van Hemmen	Risk assessment of dermal exposure of greenhouse workers to pesticides after re-entry	1992	Arch. Environ. Contam. Toxicol. 23, 273-280
9 [44]	Schipper; Brouwer and van Hemmen	Exposure to pesticides during re-entry activities in greenhouses. Field study in cucumber crop.	1998	TNO-report V98.1076
10 [21]	Kirknel; Rasmussen and Emde	Exposure of workers in Danish greenhouses with ornamentals after spraying with pesticides	1997	Bekæmpel-sesmiddelforsk-ning fra Miljøstyrelsen nr.31
11 [57]	Thongsinthusak; Ross; Sanborn; Meinders; Fong;	Estimation of exposure of persons in California to pesticide products that contain propargite	1989	HS-1527

Number Publication	Author	Title	Year of publication	Journal
	Haskell; Rech and Krieger			
12 [68]	Zweig; Gao; Witt; Popendorf; and Bogen	Exposure of strawberry harvesters to carbaryl	1985	ACS Symposium Srs 273, 123-138
13 [70]	Zweig; Leffingwell and Popendorf	The relationship between dermal pesticide exposure by fruit harvesters and dislodgeable foliar residues	1985	J. Environ. Sci. Health B20, 27-59.

Dataset
The selected references were entered into an Excel spreadsheet (MS-Excel, version 7.0) (Annex 13).

This Excel file contains information on the publications, features of the survey, initial DFR data, DE exposure data and application rates. No calculations were performed on the published data, except for conversions to make data comparable between studies and dividing DFR data by DE exposure data (to calculated the TC value). No extrapolations of DFR values were made, when only data from figures were available in the references. If a publication contains mean values (mean application rate, mean DFR and/or mean DE) and the individual values are available, only the individual values are included in the database.

Contents of database (Annex 12)
The column A - G (yellow section) includes general information. To be able to compare the initial DFR of the different publications, the following features were recorded: active substance, application rate and corresponding DFR. Application rate was converted to kg active substance / hectare. The original value as mentioned in the publications is stored in column M. In column P the converted values are stored. Original initial DFR values are stored in column AM. The initial DFR values are converted to $\mu g/cm^2$. Converted initial DFR values are stored in column AP. Original hands and body DE exposure values are stored respectively in column BB and BC. Converted values (to µg/hr) are stored in column DE and DF. The variables stored in columns are specified in table 2.

Table 2 Data stored in TC database

Column	Explanation	Column reference
Article		
Study number	Number of the study	A
Title	The title of the publication	B
Author	The names of the authors	C
Year	The year of publication	D
Reference number	Reference number for TNO documentation	E
Journal	Journal in which the survey is published	F
Page	Volume and page number of journal	G
Features of the study		
Activity (in crop)	Activity in crop	H
Crop type	Crop type	I
Crop category	Categories are: 1. Fruit trees / 2. Hops / 3. Vines (grapes) / 4. Tree nurseries / 5. Berries / 6. Lawns-Greens-Playgrounds / 7. Ornamentals / 8. Vegetables	J
Active substance	Name of active chemical	K
Formulation	Type of formulation	L
Application rate	Application rate preceding re-entry	M
SI application rate	Dimension of application rate (units given in paper)	N
Conversion rate application rate	Conversion rate of application rate value to SI	O
Application rate calc. (kg /ha)	SI units application rate kg a.s./ha	P

Column		Explanation	Column reference
Duration of activity		Duration of activity	Q
SI duration of activity		Dimension of duration of activity (units given in paper)	R
Conversion rate duration of activity		Conversion rate of duration of activity value to SI	S
Duration of activity (hours)		SI units duration of activity in hours	T
Country/State		Country or state in which samples were taken	U
Temperature		Temperature during reentry activity	V
SI temperature		SI units temperature	W
Rainfall yes/no		Rainfall yes/no	X
DFR time after application		Time DFR sample taken after application	Y
SI DFR after application		Dimension of time after application (units given in paper)	Z
DE time after application		Time DE sample taken after application	AA
SI DE time after application		Dimension of time after application (units given in paper)	AB
Conversion rate time after application		Conversion rate of time after application value to SI	AC
DFR time after application (days)		SI units DFR time after application in days	AD
DE time after application (days)		SI units DE time after application in days	AE
DE/DFR same day (yes/no)		DFR sample and DE sample taken on same day	AF
DE/DFR same lot (yes/no)		DFR sample and DE samples taken in same lot	AG
Indoor/outdoor		Samples taken indoor (greenhouses) or outdoor	AH
Remarks features		Additional remarks features	AI
DFR			
Method		Method of DFR sampling	AJ
No. of DFR samples		Number of DFR samples taken	AK
DFR single/double		DFR samples taken on one side (single) of the leaf of both sides (double)	AL
DFR		Dislodgeable foliar residue	AM
SI DFR		Dimension of dislodgeable foliar residue (units given in paper)	AN
Conversion rate DFR		Conversion rate of dislodgeable foliar residue value to SI	AO
DFR calc. (µg/cm2)		SI units dislodgeable foliar residue (µg/cm^2)	AP
Remarks DFR		Additional remarks dislodgeable foliar residue	AQ
DE			
DE method		Dermal exposure measurement method	AR
Number of DE samples / person		Number of DE exposure samples	AS
Number of persons samples		Number of persons sampled	AT
Body parts sampled	Hand	Hand exposure samples taken yes (X) / no	AU
	Arm	Arm exposure samples taken yes (X) / no	AV
	Torso	Torso exposure samples taken yes (X) / no	AW
	Legs	Legs exposure samples taken yes (X) / no	AX
	Other	Other non hand, arm, torso or leg samples taken yes (X) / no	AY
Extrapolation to whole body exposure (yes/no)		Extrapolation to whole body exposure	AZ
Total (potential) exposure / actual exposure		Total (potential) exposure / actual exposure	BA
DE body		Dermal body exposure at re-entry	BB
DE hands		Dermal hands exposure at re-entry	BC
SI DE		Dimension of dermal exposure (units given in paper)	BD
Conversion rate DE		Conversion rate of dermal exposure value to SI	BE
DE body calc. (µg/hr)		SI units dermal exposure body µg/hr.	BF
DE hands calc. (µg/hr)		SI units dermal exposure hands µg/hr.	BG
Remarks DE		Additional remarks dermal exposure	BH
TC			
TC (body) calc. (cm^2/hr)		Transfer coefficient calculated from DFR and DE body samples	BI
TC (hands) calc. (cm^2/hr)		Transfer coefficient calculated from DFR and DE hands samples	BJ
General info			
Remarks		General additional remarks	BK
Reviewer		First name of reviewer at TNO Zeist	BL

Conclusion

The database contains 213 records extracted from 10 studies. The application rate varies from 0.01 up to 3.75 kg/ha, the DFR from 0.006 up to 5 µg/cm^2 and the re-entry time from 0.48 up to 74 days. The dermal hand exposure ranges from 0.43 to 16100 µg/hr and the dermal body exposure from 0 - 11082 µg/hr.
The transfer coefficient based on the actual DE hand exposure measurements ranges from 8 to 9455 cm^2/hr. The TC based on the potential hand exposure measurements ranges from 0 to 5281 cm^2/hr. Since these data concern all bare hands, they also describe actual exposures. The TC based on the actual body exposure measurements ranges from 344 to 34614 cm^2/hr. The TC based on the potential body exposure measurements ranges from 0 to 24945 cm^2/hr. Table 3 shows the TC ranges and means per crop type. Figures 1 and 2 shows the transfer factor per crop type and study for body and hands with a linear scale for TC and figures 3 and 4 shows the same data with a logarithmic scale for TC.

Summary of database

Description of re-entry database	
Covering studies from	1984 - 1998
Number of studies in Database	10
Number of records	213
Number of active substances (incl. metabolites)	16
Number of crop types	18

Crop type	Number of records
Fruit trees	106
Hops	0
Vines (grapes)	0
Tree nurseries	0
Berries	18
Lawns-greens-playgrounds	0
Ornamentals	45
Vegetables	44

	Application rate (kg/ha)	DFR (µg/cm^2)	DE time after application (days)
Minimum	0.01	0.006	0.48
Maximum	3.75	5.00	74

Table 3 TC ranges and mean for each crop type

Crop type	Number of publications	Hands			Body		
		Mean	Min	Max	Mean	Min	Max
Fruit trees	5	1124	0	5281	6892	0	24945
Berries	1	3848	1623	9800	4926	2246	9667
Ornamentals	3	2519	8	9455	7954	344	34614
Vegetables	1	1628	347	3232	1309	3	4550

Figure 1 Transfer coefficient of the body per crop type and study

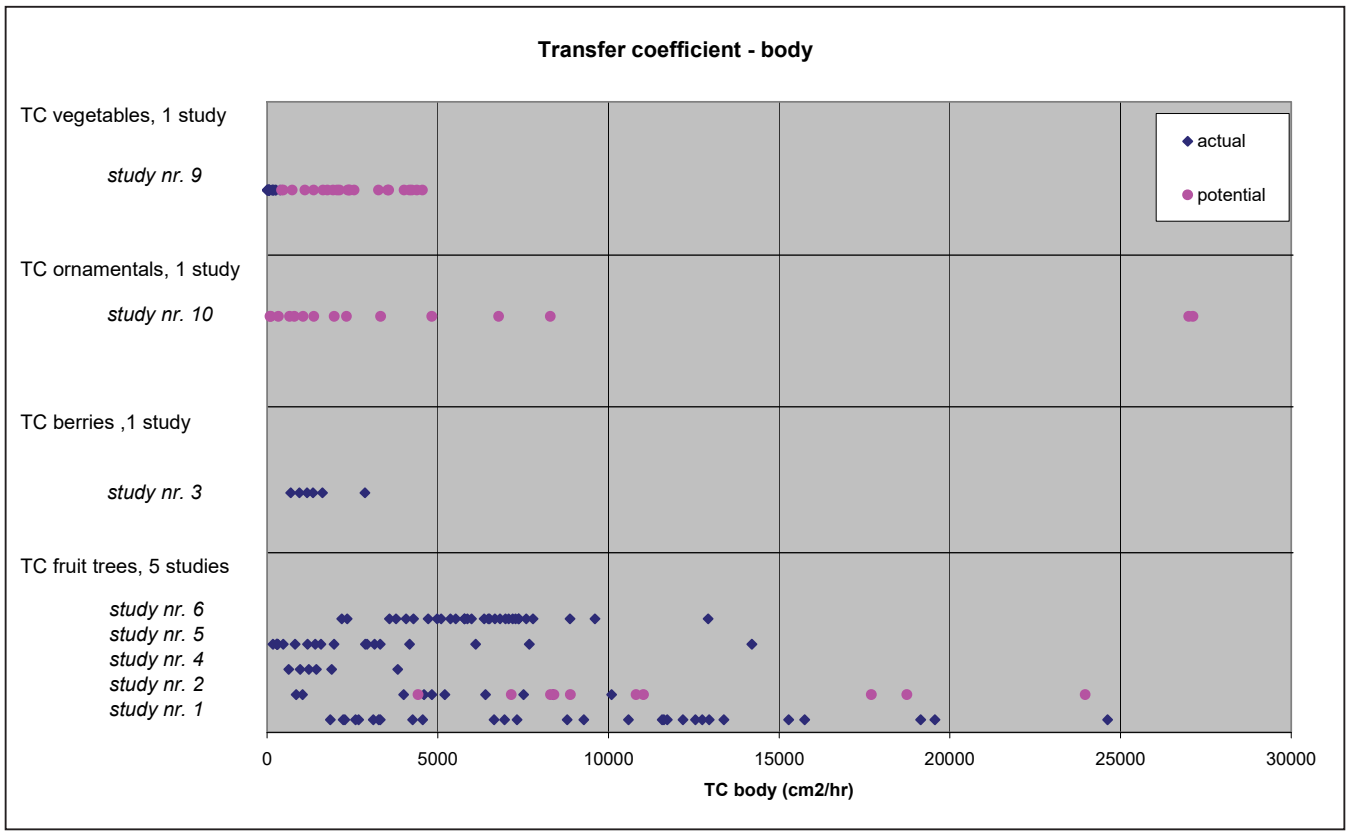


Figure 2 Transfer factor of the hands per crop type and study

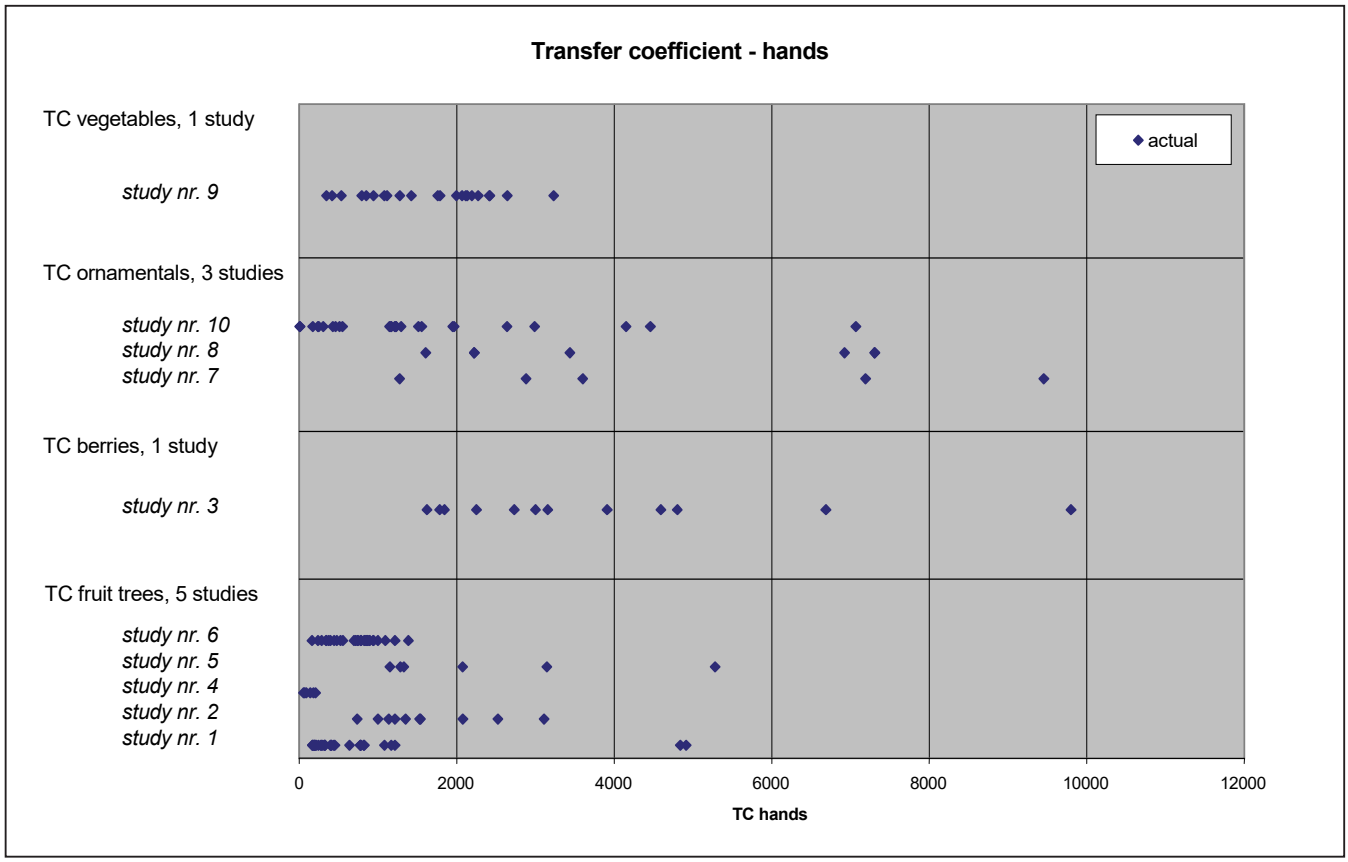


Figure 3 Transfer coefficient of the body per crop type and study (logarithmic)

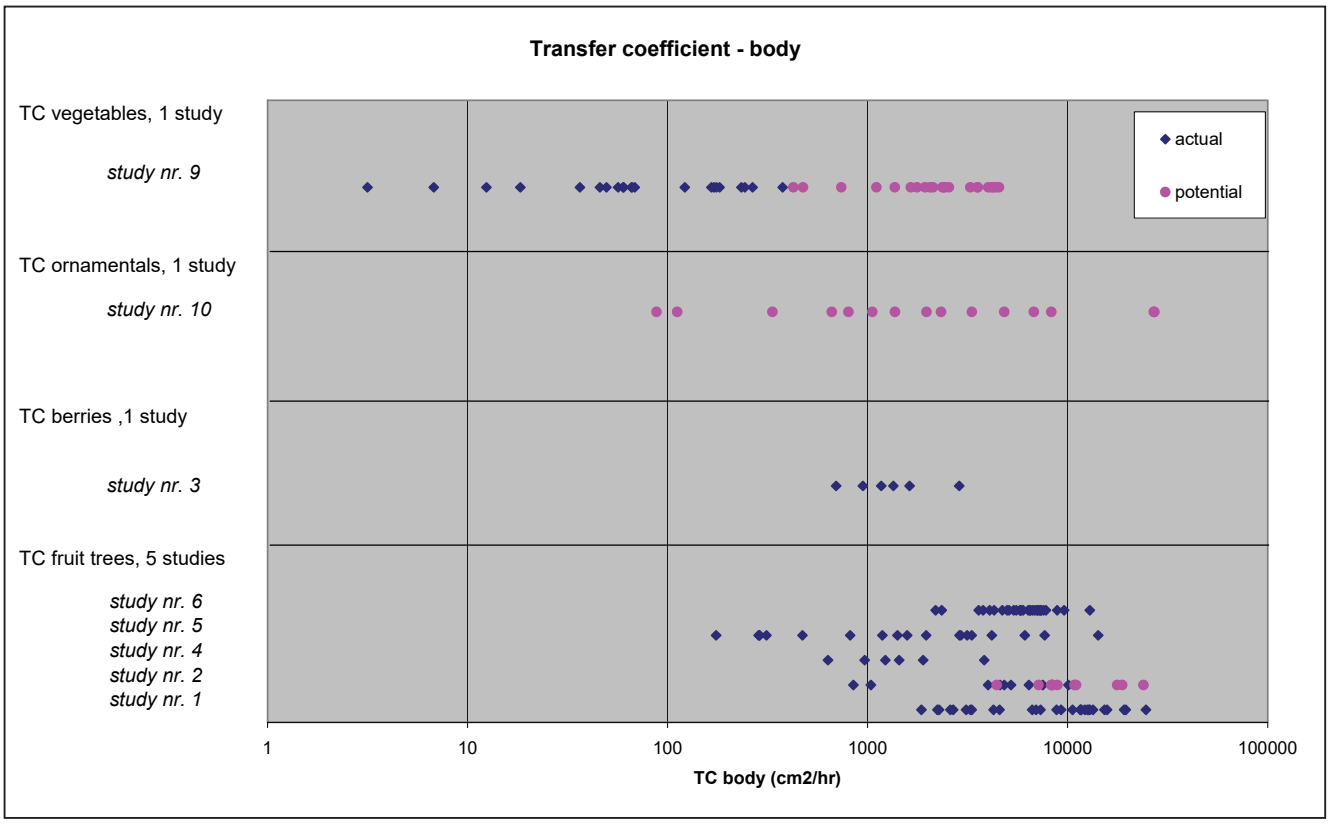
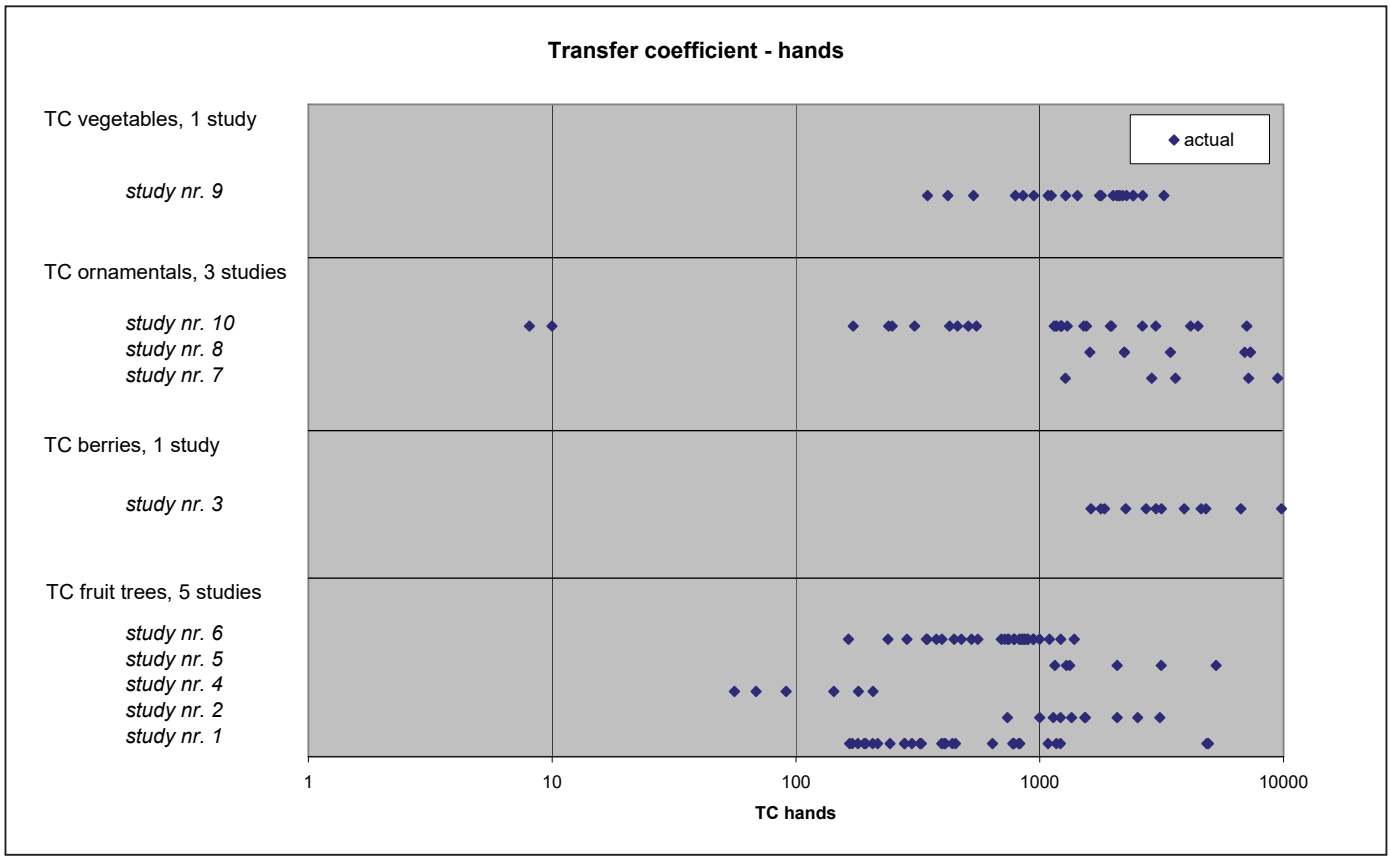


Figure 4 Transfercoefficient of the hands per crop type and study (logarithmic)



Annex 13 Database of TC values

Not presented due to size.