SZW

Ministry of Social Affairs
and Employment

Assessment of occupational exposure to pesticides in agriculture

Part III Application

S 141-3

Labour Inspectorate

Assessment of occupational exposure to pesticides in agriculture

Part III Application

J.J. van Hemmen

Onderzoek uitgevoerd in opdracht van het Directoraat-Generaal van de Arbeid door TNO Medical Biological Laboratory

april 1992

CIP-gegevens Koninklijke Bibliotheek, Den Haag

Hemmen, J.J. van

Assessment of occupational exposure to pesticides in agriculture / J.J. van Hemmen.
- The Hague: Labour Inspectorate from the Ministry of Social Affairs and Employment
Pt. III: Application. - ([Studie] / Labour Inspectorate, ISSN 0921-9218; S 141-3)
Onderzoek uitgevoerd in opdracht van het Directoraat-Generaal van de Arbeid, Ministerie van Sociale Zaken en Werkgelegenheid. - Met lit. opg.
ISBN 90-5307-260-8
Trefw.: bestrijdingsmiddelen; landbouw.

SUMMARY

For registration of pesticides data on toxicology and on occupational exposure are required. In a series of reviews the exposure data available in the literature on mixing and loading, application and re-entry are considered for the establishment of generic/surrogate data bases to be used for a specific case (*e.g.* a new pesticide) in estimating the exposure for use in a first step in risk assessment. In this third part of the series, the published data on exposure during actual application of pesticides are summarized and evaluated.

There are fourteen different types of application which are of importance for agricultural practice in The Netherlands. It is concluded that for each application technique there is a large spread in the levels of exposure. From the data (expressed in amount of spray liquid per hour application) indicative 90-percentiles of exposure have been estimated for the most important techniques :

Downward spraying outdoors (tractor mounted equipment)

Inhalation exposure	25 μl/h
Potential dermal exposure	10 ml/h

Downward spraying with aircraft

Inhalation exposure	5 μl/h
Potential dermal exposure	10 ml/h

Upward spraying outdoors (tractor mounted equipment)

Inhalation exposure	1000 μl/h
Potential dermal exposure	250 ml/h

Spraying outdoors (manual; upward and downward)

Inhalation exposure	500 μl/h
Potential dermal exposure	200 ml/h

Spraying indoors (upward and downward)

Inhalation exposure	200 μl/h
Potential dermal exposure	200 ml/h

For the other techniques no data on exposure were available in the open literature, or the number of published data was considered insufficient to obtain indicative surrogate levels of exposure that can be used in registration procedures. The data from the literature on exposure to pesticides are presented in a comprehensive way.

It is to be noted that the above-mentioned levels are based on a professional judgement of the available literature and pertain to conditions which are considered relevant for Dutch agriculture. For spraying indoors the above levels concern not only the actual application but mixing and loading as well. Although only a few data are available, it appears that the level of exposure correlates well with the amount of pesticide handled. In cases where relatively small amounts of pesticide are handled (*e.g.* up to one or two kg of active ingredient) the indicative levels of exposure to be used for registration procedures should, therefore, be lower.

Data on the distribution of exposure over the body show relatively large differences. The major part of the deposition is ususally on the hands and forearms. In Dutch agricultural practice the hands are generally bare.

A general approach for risk assessment using the indicative 90-percentiles is described.

CONTENTS

1 INTRODUCTION

Exposure to pesticides during application of sprays or dusts to crops, such as grains, vegetables or ornamental flowers occurs frequently. Since these chemicals may harm the health of the worker, it is important to consider beforehand the actual conditions at work with respect to the level of exposure. In this paper relevant articles in the open literature which contain exposure data for application of pesticides will be reviewed for possible inclusion of the data in data bases. Inclusion of such exposure data is based on an evaluation along criteria which are described in part I of this series [1] and which are thought to be relevant for occupational exposure to pesticides in Dutch agriculture. Published exposure data covering the whole period of mixing, loading and application will also be described.
From such data bases surrogate data may be extracted which can be used in conjunction with toxicological data to make a risk assessment for registration of the use of a particular (new) pesticide with a specific application. An approach for risk assessment will be presented, using indicative 90-percentiles [1,2].

2 GENERAL CONSIDERATIONS

Many reports contain data on exposure, but the majority of these reports are not published and are therefore not available in the open literature. The reports are in most cases proprietary data belonging to the manufacturers or formulators of the pesticide. The reports are presented to governments for registration procedures, but stay confidential. These reports and the data on which they are based cannot be considered, since they are not available to the author. The picture that emerges from a review of only the open literature may, therefore, be distorted to a certain extent.
As has been noted in part I of this series [1], it is very important to consider the various variables that may affect the results of measurements on dermal and inhalation exposure under field conditions. First of all, one should consider the methods used for obtaining exposure values as well as the sampling strategy. The analytical chemical data should have been presented, together with quality references for these data and figures on recovery and stability of samples. Secondly, the format of the data should be such that extrapolation is possible. This means that data on concentrations in sprays or dusts must have been presented, as well as data on the amount of pesticide handled. Thirdly, data are required on agricultural conditions (technique and working method) and climatic conditions such as temperature and wind.

The data on exposure during application will be considered separately for dermal and inhalation exposure. It should be noted that especially in case of relatively high dermal exposure oral absorption of pesticides may be expected, due to secondary ingestion. Under dusty conditions this may also be true for inhaled particles. The total amount absorbed by the body may be measured using biological monitoring. However, for reasons already given [1], results of biological monitoring are not suitable for the present purpose.

The actual application of a pesticide to crops, soil or walls of animal housing and barns generally follows mixing and loading of the pesticide. Exposure due to mixing and loading has been described in the second part of this series [2]. In the present study publications will be considered that present data on application of pesticides and studies which present data covering the whole period of mixing, loading and application.
Application can be differentiated according to the use of sprays, mists or dusts, carried out indoors or outdoors and directed upwards or downwards. Furthermore, the application can be done manually or with an automated system. Differences in exposure due to the various types of application have to be considered for the present purpose. The application of gases for fumigation will not be discussed in this paper.
Since duration of application depends, among others, on the magnitude of the area to be treated, it is also important to consider this variable. It cannot

be taken from the literature, since it largely depends on the (local) state of the art in agriculture and the nature of the crops to be treated. Therefore the format of the exposure data will be in unit of volume of the spray or weight of dust per unit of time. For registration of pesticides for particular crops, assumptions regarding specific durations per application technique may be used in risk assessment.
In the reference list the various publications with original exposure data [3-141] are given in chronological and alphabetical order. The reader may so be helped to find a specific article. The papers date back to 1954. It is, therefore, not surprising that the methods for collection and analysis of samples vary considerably. Some data will not be considered because the methods used are no longer considered adequate.

In most papers, the presentation of the analytical chemical aspects is rather poor. Since it cannot be excluded that the work is nevertheless of good quality, no data have been omitted for this reason alone. A major reason for accepting these data -for the time being- is the fact that almost none of the data meet strict criteria for evaluation of analytical chemical and other aspects. The equipment for application as well as the working method have generally been described in poor detail. Details on climatic conditions are given in a general way in most papers, but no relation is suggested or commented upon between exposure and, *e.g.*, wind speed. Nevertheless, data are not excluded from the data bases for these shortcomings alone.
It should be noted that the large majority of the data has been collected in the USA and Canada. The following studies have been carried out in Europe: Scandinavia [36,38,53,62,76,91,109,132,141]; England [10,14,18,70,111]; The Netherlands [126,130,136-138]; Germany [19,30,117]; Hungary [31,90]; Rumania [8]; Ireland [42]; Switzerland [74]. Data collected outside the USA and Europe are from Asia [33,44,47,123], Africa [6,29,34,43] and Australia [15,16,23].

Inhalation exposure
Inhalation exposure data should be obtained by personal air sampling or by the use of respirators. This does not mean, however, that the data pertain to respirable liquid or solid aerosols. Some overestimation of exposure may occur (see [1] for some comments). The use of stationary air sampling is considered inadequate to assess personal exposure as required for the present goal. The papers which contain such data will be indicated. The calculations that are necessary to obtain the format of volume of spray per hour or amount of dust per hour are based on the assumption that contact will only occur with the actual spray or dust in the dilution that has been prepared for the application. Furthermore, an average respiratory ventilation rate during the application of 1.25 m^3/h is assumed for the transformation of data from mg/m^3 into mg/h. Corrections to this ventilation rate have been made to all presented data, if required.

Dermal exposure

Dermal exposure can be measured in several ways. A distinction is generally made between potential and actual exposure [1,2]. In some papers data are given for both types of exposure. Since the exposure of the hands -in a quantitative sense- contributes considerably to the total skin exposure, the method of estimating this is very important. The use of wrist pads for doing this is considered inadequate and such data will not be presented. Data on levels of exposure measured underneath protective gloves may be very important for the actual risk to the worker, but are not suitable for inclusion in the data sets for the present goal.

The collection of data from different sources leads to the statistical problem that these data cannot be considered as a homogenous data set. Different numbers have different backgrounds and some numbers are "more equal than others". This means that there is not much statistical sense in calculating average values, neither is it sensible to calculate percentiles or a median value. Nevertheless, for pragmatic reasons that pertain to registration procedures, an estimate is made of the 90-percentile, being a value on the higher side of the data set, but not the highest. This number should be used with care, but may be useful as a relevant estimate of exposure for risk assessment if no specific exposure data are available. The premise is that higher exposure levels are not very likely to occur under conditions in the field with normal (*i.e.* calamities excluded) practice (see also [1]).

3 RESULTS AND DISCUSSION

As has been noted in chapter 2, application of pesticides can be differentiated according to several aspects. This has been done for The Netherlands by a group of agricultural experts [1]. For the present review this way of segmentation of the various methods will be used for the classification of the exposure data taken from the open literature. An additional group, called 'miscellaneous', has been introduced for techniques which were not considered by the experts. Table 1 gives an overview of these methods. The numbers indicated in the table are added to the papers (as {x}) in the reference list for convenience to the readers.

Table 1 Differentiation between methods of application

1	Downward spraying (outdoors)		
	1a	Tractor mounted equipment	
		1a.1	Treatment of soil (spraying boom low position)
		1a.2	Treatment of crop (spraying boom high position)
	1b	Aerial equipment	
2	Soil fumigation (tractor mounted equipment)		
3	Application of granules (outdoors)		
	3a	Tractor mounted equipment	
	3b	Manual	
4	Upward spraying outdoors (tractor mounted equipment)		
5	Spraying outdoors (manual; upward and downward)		
	5a	Stationary equipment	
	5b	Knapsack	
6	Spraying indoors (upward and downward)		
7	Ultra-low volume spraying (indoors)		
8	Soil fumigation under plastic cover (indoors)		
9	Dusting (indoors)		
10	Application of granules (indoors)		
11	Fumigation of enclosed locations		
12	Disinfection of seeds and bulbs		
	12a	Dipping (mechanical)	
	12b	Encapsulating/coating	
	12c	Dipping (manual)	
13	Spraying of animals		
14	Dipping of animals		
15	Miscellaneous		

In total about 140 references have been found in the open literature that present original data on exposure during application of pesticides [3-141]. The data will be presented in graphs, in order to get an overview. These exposure data (inhalation and dermal) will be given in amount of spray or dust per unit of time (ml/h or mg/h), as calculated from the data presented by the authors [1]. The calculations that were necessary to obtain the format 'ml/h' were done with the assumption that the exposure during application can be completely expressed in the amount of diluted spray, although some exposure may result from contact with the undiluted formulated product. Data which cannot be transformed in this way, will be indicated separately. Dermal exposure data will be presented as given by the authors as potential (total body, *i.e.* covered and uncovered skin) or as actual dermal exposure (uncovered skin). Actual dermal exposure is generally defined as the exposure of hands, forearms, head, neck and "V" of the chest. For estimation of actual exposure from data on potential exposure, many authors in the literature assume that penetration of the clothing can be neglected. It has been shown, however, that some (generally less than 10-20 %) penetration may occur. In some cases, penetration has been measured and is included in the data on actual exposure. Whether the amount penetrating increases significantly the actual exposure, depends largely on the distribution of exposure over the body. Further, it should be noted that due to the 'pumping' of the clothing caused by movements, contaminated air may be sucked in through the openings in the clothing, which leads to deposition of pesticide on the skin under the clothing [119].
Another factor that may be considered to differentiate some types of application is the amount of water used per unit of treated area, or rather the droplet size of the spray. As has been noted, this may differ considerably [1]. In order to be able to make a differentiation between some application techniques, the amount of water applied, in liters per hectare, as given by the authors, will be presented. For further analysis, the information given in table 2 (taken from [143] may be used if possible. Such differentiations have been studied in the literature [142,143].

The data that are taken from the open literature can be compared with published data bases. These data bases concern either exposure data from the open literature or unpublished data (see for a more detailed description [1]). To make a comparison, table 5 from [1], has been reproduced here as table 3. It should be noted, however, that the differences in the format given by different authors make a satisfactory comparison very difficult. In The Netherlands, however, for a specific situation the comparison can be made, since for registration the concentration in the spray liquid or the amount of pesticide per unit area to be treated is indicated.

The literature on exposure, especially the older literature, is not always very explicit in the description of the conditions under which the experiments have

Table 2 Classification of sprays according to volume

Volume classification		Application dose (l/ha) Field crops	Trees and bushes
High volume	HV	> 600	> 1000
Medium volume	MV	200-599	500-999
Low volume	LV	50-199	200-499
Very low volume	VLV	5-49	50-199
Ultra-low volume	ULV	< 5	< 50

been performed. In some cases data for several application techniques have been summarized, which makes it difficult to interpret the data properly. In such cases the data will not be presented, unless the context of the paper indicates a certain application technique with a reasonable certainty.

1 Downward spraying (outdoors)

As is shown in table 1, it was intended to diferentiate between the application by of airplanes and by tractor mounted equipment. Since it has been shown by Batel (see [1] for references) that the height of the boom above the ground is an important factor for the level of exposure of the applicator, a further distinction was foreseen between applications with spraying booms in a high position (above the crop) or in a low position (less than about 50 cm above the ground). In the published literature, however, the height of the boom is generally not mentioned, although in some cases this can be deduced from the description of the field conditions. Therefore, the exposure data will only be differentiated in two categories.

1a Tractor mounted equipment

In many papers exposure data are presented [5,9,11,13,21,28,30,34,36,38-41,45,53-55,57-59,66,76,77,81,82,89,96,99,102,104,107-109,111,114,127-129,132,141]. Of these papers a few contain data on downward dusting [11,36]. Data from these papers are presented under heading 15, miscellaneous. It should be noted that the method in one paper will be classified as downward spraying [5], wheras Crome [142] considered it as an upward application.
Although it has not been stated explicitly, the exposure data presented in several papers probably reflect exposure during application and mixing/loading [5,9,11]. These papers will are treated as if they concern "total" exposure

Table 3 Data bases for exposure during application

Dermal* exposure	Inhalation* exposure	Comments	Reference
1a	*Downward spraying (tractor mounted equipment)*		
Actual exposure			
1 (0.2-4) mg/h	0.015 mg/h (0.004-0.08)	median (range) appl. dose 0.3 kg/ha	[144]
0.53xAxR mg/day	0.002xAxR mg/day	geometric mean	[145]
0.003-17.3 ml/h	0.00003-0.014 ml/h	40-1000 l/ha	[142]
2.6-18.8 ml/h	0.002-0.04 ml/h	> 1000 l/ha	[142]
3.5 mg/day (0.175-7523)	no data	median (range)	[148]
Potential exposure			
10 (0-50) ml/h	0.01 (0-0.2) ml/h	75-perc. (range) hydraulic nozzles	[143]
2 (0-10) ml/h	0.005 (0-0.01) ml/h	75-perc. (range) rot. disc atomizers	[143]
24.4 (1-130) mg/h	no data	mean (low boom)	[146]
1b	*Downward spraying (aerial equipment)*		
Actual exposure			
0.0009-0.016 ml/h	0.00005 ml/h	10-100 l/ha	[142]
0.57 mg/h (0.06-2.3)	0.015 mg/h (0.001-0.199)	mean (range) appl. dose 0.7-1.7 kg/ha	[147]
6 (0-17.7) mg/h	no data	mean (range)	[148]
2	*Soil fumigation (outdoors)*		
no data base available			
3	*Application of granules (outdoors)*		
no data base available			

the table is continued on the next page

Table 3 Data bases for exposure during application (continued)

Dermal* exposure	Inhalation* exposure	Comments	Reference
4	*Upward spraying outdoors (tractor mounted equipment)*		
Actual exposure			
20 (5-100) mg/h	0.08 mg/h (0.02-0.4)	median (range) appl. dose 0.3 kg/ha	[144]
1.7xAxR mg/day	0.02xAxR mg/day	geometric mean	[145]
2.2-436 ml/h	0.002-0.4 ml/h	> 1000 l/ha AB	[142]
1.37-178 ml/h	0.018-0.12 ml/h	> 1000 l/ha	[142]
1.02-13 ml/h	0.012-0.039 ml/h	50-1000 l/ha	[142]
0.013-1.41 ml/h	0.0011-0.063 ml/h	< 50 l/ha	[142]
0.7-69.7 mg/h	0.01-1.6 mg/h	range {OP} appl. dose 0.56-3.4 kg/ha	[147]
0.4-150.6 mg/h	0.001-0.17 mg/h	range {CHC} appl. dose 1.1-3.4 kg/ha	[147]
0.3-250.1 mg/h	0.003-0.29 mg/h	range {OP} appl. dose 3.4-4.5 kg/ha	[147]
Potential exposure			
2.4-755 mg/h	no data		[149]
5	*Spraying outdoors (manual; upward and downward)*		
Actual exposure			
2-353 ml/h	0.002-1.4 ml/h	> 1000 l/ha	[142]
0.016-3.1 ml/h	0.00008-0.012 ml/h	50-1000 l/ha	[142]
Potential exposure			
50 (0-200) ml/h	0.015 (0-0.2) ml/h	75-perc. (range)	[143]
6	*Spraying indoors (upward and downward)*		
Actual exposure			
1.2 (0.2-6) mg/h	0.009 mg/h (0.015-0.45)	median (range) appl. dose 0.3 kg/ha	[144]
0.19-3.19 ml/h	0.00007-0.142 ml/h	100-1000 l/ha	[142]
7	*Ultra-low volume spraying (indoors)*		
no data base available			

the table is continued on the next page

Table 3 Data bases for exposure during application (continued)

Dermal* exposure	Inhalation* exposure	Comments	Reference
8 Soil fumigation under plastic cover (indoors)			
no data base available			
9 Dusting (indoors)			
no data base available			
10 Application of granules (indoors)			
no data base available			
11 Fumigation of enclosed locations			
no data base available			
12 Disinfection of seeds and bulbs			
no data base available			
13 Spraying of animals			
no data base available			
14 Dipping of animals			
no data base available			

* active ingredient (mg) or spray liquid (ml)
{OP} = organophosphorous compounds
{CHC} = chlorinated hydrocarbons
AB = air blast application
A = area (ha/day)
R = application dose (kg/ha)

data. Jegier has presented data which cannot be differentiated for application-techniques [13,21]. An interesting set of data has been presented by Wagner and Hoyer, but the paper contains insufficient detail on the methods and application techniques used [30]. Lavy *et al.* [39] have presented data which cannot be differentiated for applicators and mixer/loaders in so far as exposure per unit of time is concerned. In a following paper insufficient data are given on the duration of spraying [40]. Incomplete data on duration of spraying given by Lotti *et al.* [77] also preclude the use of the dermal exposure data. The same argument holds for dermal exposure data from two papers by Grover *et al.* [107,108]. The paper by Soliman *et al.* [34] contains data on dermal exposure of the hands obtained with arm pads and will therefore not be considered.
Data on inhalation exposure have been collected in some cases with stationary (high volume) sampling [38,58,59]. These will not be considered. The data given by Wojeck and Nigg [45] have also been presented, in more detail, elsewhere [82]. In a paper by Åkerblom *et al.* [53] data on inhalation exposure are given that were obtained using manual application techniques as well. Since it is further not clear whether the data on inhalation exposure were obtained by personal or stationary air sampling, the data, which refer to application together with mixing and loading, will not be considered. Carman *et al.* [55] have presented their data on dermal exposure in a format that cannot be transformed without further knowledge. The paper by Putnam *et al.* [81] mainly aimed at exposure during mixing and loading, but application is included to some degree. The presentation of the data is such that important conclusions can be drawn: (1) the use of closed transfer systems leads to lower levels of exposure than the use of open systems, (2) inhalation exposure is much higher when using wettable powders than when using emulsion concentrates. However, the data will not be considered for the present purpose.
The paper by Wojeck *et al.* [82] deals with various application techniques, which include spraying and injection in water surfaces aginst water plants. These data will be included under the heading 15, miscellaneous. The data of Winterlin *et al.* [89] on dermal exposure cannot be used because of their format. Spittler and Bourke [102] measured dermal exposure with three pads on the body, not including the hands. These data will not be considered. An interesting paper by Chester and Hart [104] contains data on the relation between external and internal exposure throughout the process of mixing, loading and application. These data on inhalation exposure cannot be transformed into exposure per hour. In two papers by Cowell *et al.* [114,127] the exposure data have been presented as a fraction of the amount of pesticide used and not per unit of time. This also applies to a paper by Dubelman and Cowell [128]. Knaak *et al.* [129] measured the exposure per day's work. From their paper it may be estimated that this concerns on the average about 2.5 hours. This estimate is used for the calculation of the levels of exposure. The

paper by Savolainen *et al.* [132] gives insufficient detail to use the measured exposure data.

Exposure data

The data on inhalation exposure have been plotted in figure 1 and on dermal exposure in figure 2. Data concerning application alone and data on mixing and loading together with application are included.

The data which could not be transformed into the desired format of unit of spray volume per unit of time are presented in figures 3 (inhalation exposure) and 4 (dermal exposure).

If the data in figure 1 pertaining to application alone are considered, it is evident that the data observed in [55] are by far the highest. This is probably due to the very high amount of water that was applied per hectare, at least 10 times higher then for all the other data considered. Taking this into account, it is obvious from figure 1 that the observed exposure was usually below 100 μl/h. Although the data base cannot be analysed statistically without various additional assumptions, such as with regard to the weight of the various numbers, it seems quite straightforward to estimate that the 90-percentile for this data set is around 25 μl/h. If mixing and loading is included, this figure may increase to about 100 μl/h. When the latter value is compared with the data presented in figure 3, assuming an average concentration of active ingredient of 1-2 g/l in the spray liquid, this number needs no adjustment.

If a value of 2 g/l is used, the exposure during spraying amounts to 50 μg/h. For a day with 4 hours of spraying exposure will then be 200 μg. This must be added to the exposure during mixing and loading, which amounts to 20 μg for a liquid formulation according to [2] assuming a 100% formulation. This results in a total exposure of about 220 μg/day, which compares fairly well with a figure of 5 (4 h spraying and 1 h mixing and loading) x 2 (g/l) x 100 (μl/h) = 1000 μg/day for the total exposure.

If a similar calculation is made for a solid formulation, it must be concluded that the value of 10 mg/h inhalation exposure during mixing and loading [2] is much higher than would be expected on the basis of a comparison of the exposure data in figures 1 and 3 on mixing, loading and application and on application alone, respectively. It should be noted, however, that the data in figures 1 and 3 refer almost exclusively to liquid formulations. One of the exceptions is given in [107].

If the data in figure 2 pertaining to application alone are considered, it is evident that all levels of exposure are below 20 ml/h. An indicative 90-percentile of about 10 ml/h may be estimated. If this number is compared with the data in figure 4, assuming an average concentration in the spray liquid of 1-2 g/l, the data from [99] are much higher, although the median value for actual exposure in that study is estimated at 0.5 ml/h. A value for the 90-percentile of the potential dermal exposure during mixing, loading and application (figure 2) is estimated to be around 200 ml/h, a value that is exclusively determined by the relatively high data on dermal exposure from [82]. The 90-percentile needs no adjustment considering the data presented in figure 4. The relatively large differences between the levels of exposure with and without mixing and loading indicate a high potential dermal exposure during mixing and loading. This is actually observed, as has been shown in [2].

Data on distribution of exposure over the body

Atallah *et al.* [54] have indicated that the larger part of the potential dermal deposition is on the arms, forearms and legs. According to Dubelman *et al.* [59] the actual exposure of the hands accounts for 74 % and that of the face and neck for 26 %. Hunt *et al.* [96] give no quantitative data, but indicate that with a low boom a large part of the observed potential exposure concerns the legs (hands were not measured). Wojeck *et al.* [82] observed that potential exposure of the hands varied between 19 and 58 %. The potential exposure of the arms varied between 9 and 57 %. Maddy *et al.* [99] noted that the potential exposure of head and neck accounts for 48 % and that of the hands for 30 %. This means 22 % exposure of the normally protected trunk. Abbott *et al.* [111] found that 58-86 % of the potential dermal deposition is on the hands.
In a study by Chester and Hart [104] involving mixing, loading and application, the potential exposition concerned mainly hands and forearms (34 %), head (4 %), legs (29 %) and the trunk (33 %). Grover *et al.* [107] did observe 80-90 % contamination of the hands. The latter data have also been presented by Grover *et al.* [150] in a different context. From a large series of studies [143] it has been estimated that the exposure of the hands is 65-75 %, of the upper body 10-15 % and of the legs 10-25 %. These data are averages and the spread is considered to be due to variations in the type of nozzles used.

Summary

Based upon the data taken from the literature it is estimated that 25 μl/h may be an indicative 90-percentile for inhalation exposure during application and 10 ml/h for potential dermal exposure. In view of the fact that there is some discrepancy, a value for potential dermal exposure during the whole process of mixing, loading and application is also given; it is estimated to be 200 ml/h. It should be noted that no summarized data are available on the partitioning of time between mixing, loading and application.
The indicative level of exposure for inhalation corresponds fairly well with data in table 3, the indicative 90-percentile for dermal exposure, however, is somewhat lower than expected.
From the data on distribution of dermal exposure over the body only a rough estimate can be made of the actual exposure of unprotected hands, forearms and head. If no precise data are available related to specific techniques and working methods, a value of about half the potential dermal exposure may

be used in registration procedures both for application alone as well as for mixing, loading and application.

1b Aerial equipment

In several papers data are presented on levels of exposure of aircraft pilots during spraying [13,31,33,39-41,44,50,54,63,66,83,86,93,97,99,101,105,113]. The data of Jegier [13] cannot be differentiated for application techniques. The paper by Sawinsky and Pásztor [31] gives data on inhalation exposure collected by stationary air sampling and the dermal exposure data cannot be transformed to a useful format. The data given by Cohen *et al.* [33] are the same as those of Richter *et al.* [44]. The data on dermal exposure [44] are inadequate for the present presentation due to the format of the data. Lavy *et al.* [39] have presented a mixture of exposure data for pilots and others. For the dermal exposure in a following paper by Lavy *et al.* [40] no durations of exposure are reported. Similar reasons make the data in [97,105] unsuitable for the present purpose. The data on air concentrations collected by Seiber and Woodrow [50] were only collected outside the airplanes with high-volume samplers and those of Frank *et al.* [93] were collected by using the swab technique. These data are considered inadequate for the present purpose.

Exposure data

Figure 5 shows the data on inhalation exposure and figure 6 shows the dermal exposure data. Both data concerning exposure from application alone and data from mixing and loading together with application are included. The data which could not be transformed into the desired format of unit of spray volume per unit of time are presented in figures 7 (inhalation exposure) and 8 (dermal exposure).

The data in figure 5 show levels of exposure below 2 μl/h in all but one study [86]. In the latter case the levels were up to 500 μl/h. The large difference is an important reason for not considering the high levels of exposure measured by Kilgore *et al.* [86], although no direct reasons for the high levels of exposure could be deduced from the paper by Kilgore *et al.* The extremely high levels of the exposure [86] are also indicated by the data in figure 7 since the concentrations of the spray liquids are generally higher than 10 g/l and the observed levels of exposure (< 50 μg/h) are, therefore probably below 5 μl/h, with a single exception of a relatively high level observed by Cohen *et al.* [33]. The level of 5 μl/h is taken as an indicative 90-percentile. From the data given in figure 6 an indicative 90-percentile of about 2 ml/h potential dermal exposure is estimated. When the data from figure 8 are also considered, this value should probably be adjusted to a higher level since depositions of up to 350 mg/h (single value largely due to manipulating nozzles, according to the authors) have been observed [66]. Although the adjustment cannot be done on the basis of available data, for use in registration procedures an educated guess might be a level of exposure of 10 ml/h.

Data on distribution of exposure over the body
Atallah *et al.* [54] indicate that the potential exposure of the body is evenly distributed. According to Maitlen *et al.* [66] the (potential) deposition is mainly on the hands of the pilots (more than 50 %). Chester and Ward [83] have shown that 40-80 % of the dermal deposition is on the hands. Knarr *et al.* [97] observed a relatively large deposition on the legs of the pilots. On the basis of a large series of measurements, Maddy *et al.* [99] concluded that about 54 % of the contamination is on the hands of the pilots. Mumma *et al.* [101] presented data which indicate a relatively high exposure of face and hands. Chester *et al.* [113] noted that potential and actual exposure are almost equal, which means that total exposure is determined by the exposure of hands, face and neck.

Summary
Based upon the data taken from the literature an indicative 90-percentile for inhalation exposure during application is derived of 5 μl/h. The potential dermal exposure (indicative 90-percentile) for application is estimated to be 10 ml/h.
The levels for inhalation agree fairly well with the exposure data given in table 3. This further indicates that the levels of exposure observed by Kilgore *et al.* [86] are extraordinary high. The level for dermal exposure is (much) higher than is expected from the data in table 3.
From the data on the distribution of dermal exposure over the body, only a rough estimate can be made of the actual exposure of unprotected hands, forearms and head. This estimate indicates that for registration procedures potential dermal exposure may be considered about equal to actual exposure, provided no precise data are available related to specific techniques and working methods.

2 *Soil fumigation (tractor mounted equipment)*

Three publications [112,131,137] are available which present data on inhalation exposure during soil fumigation. These papers deal with the compound dichloropropene, which is quantitatively the most important pesticide used in The Netherlands. The paper by Brouwer *et al.* [137] deals with conditions in The Netherlands, the other two with conditions in the USA. The exposure data for drivers vary between 0.4 and 4 mg/h [112], 0.3-12 mg/h [131] and 2-20 mg/h [137] (active ingredient for all figures). Since the exposure concerns one particular compound, which is relatively volatile, no further estimates for extrapolation to other substances can be made. No data on dermal exposure have been published in the open literature.

3 *Application of granules (outdoors)*

A differentiation should be made between application by hand and with tractor mounted equipment. In practice this could not be achieved because of lack of data. Only three articles have been found dealing with granules [18,26,125]. Lloyd and Bell [18] measured the exposure during the use of tractors or aircraft, whereas Wolfe *et al.* [26] studied manual application. Weisskopf *et al.* [125] studied the exposure during the use of various simple machines such as belly grinders, hand-pushed spreaders and home-made systems such as a "coffee can" applicator. The data on inhalation exposure presented in the latter paper will not be considered, since during the actual application the sampling was discontinued (the workers used respirators for protection). The dermal exposure was measured during 'watering in' of the formulation as well. This may explain -in part- the relatively low levels observed.
The inhalation exposure observed by Lloyd and Bell [18] during application was on the average between 0.15 and 0.56 mg/h formulated product. All levels of exposure were below 1 mg/h. Wolfe *et al.* [26] observed levels of actual exposure for manual application between 0.4 and 19 mg/h, with an average value of 9 mg/h formulated product.
The potential dermal exposure observed by Lloyd and Bell [18] was between 400 and 3000 mg/h. Wolfe *et al.* [26] found an average level of 2000 mg/h with a range of 280-5900 mg/h. Weiskopf *et al.* [125] measured actual exposure levels which varied between 0.4 and 30 mg/h formulated product.
It must be mentioned that the degree of exposure will largely depend on the size of the granules and the amount of dust present in the granules.
The number of data is such that no 'realistic' 90-percentiles can be derived.

4 *Upward spraying outdoors (tractor mounted equipment)*

In many papers exposure data are presented on upward spraying outdoors [3,4,8,11-13,15,17,19-22,24,25,27,30,45,48,52,55,56,69,74,78,80,84,88,92,99,101, 102,106,110,118-120,122,126,139]. It is not clear in all papers whether tractor mounted equipment systems were used or whether spraying was done by hand. From the description of the technique it is probable, however, that tractor mounted equipment was used. Manual techniques are described as a separate category under heading 5.
Although it is not stated explicitly, the data in a few papers probably reflect exposure during application, mixing and loading. These data will be treated as concerning total exposure. Wassermann *et al.* [8] give insufficient detail on the methods for measuring dermal and inhalation exposure. Jegier [13,21] offers data with hardly any details and which cannot be differentiated for application technique. Winkler and Arent [19] have used a stationary sampling technique for inhalation exposure. Therefore their data will not be considered. An interesting collection of data has been presented by Wagner and Hoyer

[30], but the paper contains insufficient detail on the methods and application techniques used. The data given by Wojeck and Nigg [45] have also been presented, in more detail, elsewhere [52,69]. The data of Franklin *et al.* [48] on dermal exposure are not relevant for the present goal, since they measured the exposure underneath protective garments and gloves. Carman *et al.* [55] published their data on dermal exposure in a format that cannot be transformed without additional information. The paper by Davies *et al.* [56] is relevant for the evaluation of the effectivity of protective clothing, but contains no exposure data relevant in the present context. Nigg and Stamper [80] have shown that the protecting gloves used in the field may be heavily contaminated on the inside. Their data will be presented, since data on exposure of the hands and the other parts of the body are given separately. The data of Franklin [84] have a format that cannot be transformed into the chosen format of volume of spray liquid per unit of time. Smith [88] has presented data but referred for details to a more descriptive paper to be published elsewhere. The present author has not succeeded in finding such a paper. The data will not be used. The dermal exposure data of Fenske *et al.* [92] are very interesting in the sense that they indicate major differences between various methods of sampling. The format of the data is such that they cannot be used in the present context.

Maddy *et al.* [99] offer a large set of dermal exposure data. Unfortunately, the presentation is such that it is not possible to extract specific data on upward spraying. Spitler and Bourke [102] have measured dermal exposure with three pads on the body, not including the hands. These data will not be considered. Franklin *et al.* [106] provide dermal exposure data for workers using protective gloves. They showed that even in such cases exposure of the hands forms a major part of the total exposure. The format of the data prevents their use for the present data base. Fenske [119] has shown that deposition of pesticides on the skin under the clothing occurs by penetration as well as by entering through openings in the clothing. His exposure data cannot be converted to the format chosen for this review. Lunchick *et al.* [120] have not presented original exposure data, but transformations of data from the literature. Van Amelsvoort *et al.* [126] presented data on dermal exposure based on a very small number of pads. The hands were monitored using wrist pads. These data will not be considered. Fenske [139] showed that the patch technique has certain disadvantages for the estimation of dermal exposure. Fenske's exposure data, however, cannot be converted to the format required for the present review.

Exposure data

The data on inhalation exposure are shown in figure 9 and those on dermal exposure in figure 10. Data concerning application alone and data on mixing/loading together with application are included. The data which could not be transformed into the desired format of unit of spray volume per unit of time have been plotted in figures 11 (inhalation exposure) and 12 (dermal

exposure).
If the data in figure 9 pertaining to application alone are considered, it is evident that an indicative 90-percentile will be around 1000 μl/h spray liquid. The few experiments on exposure during application and mixing/loading do not suggest a correction to this value. Based on the data in figure 11, the 90-percentile will be around 1000 μg/h active ingredient, which is quite close to 1000 μl/h for spray liquids containing around 1 g/l. Anyway, from these data it may be concluded that mixing and loading leads to a relatively small inhalation exposure. This conclusion is in agreement with the value of 20 μg/h derived for the indicative 90-percentile of liquid formulations [2]. For solid formulations this conclusion is at variance with the indicative 90-percentile of about 10 mg/h given elsewhere [2]. It should be noted, however, that in only a few studies which included mixing, loading and application solid formulations have been used [48,74,126]. From the description of the formulation in [92] it cannot be concluded whether a solid or a liquid formulation is involved.
Although the number of data is too small to draw definite conclusions, it is tempting to point to the relatively low level of exposure (in unit of volume of spray liquid) for applications with small amounts of water [17,48,78,101]. These observations indicate, in accordance with the assumptions underlying the distinctions in table 2, that for these low-volume techniques lower values should be used in registration procedures. It is difficult, however, to suggest indicative 90-percentiles for these conditions on the basis of the relatively small number of data.
Since there appears to be quite some overlap between the studies dealing with the use of solid formulations and those with low volumes of liquid per area treated, it must be concluded that a comparison of the exposure during application of solid formulations alone and that during the total period of mixing, loading and application is not possible with the present data.

From the levels of dermal exposure in figure 10 it is obvious that the data of Wojeck *et al.* [52] are by far the highest. The authors indicate the climatic conditions (temperature and relative humidity), spills and spray drift as major reasons for some of these high levels. The data in figure 10 suggest an indicative 90-percentile of about 250 ml/h spray liquid. On the basis of the (few) data in figure 12 there is no reason to increase this value. With respect to the studies which do and those which do not include mixing and loading there is no obvious reason to consider different levels of exposure. This conclusion is at variance with the observed levels of exposure during mixing and loading without application, as is shown in [2]. This difference may be due to the following reasons: (1) the small number (n=5) of studies on mixing/loading and application, (2) the low amount of volume per hectare used in three of these studies [17,78,101]. Therefore it is concluded that the data on exposure during mixing/loading and application are insufficient to warrant the above conclusion.

Data on distribution of exposure over the body

Batchelor *et al.* [3,4] indicate that the highest deposition is on shoulders, forearms and thighs. According to Wolfe *et al.* [11] about 70 % of the actual deposition is on the hands. Simpson [15] has observed a similar value for hands and forearms. Wojeck *et al.* [52,69] have found that the potential exposure of the hands is about 40 % of the total body exposure. According to Smith [88] the exposure of hands and forearms amounts to 93 % of the total. According to Fenske *et al.* [92] the distribution of exposure over the body surface varies widely due to differences in protective clothing, working practices and environmental conditions. No specific data are presented for workers using only normal work clothing. Mumma *et al.* [101] have observed two air-blast applicators and found 7 and 67 % of the total deposition on hands and forearms, respectively. Nigg *et al.* [110] found that about 50 % of the total deposition is on the hands. Fenske [118] measured about 36 % of the total deposition on hands, head and neck.

In a very interesting paper on the distribution of a fluorescent tracer over the body, Fenske [119] observed that the deposition underneath clothing is not only due to penetration through the clothing. The heaviest exposure was seen close to openings in the clothing. This so-called 'bellows' effect is due to air movement underneath clothing close to openings. Popendorf [122] noted that 46 % of the total dermal exposure concerns head, hands (38 %) and forearms.

Summary

On the basis of the data taken from the literature 1000 μl/h seems a reasonable indicative 90-percentile for inhalation exposure during application. The indicative 90-percentile for potential dermal exposure is estimated to be 250 ml/h.

The indicative level of inhalation exposure is higher than indicated by the data in table 3. That of dermal exposure agrees fairly well with the data in table 3.

From the data on distribution of potential dermal exposure over the body, only a rough estimate can be made of the actual exposure of unprotected hands, forearms and head. If no precise data are available on specific techniques and working methods, a value of about half the potential dermal exposure may be used in registration procedures for application of pesticides.

5 Spraying outdoors (manual; upward and downward)

A differentiation is possible between backpack spraying and the use of handguns. In view of the fact that only a few papers are available which describe levels of exposure during the use of backpack sprayers outdoors, the data will be described in the same context, mentioning the type of manual technique if described.

Many papers contain data on levels of exposure during manual application outdoors [3,8,16,19-21,26,29,32,34,39,40,43,47,53,60,61,64,66,67,70,72,76,79,82, 87,94,98,101,104,111,123,127]. Wassermann *et al.* [8] have presented insufficient detail on the methods for measuring dermal and inhalation exposure. Winkler and Arent [19] used a stationary sampling technique for inhalation exposure. Therefore their data will not be considered further. Jegier has presented data which cannot be differentiated for different application techniques [21]. The paper by Soliman *et al.* [34] contains data on dermal exposure of the hands obtained with arm pads and will, therefore, not be considered. The dermal exposure observed by Lavy *et al.* [40] was only measured on the upper part of the body. Hands were not measured. The data will not be considered. In a paper by Åkerblom *et al.* [53] data on inhalation exposure are given that were obtained using manual and automated techniques as well. Since it is further not clear whether the data on inhalation exposure were obtained by personal or stationary air sampling, the data which refer to application together with mixing and loading, will not be considered. The data of Gold *et al.* [61] and Leavitt *et al.* [64] were obtained in a less adequate way of measuring dermal exposure and are presented such that it is not possible to gain insight into the various application methods used. Due to printing errors in the papers some numbers are at variance with each other. The data will not be considered. Taskar *et al.* [67] have used an inadequate sampling strategy and have presented their data in a format which cannot be converted in order to be used for this review. The data of Wojeck *et al.* [82] that were obtained by stationary air sampling will not be included in the graphs. The paper by Freeborg *et al.* [94] is not considered because numbers in text and tables are at variance and since the dermal exposure of the hands was measured by wrist pads. Furthermore, the dermal exposure has been presented in a format which can not be transformed into a relevant one for this review. The description of the study of the backpack sprayers by Chester and Hart [104] is such that the data cannot be transformed adequately for the present purpose. The format of the data on dermal exposure of Shujie *et al.* [123] and that of the data presented by Cowell *et al.* [127] are inadequate.

Exposure data

The data on inhalation exposure are shown in figure 13 and those on dermal exposure in figure 14. Both data concerning application alone and data on mixing/loading together with application are included. The data which could not be transformed into the desired format of unit of spray volume per unit of time are presented in figures 15 (inhalation exposure) and 16 (dermal exposure).

If the data in figure 13 are considered, it is evident that the highest levels of exposure are from [20,123]. An indicative 90-percentile will be about 500 μl/h. This value is for the use of spray guns. The value for backpack sprayers may

be lower. Since the number of papers describing exposure during the use of backpack sprayers is rather small, an indicative level of exposure will not be given. Based upon the (very few) results given in figure 15 there is no reason to adapt the given value.
The highest levels of dermal exposure have been observed by Wolfe *et al.* [20] and by Chester and Ward [70]. From the data in figure 14 an indicative level of about 200 ml/h can be deduced. This value needs no adjustment on the basis of data in figure 16, assuming spray concentrations of about 1-2 g/l. If such a concentration is considered, it is surprising that the studies in which mixing/loading and application are taken together do not show a much higher level of exposure, since dermal exposure during mixing and loading was estimated to be 300 mg/h for liquid and 2 g/h for solid formulations (corresponding with 150-300, respectively 1000-2000 ml of spray liquid for a 100 % formulation) [2]. For backpack spraying this may be explained, at least in part, by the fact that relatively small amounts of pesticides are handled. For the use of spray guns there exists a discrepancy which is not easily explainable. It has to be noted, however, that data on the volume applied per treated area are sparse. In several cases it is relatively small (i.e high concentration in the liquid).

Data on distribution of exposure over the body
From the data presented by Chester and Woollen [47] it may be estimated that the actual exposure is much smaller than the potential exposure, indicating a large degree of protection by clothing. This is partly explainable by the observed exposure of the clothed legs. According to Everhart and Holt [60] the exposure of hands and forearms is by far the most important. The data from Maitlen *et al.* [66] do not confirm this, however. Chester and Ward [70] showed that the use of pads may lead to erroneous results due to inhomogeneous exposure. According to Davis *et al.* [72] the hands are subjected to about 85 % or more of the total deposition. In a study by Wojeck *et al.* [82] this percentage is 47 for only the hands. According to Kurtz and Bode [98] the highest exposure concerns feet and legs. The distribution over the body has been studied in some detail by Abbott *et al.* [111] for the use of backpack sprayers spraying downward. Their observations indicate that more than half of the total deposition is on the legs. This can also be shown by a large series of experiments on downward spraying [143] indicating that about 50 % of the deposition is on the legs and about 25 % on the hands. It seems evident that the distribution over the body depends on the direction of the spraying.

Summary
Based upon data taken from the literature an indicative 90-percentile for inhalation exposure during application alone of 500 μl/h is deduced. The corresponding indicative 90-percentile for potential dermal exposure is estimated to be 200 ml/h. It should be noted that discrepancies exist between

values of studies which include mixing, loading and those which consider only application. The data on the levels of exposure during application agree fairly well with those presented in table 3. It is to be noted that for smaller volumes per treated area, the value may be on the high side, indicating that for such conditions some downward correction of the indicative level of exposure is needed. The magnitude of this correction cannot be calculated from the present data. The data on inhalation exposure obtained during backpack spraying tend to be lower than those obtained during the use of spray guns. From the data on the distribution of dermal exposure over the body only a rough estimate can be made of the actual exposure of the body. Due to the large variations that have been observed, probably due to differences in upward and downward spraying, for registration procedures the actual exposure may be assumed equal to the potential dermal exposure, if no precise data are available for specific techniques and working methods.

6 *Spraying indoors (upward and downward)*

Several papers on inhalation and dermal exposure during upward and downward spraying indoors (greenhouses) have been published [10,21,30,60,68, 90,100,103,115,117,130,133-135,138,139]. Lloyd [10] describes measurements of vapour of bis-ethylmercury phosphate which was 'watered in' dry soil. The inhalation exposure was determined by stationary air sampling and will not be considered. The data from Jegier [21] and Wagner and Hoyer [30] have been presented with hardly any details and will not be considered either. The monitoring of pesticide vapour by Williams *et al.* [68] during and after application has been done by means of stationary air sampling. Mestres *et al.* [100] have collected ambient air by stationary sampling. Waldron [103] also used stationary air sampling. Data on dermal exposure have been measured but not presented in sufficient detail. Although relatively meagrely detailed, the data of Wagner and Hermes [117] on inhalation exposure will be used. One of the compounds investigated was the highly volatile dichlorvos. The data on dermal exposure will not be referred to because no exact data on duration are given. Van Lookeren Campagne *et al.* [130] measured dermal exposure with wrist pads for the hands. They did not investigate inhalation exposure. This paper will not be considered. Stamper *et al.* [133,134] have presented data on exposure in open-sided greenhouses. Neverthelesss, these data will be used. It should be mentioned that Stamper *et al.* [134] measured the exposure for applications with tractor-driven systems. The data of Fenske [139] are the same as those of Fenske *et al.* [115].

Exposure data

The data on inhalation exposure have been plotted in figure 17 and those on dermal exposure in figure 18. Both data concerning application alone and data on mixing/loading together with application have been included. It should be noted that in most papers it is not explicitly stated whether the mixing and

loading is included in the measurement of the level of exposure. In such cases it is assumed that it is included.
The data which could not be transformed into the desired format of unit of spray volume per unit of time are depicted in figures 19 and 20 for inhalation and dermal exposure, respectively.
From the data in figures 17 and 19, an indicative level (90-percentile) of inhalation exposure of around 200 µl/h spray liquid may be estimated, assuming that the concentration in the spray liquid may be taken as 1-2 g/l and considering the fact that the two highest figures on inhalation exposure, observed by Wagner and Hermes [117] for dichlorovos, concern a pesticide which is far more volatile than most others and should therefore be excluded from the data base. The obtained indicative 90-percentile is for mixing/loading and application together.
From the data on dermal exposure in figures 18 and 20, an indicative 90-percentile may be derived of 200 ml/h, making the same assumptions as above for inhalation exposure.

Data on distribution of exposure over the body
According to Everhart and Holt [60] the major part of the potential dermal deposition concerns the hands. Adamis *et al.* [90] (for potential exposure) and Mestres *et al.* [100] (for actual exposure) observed the major part on hands and legs. Fenske *et al.* [115] measured actual exposure during the use of new protective gloves and even in that case 6 % of the deposition is located on the skin underneath the gloves. Stamper *et al.* [133] observed that, with the hands excluded, more than 90 % of the deposition is on the legs. Similar conclusions were reached by Stamper *et al.* [135].

Summary
Based upon data taken from the literature the indicative 90-percentiles for inhalation and potential dermal exposure are 200 µl/h and 200 ml/h, respectively. The figure for inhalation exposure agrees fairly well with the data in table 3, the indicative 90-percentile for dermal exposure is somewhat higher than expected. It should be noted that for volumes below 1000 l/ha lower levels of dermal exposure are observed.
Since no consistent data have been presented on the distribution of the dermal exposure over the body and in view of the minor differences observed between potential and actual exposure in figures 18 and 20, it seems necessary to take for registration procedures the actual dermal exposure equal to the potential exposure. The values of 200 µl/h and 200 ml/h are considered relevant for the total process of mixing, loading <u>and</u> application. This may explain part of the differences in the data for dermal exposure given here and in table 3.

7 *Ultra-low volume spraying (indoors)*

Data on exposure when using fogging devices have been presented in [30,100,103,124,138]. The data of Wagner and Hoyer [30] have been given with hardly any details and will, therefore, not be considered. Mestres *et al.* [100] used stationary sampling for air measurements a did Waldron [103]. The latter also published data on dermal exposure but not in sufficient detail. Stamper *et al.* [124] observed for three different pesticides average inhalation exposure levels of 21 to 91 μg/h active ingredient. Brouwer *et al.* [138] observed levels of 49 and 590 μg/h active ingredient for two situations.
Mestres *et al.* [100] found an actual dermal exposure of 3.4 mg/h. The average potential dermal exposure (excluding the hands) for three pesticides was between 0.4 and 2.2 mg/h. The levels of exposure of hands and forearms, observed by Brouwer *et al.* [138], were 8 and 12 mg/h. All data concern the active ingredient. According to Stamper *et al.* [124] the dermal deposition is to a large extent on the legs. The hands were covered with protective gloves. These data are insufficient to obtain indicative levels of exposure for this application technique.

8 *Soil fumigation under plastic cover (indoors)*

No papers have been found which present exposure data for this application technique.

9 *Dusting (indoors)*

The only paper with data on exposure during mixing and loading and application is by Brouwer *et al.* [138]. The data on inhalation exposure ranged from 0.3 to 250 mg/h formulated product. The levels of dermal deposition on the hands ranged from 0.6 to 3000 mg/h formulated product for the same pesticides. It should be noted that the current durations of exposure are well below one hour for the average Dutch greenhouse.

10 *Application of granules (indoors)*

Only one paper, by Wagner and Hermes [117], presents data on exposure to a rather volatile pesticide (aldicarb). The level of inhalation exposure was between 12.5 and 638 μg/h active ingredient.

11 *Fumigation of enclosed locations*

In only a few papers data are presented on the level of exposure during disinfection of stables, barns and stores. Therefore exposure data on pest control in houses are also considered. The relevant papers are [6,7,21,23,30, 35,46,61,65,71,85,95,121]. The data given by Fletcher *et al.* [6] and by Wolfe *et al.* [7] have been obtained with equipment that probably is no longer in use. This is especially so for the study done in Tanganyika [6]. Jegier [21] and Wagner and Hoyer [30] presented their data in insufficient detail to be considered. Simpson and Shandar [23] have given data on dermal exposure in a format which cannot be transformed. The data of Wright and Leidy [46] deal more with the levels of exposure in the ambient air than with exposure of workers and will not be used. Gold *et al.* [61] compared worker exposure for spraying and painting of walls of rooms with a slow-release formulation of chlorpyrifos. The data presented by Das *et al.* [71] cannot be transformed to the format for the present review. The data of Gold *et al.* [85] are the same as those published by Gold and Holcslaw [95].

Exposure data
The data on inhalation exposure are shown in figure 21 and those on dermal exposure in figure 22. All data pertain to mixing, loading and application, as far as can be gathered from the description in the papers.
From the data no indicative levels will be drawn for treatment of barns, stables etc., since these enclosed spaces are not included in the data presented. Almost all data reflect exposure of applicators in residential surroundings.

12 Disinfection of seeds and bulbs

Only seven papers [42,51,62,73,91,136,140] have been found that contain data on disinfection of seeds and bulbs. Therefore, these papers will not be subdivided as was intended under this heading. The data are given in amounts of active ingredient, since data on formulations and disinfection liquids are seldom given.
The data of O'Keeffe and Pierse [42] relate to the pelleting of seeds, which consists of moistening with water, adding clay and spraying of the seeds. The levels of inhalation exposure are average values for a working day: 117 μg/h, with a range from 17 to 288 μg/h. It is indicated that these values are lowered with a factor of about ten by using ventilation. Stevens and Davis [51] have presented data on exposure during filling of hoppers of seed dusting machines and during cutting and sorting of seed potatoes on seed cutting machines. These activities were carried out in the vicinity of each other, so cross-exposure was assumed. Exposure during filling of the dusting machines varied, depending on location and sort of seed, between 1.2 and 15 mg/h potential dermal exposure and between 0.15 and 1.7 mg/h inhalation exposure. Kolmodin-Hedman *et al.* [62] published data on inhalation exposure during dipping of seedlings (24 μg/h active ingredient, 1,2 μl/h dipping solution) and during tunnel spraying and packaging of seedlings (14-106 μg/h active ingredient, 0.7-5 μl/h spray liquid). Grey *et al.* [73] provided data on exposure during several different seed treatments with liquids and dusts. The conditions

are described with little detail. Inhalation exposure ranged from not detectable (≤ 0.5 mg!) and 0.54 mg/h. Exposure of the hands varied between not detectable (≤ 0.5 mg) and 8.62 mg/h for the liquid formulations and between 54.8 and 81.4 mg/h for the dusts. Edling *et al.* [91] have studied exposure during the use of some new devices for planting conifer seedlings, together with spraying of the seedlings. The observed inhalation exposure was between not detectable (≤ 1.25 μg/h) and 5 μg/h. Brouwer *et al.* [136] investigated dermal exposure of the hands for two different techniques of disinfecting bulbs. The average exposure was 12 mg/h for manual dipping of a typical bulb variety and for the same, but a much larger amount of bulbs, 15.2 mg/h when drive-in vessels were used. The data are based on a dipping solution with an average concentration of 0.1 %. Fenske *et al.* [140] monitored workers during manual treatment of wheat seed with dust. The average inhalation exposure was 7 μg/h, the average actual dermal exposure when using protective gloves 41 mg/h. The major part of the pesticide was observed underneath the clothing.

13 Spraying of animals

Only one paper by Jegier [21] has been found containing data on exposure during spraying of animals. These data can, however, not be used, because of insufficient detail and because the data have been presented together with data on other application techniques, which cannot be dissected.

14 Dipping of animals

No papers have been found which contain data on exposure during dipping of animals.

15 Miscellaneous

Eight papers [11,14,28,36,75,79,82,98] have been found with exposure data for application techniques which can not be classified under one of the headings 1-14. All exposure data have been presented in amount of active ingredient.

The papers by Wolfe *et al.* [11] and Kangas *et al.* [36] deal with dusting machines outside. The observed inhalation exposure was on the average 0.41 mg/h [11] and 1.3 mg/h [36], respectively. The actual dermal exposure showed an average of 18.7 mg/h [11]. Kurtz and Bode [98] studied dusting outside by means of a small shaker and a manual dust pump. The potential dermal exposure for two different crops were on the average 27 and 34 mg/h. Lloyd and Tweddle [14] studied 'watering in' of a crop with a solution of the very volatile dimefox. The inhalation data were not obtained by personal air sampling. Staiff *et al.* [28] investigated the use of pressurized dispensers outdoors. The inhalation exposure was not detectable in all but one case and below 1 μl/h. The dermal exposure was on the average 0.15 ml/h, with a range from 0.005 to 0.285 ml/h.

Haverty *et al.* [75] have compared two different spraying techniques to wet pine barks thoroughly, one more classical approach and one with a telescope pole. The technique used to measure dermal exposure as well as the format of the exposure data are not suitable for the present review.

Nigg and Stamper [79] and Wojeck *et al.* [82] studied the exposure of workers spraying aquatic weeds from a boat. Wojeck *et al.* [82] used stationary sampling for the determination of inhalation exposure. The data will not be presented. The inhalation exposure measured by Nigg and Stamper [79] was 0.5 μl/h. The average potential dermal exposure was 3.3 ml/h [79] and 0.1 ml/h [82], respectively.

Exposure data expressed per unit amount of pesticide handled

In several papers data on inhalation or dermal exposure are related to the amount of pesticide (active ingredient) handled [6,41,48,84,104,106-108,111, 113-115,118,122,124,127-129,133-135,140]. As has been demonstrated before [1,2], there appears to exist a good relation between the level of exposure and this amount. In some cases the data presented [127-129] could not be used, since the required information on body weights was not given by the authors. The data of Franklin *et al.* [84] have also been presented by Franklin *et al.* [106].

The data on inhalation exposure have been plotted in figure 23 and the data on dermal exposure in figure 24. Since exposure will also depend on the type of application, the latter has been indicated in the figures by means of the numbers of the headings. As may be seen from the graphs, quite some spread exists between the data. In view of the different application techniques used, no further conclusions can be drawn. The numbers of papers pertaining to a particular application technique are too small for a good comparison.

For registration procedures, data on potential exposure must be transformed into actual exposure and subsequently into uptake by the body. The result must be compared with toxicological data. This is a difficult process. It requires much specific knowledge on the compound and its use in practice.
Assuming that the toxicological information is such that acceptable levels ('no-effect' levels) for oral, inhalation and dermal daily intake are available for man, the comparison with indicative 90-percentiles as presented in chapter 3 on inhalation exposure is relatively simple and straightforward, using for registration available knowledge on the percentage active ingredient in the spray liquid. On the basis of such a comparison it may be necessary to get more precise information on levels of actual exposure for more specific conditions of the application proces involved. As a second step it may be useful to consider the original literature or available data sets for comparable situations. In a third step a study of exposure in representative situations for the particular compound may be required.
If this does not lead to a health-based acceptable 'matching' of exposure and toxicological level, measures should be taken or prescribed to lower the exposure by changing the application technique, application equipment, nozzle characteristics, concentration of active ingredient in the spray liquid (*i.e.* amount of volume sprayed per hectare), task time, personal hygiene and, finally, specific protective measures.
If an inhalation 'no-effect' level is not available, the oral 'no-effect' level may be considered for comparison, using data on differences in oral and inhalation absorption (the latter taken as 100 % if no specific data are available) and data on possible differences in toxicokinetics for these different ways of exposure.

For dermal exposure the situation is more complex. First of all, the actual exposure has to be estimated from the potential exposure. Some indicative data that can be used for registration procedures have been given. From here the analysis is straightforward unless a dermal 'no-effect' level (mainly for hands and forearms) is lacking. In this case a strategy may be followed as indicated above for inhalation. This will always mean that data are required on dermal penetration. If these are not available, it may be assumed, for safety reasons, that the amount of the compound under consideration deposited on the skin will be completely absorbed. For most compounds complete absorption is unlikely to happen in practice, especially not for the amounts indicated by the indicative 90-percentiles. In the British and German procedures [143,145] an absorption of 10 % is assumed in the calculations if no data are available indicating higher or lower percentages. It should be noted, however, that the dermal penetration process cannot be described adequately in terms of percentage absorption, since the amount penetrating will depend on the area of the skin involved, the amount present on the skin acting as a 'driving force' for penetration, the duration of the presence on the skin, as well as on many other aspects related to the worker (skin) and the work situation.

5 CONCLUDING REMARKS

Different application techniques and different situations are shown to result in considerable differences in exposure. Possible reasons for this are differences in equipment, direction of spraying, application indoors or outdoors, weather conditions, working methods, personal hygiene and the amount of product that is handled. The specific effects of several of these factors are unknown, but it is assumed that the presently available data bases of data from the literature, the volume and quality of which will increase further in the future, are already large enough to include the most important consequences of these factors. If this assumption is correct, it seems possible to extract surrogate exposure data from these data bases to make risk assessments for specific application techniques in registration procedures. Nevertheless, one should be very careful in using these data, since not all effects of differences in conditions on exposure are known. This is a major reason for using indicative 90-percentiles as a first step in a risk assessment. On the basis of specific knowledge of a formulation of a pesticide and the conditions of application it may be possible to use other figures. This may be important, for instance, when relatively low amounts of formulations will be handled. Other data bases, constructed from unpublished exposure data, should also be consulted to increase the validity of the surrogate exposure to be used in risk assessment.

It is emphasized that volatile compounds have to be treated separately, since the present data are largely based on exposure to liquid and solid aerosols and on exposure due to direct contact, rather than on exposure to vapours and gases. Further, it should be noted that relatively high levels of exposure appear to occur with upward spraying techniques.

The relation between the amount of active ingredient or formulation handled and the level of exposure during application has been stressed by Batel (see discussion in [1]) and Reinert and Severn [146]. It has been observed for spraying in the British and German data bases [143,145] and it has been intuitively expected by many authors. It has not been possible, however, to use the various data published in the open literature to prove this relation. Since exposure data for application in greenhouses generally include exposure during mixing and loading, this may, nevertheless, be a pragmatic reason for using the present indicative 90-percentiles for exposure due to mixing, loading <u>and</u> application, as well as for other situations in which amounts below, say, one or two kg of active ingredient are used.

6 LITERATURE

The numbers after various references between {} indicate the headings as given in table 1, page 5. These headings refer to the distinguished forms of application.

1 *J.J. van Hemmen*, 1991, Assessment of occupational exposure to pesticides in agriculture. Part I General aspects, S-reeks, Directorate-General of Labour, The Hague, The Netherlands.

2 *J.J. van Hemmen*, 1991, Assessment of occupational exposure to pesticides in agriculture. Part II Mixing and loading, S-reeks, Directorate-General of Labour, The Hague, The Netherlands.

3 *G.S.Batchelor and K.C.Walker*, 1954, Health hazards involved in use of parathion in fruit orchards of North Central Washington, Arch. Ind. Hyg. Occup. Med. 10, 522-529. {1,4,5}

4 *G.S.Batchelor, K.C.Walker and J.W.Elliott*, 1956, Dinitroorthocresol exposure from apple-thinning sprays, Arch. Ind. Health 13, 593-596. {4}

5 *D.Culver, P.Caplan and G.S.Batchelor*, 1956, Studies of human exposure during aerosol application of malathion and chlorthion, Arch. Ind. Health 13, 37-50. {1}

6 *T.E.Fletcher, J.M.Press and D.Bagster Wilson*, 1959, Exposure of spraymen to dieldrin in residual spraying, Bull. Wld Hlth Org. 20, 15-25. {11}

7 *H.R.Wolfe, K.C.Walker, J.W.Elliott and W.F.Durham*, 1959, Evaluation of the health hazards in house-spraying with DDT, Bull. Wld Hlth Org. 20, 1-14. {11}

8 *M.Wassermann, S.Iliescu, G.Mandric and P.Horvath*, 1960, Toxic hazards during DDT- and BHC-spraying of forests against Lymanthria monacha, A.M.A. Arch. of Ind. Health 21, 503-508. {4,5}

9 *H.R.Wolfe, W.F.Durham and G.S.Batchelor*, 1961, Health hazards of some dinitro compounds, Arch. Environ. Health 3, 468-475. {1}

10 *G.A.Lloyd*, 1963, The concentration of bis-ethylmercury phosphate in air resulting from its use in glasshouses, J. Sci. Fd. Agric., 14, 845-848. {6}

11 *H.R.Wolfe, W.F.Durham and J.F.Armstrong*, 1963, Health hazards of the pesticides endrin and dieldrin, Arch. Environ. Health 6, 458-464. {1,4,15}

12 *Z.Jegier*, 1964, Exposure to guthion during spraying and formulating, Arch. Environ. Health 8, 565-569. {4}

13 *Z.Jegier*, 1964, Health hazards in insecticide spraying of crops, Arch. Environ. Health 8, 670-674. {1,4}

14 *G.A.Lloyd and J.C.Tweddle*, 1964, The concentration of dimefox in air resulting from its use on hops, J. Sci. Fd. Agric., 15, 169-172. {15}

15 *G.R.Simpson*, 1965, Exposure to orchard pesticides, Arch. Environ. Health 10, 884-885. {4}

16 *G.R.Simpson and A.Beck*, 1965, Exposure to parathion, Arch. Environ. Health 11, 784-786. {5}

17 *H.R.Wolfe, J.F.Armstrong and W.F.Durham*, 1966, Pesticide exposure from concentrate spraying, Arch. Environ. Health 13, 340-344. {4}

18 *G.A.Lloyd and G.J.Bell*, 1967, The exposure of agricultural workers to pesticides used in granular form, Ann. Occup. Hyg., 10, 97-104. {3}

19 *K.O.Winkler and H.Arent*, 1967, Arbeitsmedizinische Untersuchungen bei der Anwendung des Insektizids mevinphos (phosdrin), einem organischen Phosphorsäureester, im Hopfenbau, Zentralblatt Arbeitsmed. Arbeitsschutz 17, 373-381. {4,5}

20 *H.R.Wolfe, W.F.Durham and J.F.Armstrong*, 1967, Exposure of workers to pesticides, Arch. Environ. Health 14, 622-633. {4,5}

21 *Z.Jegier*, 1969, Pesticide residues in the atmosphere, Annals New York Academy of Sciences 160, 143-154. {1,4,5,6,11,13}

22 *W.F.Durham, H.R.Wolfe and J.W.Elliott*, 1972, Absorption and excretion of parathion by spraymen, Arch. Environ. Health 24, 381-387. {4}

23 *G.R.Simpson and A.Shandar*, 1972, Exposure to chlorinated hydrocarbon pesticides by pest control operators, Med. J. Austr., 2, 1060-1063. {11}

24 *H.R.Wolfe, J.F.Armstrong, D.C.Staiff and S.W.Comer*, 1972, Exposure of spraymen to pesticides, Arch. Environ. Health 25, 29-31. {4}

25 *A.J.Oudbier, A.W.Bloomer, H.A.Price and R.L.Welch*, 1974, Respiratory route of pesticide exposure as a potential health hazard, Bull. Environ. Contam. Tox., 12, 1-9. {4}

26 *H.R.Wolfe, J.F.Armstrong and W.F.Durham*, 1974, Exposure of mosquito control workers to fenthion, Mosquito News 34, 263-267. {3,5}

27 *S.W.Comer, D.C.Staiff, J.F.Armstrong and H.R.Wolfe*, 1975, Exposure of workers to carbaryl, Bull. Environ. Contam. Tox., 13, 385-391. {4}

28 *D.C.Staiff, S.W.Comer, J.F.Armstrong and H.R.Wolfe*, 1975, Exposure to the herbicide, paraquat, Bull. Environ. Contam. Tox., 14, 334-340. {1,15}

29 *J.F.Copplestone, Z.I.Fahkri, J.W.Miles, C.A.Mitchell, Y.Osman and H.R.Wolfe*, 1976, Exposure to pesticides in agriculture: a survey of spraymen using dimethoate in the Sudan, Bull. World Health Organ., 54, 217-223. {5}

30 *R.Wagner and J.Hoyer*, 1976, Arbeitsplatzkonzentration von PSM während der Ausbringung im Freiland und unter Glas und Folie sowie in Getreidespeichern, Z. ges. Hyg., 22, 583-585. {1,4,6,7,11}

31 *A.Sawinsky and G.Pásztor*, 1977, Expositionsprüfungen bei der Reglone-Berieselung mittels Flugzeugen, Z. ges. Hyg., 23, 845-846. {1}

32 *J.D.Hansen, B.A.Schneider, B.M.Olive and J.J.Bates*, 1978, Personnel safety and foliage residue in an orchard spray program using azinphosmethyl and captan, Arch. Environ. Contam. Tox., 7, 63-71. {5}

33 *B.Cohen, E.Richter, E.Weisenberg, J.Schoenberg and M.Luria*, 1979, Sources of parathion exposures for Israeli aerial spray workers, 1977, Pest. Monit. J., 13, 81-86. {1}

34 *S.A.Soliman, A.H.El-Sebae and S.El-Fiki*, 1979, Occupational effect of phosfolan insecticide on spraymen during field exposure, J. Environ. Sci. Health B14, 27-37. {1,5}

35 *A.L.Hayes, R.A.Wise and F.W.Weir*, 1980, Assessment of occupational exposure to organophosphates in pest control operators, Am. Ind. Hyg. Assoc. J., 41, 568-575. {11}

36 *J.Kangas, A.Koskinen and K.Husman*, 1980, Exposure of Finnish forestry nursery workers to quintozene and maneb, in Field Worker Exposure during Pesticide Application (W.F.Tordoir and E.A.H. van Heemstra, eds.) p. 79-84, Elsevier, Amsterdam, The Netherlands. {1,15}

37 *J.B.Knaak, T.Jackson, A.S.Fredrickson, L.Rivera, K.T.Maddy and N.B.Akesson*, 1980, Safety effectiveness of closed-transfer, mixing-loading, and application equipment in preventing exposure to pesticides, Arch. Environ. Contam. Tox., 9, 231-245. {1}

38 *B.Kolmodin-Hedman, K.Erne and M.Åkerblom*, 1980, Field application of phenoxy acid herbicides in Field Worker Exposure during Pesticide Application (W.F.Tordoir and E.A.H. van Heemstra, eds.) p. 73-77, Elsevier, Amsterdam, The Netherlands. {1}

39 *T.L.Lavy, J.S.Shepard and D.C.Bouchard*, 1980, Field worker exposure and helicopter spray pattern of 2,4,5-T, Bull. Environ. Contam. Tox., 24, 90-96. {1,5}

40 *T.L.Lavy, J.S.Shepard and J.D.Mattice*, 1980, Exposure measurements of applicators spraying (2,4,5-trichlorophenoxy) acetic acid in the forest, J. Agric. Food Chem., 28, 626-630. {1,5}

41 *C.S.Miller, W.L.Hoover and W.H.Culver*, 1980, Exposure of pesticide applicators to arsenic acid, Arch. Environ. Contam. Tox., 9, 281-288. {1}

42 *M.O'Keeffe and C.Pierse*, 1980, Exposure of seed pelleting plant workers to methiocarb, Bull. Environ. Contam. Tox., 25, 777-781. {12}

43 *G.H.Prinsen and N.J.van Sittert*, 1980, Exposure and medical monitoring study of a new synthetic pyrethroid after one season of spraying on cotton in Ivory Coast, in Field Worker Exposure during Pesticide Application (W.F.Tordoir and E.A.H. van Heemstra, eds.) p. 105-120, Elsevier, Amsterdam, The Netherlands. {5}

44 *E.D.Richter, B.Cohen, M.Luria, J.Schoenberg, E.Weisenberg and M.Gordon*, 1980, Exposures of aerial spray workers to parathion, Isr. J. Med. Sci., 16, 96-100. {1}

45 *G.A.Wojeck and H.N.Nigg*, 1980, Worker exposure to pesticides in Florida citrus operations, Proc. Fla. State Hort. Soc., 93, 60-62. {1,4}

46 *C.G.Wright and R.B.Leidy*, 1980, Insecticide residues in the air of buildings and pest control vehicles, Bull. Environ. Contam. Tox., 24, 582-589. {11}

47 *G.Chester and B.H.Woollen*, 1981, Studies of the occupational exposure of Malaysian plantation workers to paraquat, Br. J. Ind. Med., 38, 23-33. {5}

48 *C.A.Franklin, R.A.Fenske, R.Greenhalgh, L.Matthieu, H.V.Denley, J.T.Leffingwell and R.C.Spear*, 1981, Correlation of urinary pesticide metabolite excretion with estimated dermal contact in the course of occupational exposure to guthion, J. Tox. Environ. Health 7, 715-731. {4}

49 *R.E.Gold, J.R.C.Leavitt and J.Ballard*, 1981, Effect of spray and paint-on applications of a slow-release formulation of chlorpyrifos on German cockroach control and human exposure, J. Econ. Entomol., 22, 552-554. {11}

50 *J.N.Seiber and J.E.Woodrow*, 1981, Sampling and analysis of airborne residues of paraquat in treated cotton field environments, Arch. Environ. Contam. Tox., 10, 133-149. {1}

51 *E.R.Stevens and J.E.Davis*, 1981, Potential exposure of workers during seed potato treatment with captan, Bull. Environ. Contam. Tox., 26, 681-688. {12}

52 *G.A.Wojeck, H.N.Nigg, J.H.Stamper and D.E.Bradway*, 1981, Worker exposure to ethion in Florida citrus, Arch. Environ. Contam. Tox., 10, 725-735. {4}

53 *M.Åkerblom, B.Kolmodin-Hedman and S.Hoglund*, 1982, Studies of occupational exposure to phenoxy acid herbicides, in Pesticide Chemistry: Human Welfare and the Environment. Vol. 4 Pesticide Residues and Formulation Chemistry (J.Miyamoto, P.C.Kearney, R.Greenhalgh and N.Drescher, eds.) p. 227-232. Pergamon Press, New York, USA. {1,5}

54 *Y.H.Atallah, W.P.Cahill and D.M.Whitacre*, 1982, Exposure of pesticide applicators and support personnel to *O*-ethyl-*O*-(4-nitrophenyl) phenylphosphonothioate (EPN), Arch. Environ. Contam. Tox., 11, 219-225. {1}

55 *G.E.Carman, Y.Iwata, J.L.Pappas, J.R.O'Neal and F.A.Gunther*, 1982, Pesticide applicator exposure to insecticides during treatment of citrus trees with oscillating boom and airblast units, Arch. Environ. Contam. Tox., 11, 651-659. {1,4}

56 *J.E.Davies, V.H.Freed, H.F.Enos, R.C.Duncan, A.Barquet, C.Morgade, L.J.Peters and J.X.Danauskas*, 1982, Reduction of pesticide exposure with protective clothing for applicators and mixers, J. Occup. Med., 24, 464-468. {4}

57 *E.W.Day, D.G.Saunders, J.W.Mosler, E.M.McKinney, F.L.Powers, R.D.Griggs and R.Frank*, 1982, Estimation of inhalation exposure to *N*-nitrosodipropylamine during the application and incorporation of the herbicide trifluralin, Environ. Sci. Technol., 16, 131-136. {1}

58 *W.H.Draper and J.C.Street*, 1982, Applicator exposure to 2,4-D, dicamba, and a dicamba-isomer, J. Environ. Sci. Health B17, 321-339. {1}

59 *S.Dubelman, R.Lauer, D.D.Arras and S.A.Adams*, 1982, Operator exposure measurements during application of the herbicide diallate, J. Agric. Food Chem., 30, 528-532. {1}

60 *L.P.Everhart and R.F.Holt*, 1982, Potential benlate fungicide exposure during mixer/loader operations, crop harvest, and home use, J. Agric. Food Chem., 30, 222-227. {1,5,6}

61 *R.E.Gold, J.R.C.Leavitt, T.Holcslaw and D.Tupy*, 1982, Exposure of urban applicators to carbaryl, Arch. Environ. Contam. Tox., 11, 63-67. {5}

62 *B.Kolmodin-Hedman, Å.Swensson and M.Åkerblom*, 1982, Occupational exposure to some synthetic pyrethroids (permethrin and fenvalerate), Arch. Tox., 50, 27-33. {12}

63 *T.L.Lavy, J.D.Walstad, R.R.Flynn and J.D.Mattice*, 1982, (2,4-Dichlorophenoxy) acetic acid exposure received by aerial application crews during forest spray operations, J. Agric. Food Chem., 30, 375-381. {1}

64 *J.R.C.Leavitt, R.E.Gold, T.Holcslaw and D.Tupy*, 1982, Exposure of professional pesticide applicators to carbaryl, Arch. Environ. Contam. Tox., 11, 57-62. {5}

65 *R.B.Leidy, C.G.Wright and E.H.Dupree*, 1982, Concentration and movement of diazinon in air, J. Environ. Sci. Health B17, 311-319. {11}

66 *J.C.Maitlen, C.R.Sell, L.M.McDonough and S.N.Fertig*, 1982, Workers in the agricultural environment. Dermal exposure to carbaryl, in Pesticide Residues and Exposure (J.R.Plimmer, ed.), ACS Symposium Series 182, 83-103. {1,5}

67 *P.K.Taskar, Y.T.Das, J.R.Trout, S.K.Chattopadhyay and H.D.Brown*, 1982, Measurement of 2,4-dichlorophenoxyacetic acid (2,4-D) after occupational exposure, Bull. Environ. Contam. Tox., 29, 586-591. {5}

68 *D.T.Williams, H.V.Denley, D.A.Lane and E.S.K.Quan*, 1982, Real time monitoring of methomyl air levels during and after spraying in a greenhouse, Am. Ind. Hyg. Assoc. J., 43, 190-195. {6}

69 *G.A.Wojeck, H.N.Nigg, R.S.Braman, J.H.Stamper and R.L.Rouseff*, 1982, Worker exposure to arsenic in Florida grapefruit spray operations, Arch. Environ. Contam. Tox., 11, 661-667. {4}

70 *G.Chester and R.J.Ward*, 1983, An accurate method for measuring potential dermal exposure to pesticides, Human Tox., 2, 555-556. {5}

71 *Y.T.Das, P.K.Taskar, H.D.Brown and S.K.Chattopadhyay*, 1983, Exposure of professional pest control operator to dichlorvos (DDVP) and residue on house structures, Tox. Letters 17, 95-99. {11}

72 *J.E.Davis, E.R.Stevens, D.C.Staiff and L.C.Butler*, 1983, Potential exposure to diazinon during yard applications, Environ. Mon. Ass. 3, 23-28. {5}

73 *W.E.Grey, D.E.Marthre and S.J.Rogers*, 1983, Potential exposure of commercial seed-treating applicators to the pesticides carboxin-thiram and lindane, Bull. Environ. Contam. Tox., 31, 244-250. {12}

74 *M.Hagmann and Ch.Schlatter*, 1983, Feldmessungen zur Bestimmung der Belastung von Spritzpersonal mit Pflanzenschutzmitteln, Chimia 37, 135-140. {4}

75 *M.I.Haverty, M.Page, P.J.Shea, J.B.Hoy and R.W.Hall*, 1983, Drift and worker exposure resulting from two methods of applying insecticides to pine bark, Bull. Environ. Contam. Tox., 30, 223-228. {15}

76 *B.Kolmodin-Hedman, S.Hoglund and M.Åkerblom*, 1983, Studies on phenoxy acid herbicides I Field study. Occupational exposure to phenoxy acid herbicides (MCPA, dichlorprop, mecoprop and 2,4-D) in agriculture, Arch. Tox., 54, 257-265. {1}

77 *M.Lotti, C.E.Becker, M.J.Aminoff, J.E.Woodrow, J.N.Seiber, R.E.Talcott and R.J.Richardson*, 1983, Occupational exposure to the cotton defoliants DEF and merphos. A rational approach to monitoring organophosphorous-induced delayed neurotoxicity, J. Occup. Med., 25, 517-522. {1}

78 *C.E.McJilton, G.E.Berckmann and H.M.Deer*, 1983, Captan exposure in apple orchards, Am. Ind. Hyg. Assoc. J., 44, 209-210. {4}

79 *H.N.Nigg and J.H.Stamper*, 1983, Exposure of Florida airboat aquatic weed applicators to 2,4-dichlorophenoxyacetic acid (2,4-D), Chemosphere 12, 209-215. {5}

80 *H.N.Nigg and J.H.Stamper*, 1983, Exposure of spray applicators and mixer-loaders to chlorobenzilate miticide in Florida citrus groves, Arch. Environ. Contam. Tox., 12, 477-482. {4}

81 *A.R.Putnam, M.D.Willis, L.K.Binning and P.F.Boldt*, 1983, Exposure of pesticide applicators to nitrofen: influence of formulation, handling systems, and protective garments, J. Agric. Food Chem., 31, 645-650. {1}

82 *G.A.Wojeck, J.F.Price, H.N.Nigg and J.H.Stamper*, 1983, Worker exposure to paraquat and diquat, Arch. Environ. Contam. Tox., 12, 65-70. {1,15}

83 *G.Chester and R.J.Ward*, 1984, Occupational exposure and drift hazard during aerial application of paraquat to cotton, Arch. Environ. Contam. Tox., 13, 551-563. {1}

84 *C.A.Franklin*, 1984, Estimation of dermal exposure to pesticides and its use in risk assessment, Can. J. Physiol. Pharmacol., 62, 1037-1039. {4}

85 *R.E.Gold, T.Holcslaw and J.Ballard*, 1984, Dermal and respiratory exposure to applicators and occupants of residences treated with dichlorvos (DDVP), J. Econ. Entomol., 77, 430-436. {11}

86 *W.Kilgore, C.Fischer, J.Rivers, N.Akesson, J.Wicks, W.Winters and W.Winterlin*, 1984, Human exposure to DEF/merphos, Residue Reviews 91, 72-101. {1}

87 *S.Libich, J.C.To, R.Frank and G.J.Sirons*, 1984, Occupational exposure of herbicide applicators to herbicides used along electric power transmission line right-of-way, Am. Ind. Hyg. Assoc. J., 45, 56-62. {5}

88 *L.W.Smith*, 1984, Development of safe use practices for pesticides, in Determination and Assessment of Pesticide Exposure (M.Siewierski, ed.) p. 39-52. Elsevier, Amsterdam, The Netherlands. {4}

89 *W.L.Winterlin, W.W.Kilgore, C.R.Mourer and S.R.Schoen*, 1984, Worker reentry studies for captan applied to strawberries in California, J. Agric. Food Chem., 32, 664-672. {1}

90 *Z.Adamis, A.Antal, I.Füzesi, J.Molnár, L.Nagy and M.Susán*, 1985, Occupational exposure to organophosphorus insecticides and synthetic pyrethroid, Int. Arch. Occup. Environ. Health 56, 299-305. {6}

91 *C.Edling, B.Kolmodin-Hedman, M.Åkerblom, G.Rand and T.Fischer*, 1985, New methods for applying synthetic pyrethroids when planting conifer seedlings: symptoms and exposure relationships, Ann. Occup. Hyg., 29, 421-427. {12}

92 *R.A.Fenske, J.T.Leffingwell and R.C.Spear*, 1985, Evaluation of fluorescent tracer methodology for dermal exposure assessment, in Dermal Exposure Related to Pesticide Use (R.C.Honeycutt, G.Zweig and N.N.Ragsdale, eds.) ACS Symposium Series 273, 377-393. {4}

93 *R.Frank, R.A.Campbell and G.J.Sirons*, 1985, Forestry workers involved in aerial application of 2,4-dichlorophenoxyacetic acid (2,4-D): exposure and urinary excretion, Arch. Environ. Contam. Tox., 14, 427-435. {1}

94 *R.P.Freeborg, W.H.Daniel and V.J.Konopinski*, 1985, Applicator exposure to pesticides applied to turfgrass, in Dermal Exposure Related to Pesticide Use (R.C.Honeycutt, G.Zweig and N.N.Ragsdale, eds.) ACS Symposium Series 273, 287-285. {5}

95 *R.E.Gold and T.Holcslaw*, 1985, Dermal and respiratory exposure of applicators and residents to dichlorvos-treated residences, in Dermal Exposure Related to Pesticide Use (R.C.Honeycutt, G.Zweig and N.N.Ragsdale, eds.) ACS Symposium Series 273, 253-264. {11}

96 *T.W.Hunt, G.A.Wojeck and T.J.Sheets*, 1985, Applicator exposure to maleic hydrazide (MH) in flue-cured tobacco, Bull. Environ. Contam. Tox., 34, 403-406. {1}

97 *R.D.Knarr, G.L.Cooper, E.A.Brian, M.G.Kleinschmidt and D.G. Graham*, 1985, Worker exposure during aerial application of a liquid and a granular formulation of Ordram[R] selective herbicide to rice, Arch. Environ. Contam. Tox., 14, 523-527. {1}

98 *D.A.Kurtz and W.M.Bode*, 1985, Applicator exposure to the home gardener, in Dermal Exposure Related to Pesticide Use (R.C.Honeycutt, G.Zweig and N.N.Ragsdale, eds.) ACS Symposium Series 273, 139-161. {5,15}

99 *K.T.Maddy, R.G.Wang, J.B.Knaak, C.L.Liao, C.S.Edmiston and C.K.Winter*, 1985, Risk assessment of excess pesticide exposure to workers in California, in Dermal Exposure Related to Pesticide Use (R.C.Honeycutt, G.Zweig and N.N.Ragsdale, eds.) ACS Symposium Series 273, 445-465. {1,4}

100 *R.Mestres, C.Francois, C.Causse, L.Vian and G.Winnett*, 1985, Survey of exposure to pesticides in greenhouses, Bull. Environ. Contam. Tox., 35, 750-756. {6,7}

101 *R.O.Mumma, G.O.Brandes and C.F.Gordon*, 1985, Exposure of applicators and mixer-loaders during the application of mancozeb by airplanes, airblast sprayers, and compressed-air backpack sprayers, in Dermal Exposure Related to Pesticide Use (R.C.Honeycutt, G.Zweig and N.N.Ragsdale, eds.) ACS Symposium Series 273, 201-219. {1,4,5}

102 *T.D.Spittler and J.B.Bourke*, 1985, Potential exposure in the application of pesticides to orchard and field crops, in Dermal Exposure Related to Pesticide Use (R.C.Honeycutt, G.Zweig and N.N.Ragsdale, eds.) ACS Symposium Series 273, 297-310. {1,4}

103 *A.C.Waldron*, 1985, The potential for applicator-worker exposure to pesticides in greenhouse operations, in Dermal Exposure Related to Pesticide Use (R.C.Honeycutt, G.Zweig and N.N.Ragsdale, eds.) ACS Symposium Series 273, 311-319. {6,7}

104 *G.Chester and T.B.Hart*, 1986, Biological monitoring of a herbicide applied through backpack and vehicle sprayers, Tox. Letters, 33, 137-149. {1,5}

105 *J. van Emon, B.Hammock and J.N.Seiber*, 1986, Enzyme-linked immunosorbent assay for paraquat and its application to exposure analysis, Anal. Chem., 58, 1866-1873. {1}

106 *C.A.Franklin, N.I.Muir and R.P.Moody*, 1986, The use of biological monitoring in the estimation of exposure during the application of pesticides, Tox. Letters 33, 127-136. {4}

107 *R.Grover, A.J.Cessna, N.I.Muir, D.Riedel, C.A.Franklin and K.Yoshida*, 1986, Factors affecting the exposure of ground-rig applicators to 2,4-D dimethylamine salt, Arch. Environ. Contam. Tox., 15, 677-686. {1}

108 *R.Grover, C.A.Franklin, N.I.Muir, A.J.Cessna and D.Riedel*, 1986, Dermal exposure and urinary metabolite excretion in farmers repeatedly exposed to 2,4-D amine, Tox. Letters 33, 73-83. {1}

109 *A.Manninen, J.Kangas, T.Klen and H.Savolainen*, 1986, Exposure of Finnish farm workers to phenoxy acid herbicides, Arch. Environ. Contam. Tox., 15, 107-111. {1}

110 *H.N.Nigg, J.H.Stamper and R.M.Queen*, 1986, Dicofol exposure to Florida citrus applicators: effects of protective clothing, Arch. Environ. Contam. Tox., 15, 121-134. {4}

111 *I.M.Abbott, J.L.Bonsall, G.Chester, T.B.Hart and G.J.Turnbull*, 1987, Worker exposure to a herbicide applied with ground sprayers in the United Kingdom, Am. Ind. Hyg. Assoc. J., 48, 167-175. {1,5}

112 *W.N.Albrecht*, 1987, Occupational exposure to 1,3-dichloropropene (Telone[R] II) in Hawaiian pineapple culture, Arch. Environ. Health 42, 286-291. {2}

113 *G.Chester, L.D.Hatfield, T.B.Hart, B.C.Leppert, H.Swaine and O.J.Tummon*, 1987, Worker exposure to, and absorption of, cypermethrin during aerial application of an "ultra low volume" formulation to cotton, Arch. Environ. Contam. Tox., 16, 69-78. {1}

114 *J.E.Cowell, R.G.Danhaus, J.L.Kunstman, A.G.Hackett, M.E.Oppenhuizen and J.R.Steinmetz*, 1987, Operator exposure from closed system loading and application of alachlor herbicide, Arch. Environ. Contam. Tox., 16, 327-332. {1}

115 *R.A.Fenske, S.J.Hamburger and C.L.Guyton*, 1987, Occupational exposure to fosetyl-Al fungicide during spraying of ornamentals in greenhouses, Arch. Environ. Contam. Tox., 16, 615-621. {6}

116 *C.A.Nillson, O.Nygren and E.Sikström*, 1987, Determination of mancozeb in air. Occupational exposure during its use in control of potato late blight, Chemosphere 16, 2413-2428. {1}

117 *R.Wagner and H.Hermes*, 1987, Exposition der Gärtner während und nach der Applikation von Dichlorvos, Methamidophos sowie Aldicarb in Gewächshausanlagen, Z. ges. Hyg., 33, 255-257. {6,10}

118 *R.A.Fenske*, 1988, Correlation of fluorescent tracer measurements of dermal exposure and urinary metabolite excretion during occupational exposure to malathion, Am. Ind. Hyg. Assoc. J., 49, 438-444. {4}

119 *R.A.Fenske*, 1988, Use of fluorescent tracers and video imaging to evaluate chemical protective clothing during pesticide applications, in Performance of Protective Clothing: Second Symposium, ASTM STP 989 (S.Z.Mansdorf, R.Sager and A.P.Nielsen, eds.) p. 630-639. American Society for Testing and Materials, Philadelphia, USA. {4}

120 *C.Lunchick, A.P.Nielsen and J.C.Reinert*, 1988, Engineering controls and protective clothing in the reduction of pesticide exposure to tractor drivers, in Performance of Protective Clothing: Second Symposium, ASTM STP 989 (S.Z.Mansdorf, R.Sager and A.P.Nielsen, eds.) p. 605-610. American Society for Testing and Materials, Philadelphia, USA. {4}

121 *C.L.Ogg and R.E.Gold*, 1988, Exposure and field evaluation of fenoxycarb for German cockroach (orthoptera: blattellidae) control, J. Econ. Entomol,, 81, 1408-1413. {11}

122 *W.Popendorf*, 1988, Mechanisms of clothing exposure and dermal dosing during spray application, in Performance of Protective Clothing: Second Symposium, ASTM STP 989 (S.Z.Mansdorf, R.Sager and A.P.Nielsen, eds.) p. 611-624. American Society for Testing and Materials, Philadel-phia, USA. {4}

123 *W.Shujie, Z.Quinglang, Y.Lan, X.Bohong and L.Yurui*, 1988, Health survey among farmers exposed to deltamethrin in the cotton fields, Ecotox. Environ. Safety 15, 1-6. {5}

124 *J.H.Stamper, H.N.Nigg, W.D.Mahon and A.P.Nielsen*, 1988, Pesticide exposure to greenhouse foggers, Chemosphere 17, 1007-1023. {7}

125 *C.P.Weisskopf, J.N.Seiber, N.Maizlish and M.Schenker*, 1988, Personnel exposure to diazinon in a supervised pest eradication program, Arch. Environ. Contam. Tox., 17, 201-212. {3}

126 *L. van Amelsvoort, P.Duijzings and T.Huy*, 1989, Arbeidsomstandigheden in de fruitteelt. Een onderzoek naar de blootstelling van fruittelers aan het gewasbeschermingsmiddel captan. Landbouwuniversiteit Wageningen, Vakgroep Gezondheidsleer, rapport nr. 1989-387, Wageningen, The Netherlands. {4}

127 *J.E.Cowell, S.Dubelman, A.J.Klein and K.Ohta*, 1989, Ways to reduce applicator exposure to pesticides, in Biological Monitoring for Pesticide Exposure. Measurement, Estimation, and Risk Reduction (R.G.M.Wang, C.A.Franklin, R.C.Honeycutt and J.C.Reinert, eds.) ACS Symposium Series 382, 28-37. {1,5}

128 *S.Dubelman and J.E.Cowell*, 1989, Biological monitoring technology for measurement of applicator exposure, in Biological Monitoring for Pesticide Exposure. Measurement, Estimation, and Risk Reduction (R.G.M.Wang, C.A.Franklin, R.C.Honeycutt and J.C.Reinert, eds.) ACS Symposium Series 382, 240-250. {1}

129 *J.B.Knaak, M.A.Al-Bayati, O.G.Raabe, J.L.Wiedmann, J.W.Pensyl, J.H.Ross, A.P.Leber and P.Jones*, 1989, Mixer-loader-applicator exposure and percutaneous absorption studies involving EPTC herbicide, in Biological Monitoring for Pesticide Exposure. Measurement, Estimation, and Risk Reduction (R.G.M.Wang, C.A.Franklin, R.C.Honeycutt and J.C.Reinert, eds.) ACS Symposium Series 382, 288-303. {1}

130 *P. van Lookeren Campagne, A.L.M.Rutten en B.Witteveen*, 1989, Werkmethode en arbeidshygiënische aspecten bij het gebruik van gewasbeschermingsmiddelen, Instituut voor Mechanisatie, Arbeid en Gebouwen, Wageningen, The Netherlands. {6}

131 *J.D.Osterloh, R.Wang, F.Schneider and K.Maddy*, 1989, Biological monitoring of dichloropropene: air concentrations, urinary metabolite, and renal enzyme excretion, Arch. Environ. Health 44, 207-213. {2}

132 *K.Savolainen, P.Kurttio, T.Vartiainen and J.Kangas*, 1989, Ethylenethiourea as an indicator of exposure to ethylenebisdithiocarbamate fungicides, in Biological Monitoring of Exposure and the Response at the subcellular Level to Toxic Substances (P.L.Chambers, C.M.Chambers and H.Greim, eds.) Arch. Tox., Sup. 13, 120-123. {1}

133 *J.H.Stamper, H.N.Nigg, W.D.Mahon, A.P.Nielsen and M.D.Royer*, 1989, Pesticide exposure to a greenhouse drencher, Bull. Environ. Contam. Tox., 42, 209-217. {6}

134 *J.H.Stamper, H.N.Nigg, W.D.Mahon, A.P.Nielsen and M.D.Royer*, 1989, Applicator exposure to fluvalinate, chlorpyrifos, captan and chlorothalonil in Florida ornamentals, J. Agric. Food Chem., 37, 240-244. {6}

135 *J.H.Stamper, H.N.Nigg, W.D.Mahon, A.P.Nielsen and M.D.Royer*, 1989, Pesticide exposure to greenhouse handgunners, Arch. Environ. Contam. Tox., 18, 515-529. {6}

136 *D.H.Brouwer, E.J.Brouwer and J.J. van Hemmen*, 1990, Effects of occupational exposure to pesticides in the Dutch flower bulb culture. Part 2 Estimation of long-term exposure to pesticides. TNO Medical Biological Laboratory, Rijswijk, The Netherlands. {12}

137 *D.H.Brouwer, E.J.Brouwer, J.A.F. de Vreede, R.T.H. van Welie, N.P.E.Vermeulen and J.J. van Hemmen*, 1990, Inhalation exposure to 1,3-dichloropropene in the Dutch flower-bulb culture. Part I. Environmental monitoring, Arch. Environ. Contam. Tox. 20, 1-5. {2}

138 *R.Brouwer, D.H.Brouwer, G. de Mik and J.J. van Hemmen*, 1990, Exposure to pesticides. Part I The cultivation of carnations in greenhouses. S-reeks, Directorate-General of Labour, The Hague, The Netherlands, in press. {6,9}

139 *R.A.Fenske*, 1990, Nonuniform dermal deposition patterns during occupational exposure to pesticides, Arch. Environ. Contam. Tox., 19, 332-337. {4,6}

140 *R.A.Fenske, A.M.Blacker, S.J.Hamburger and G.S.Simon*, 1990, Worker exposure and protective clothing performances during manual seed treatment with lindane, Arch. Environ. Contam. Tox., 19, 190-196. {12}

141 *P.Kurttio, T.Vartiainen and K.Savolainen*, 1990, Environmental and biological monitoring of exposure to ethylenebisdithiocarbamate fungicides and ethylenethiourea, Br. J. Ind. Med., 47, 203-206. {1}

142 *G.J.Turnbull, D.M.Sanderson and J.L.Bonsall*, 1985, Occupational Hazards of Pesticide Use, Taylor & Francis, London.

S.J.Crome, 1985, Worker exposure to pesticides during use, in Occupational Hazards of Pesticide Use (G.J.Turnbull, D.M.Sanderson and J.L.Bonsall, eds.) p. 117-168.

G.J.Turnbull, D.M.Sanderson and S.J.Crome, 1985, Exposure to pesticides during application, in Occupational Hazards of Pesticide Use (G.J.Turnbull, D.M.Sanderson and J.L.Bonsall, eds.) p. 35-49.

143 *Joint Medical Panel of the Scientific Subcommittee on Pesticides of the Ministry of Agriculture, Fisheries and Food and the Toxicology Committee of the British Agrochemical Association*, 1986, Estimation of exposure and absorption of pesticides by spray operators, MAFF, Pesticides Registration Department, Harpenden, Herts, UK.

144 *W.Batel and T.Hinz*, 1988, Exposure measurements concerning protective clothing in agriculture, in Performance of Protective Clothing: Second Symposium ASTM, STP 989 (S.Z.Mansdorf, R.Sager and A.P.Nielsen, eds.) p. 584-596, Philadelphia, USA.

145 *Biologische Bundesanstalt für Land- und Forstwirtschaft Bundesrepublik Deutschland*, 1988, Richtlinien für die Amtliche Prüfung von Pflanzenschutzmitteln Teil I. 3-3/1 Kennzeichnung von Pflanzenschutzmitteln - Gesundheitsschutz -. Risikoabschätzung für die Auswahl geeigneter Hinweise und sonstiger Massnahmen zum Schutz des Anwenders beim Umgang mit Pflanzenschutzmitteln, Abteilung für Pflanzenschutzmittel und Anwendungstechnik der Biologischen Bundesanstalt Braunschweig, West-Germany.

146 *J.C.Reinert and D.J.Severn*, 1985, Dermal exposure to pesticides. The Environmental Protection Agency's Viewpoint, in Dermal Exposure Related to Pesticide Use (R.C.Honeycutt, G.Zweig and N.N.Ragsdale, eds.) ACS Symposium Series 273, 357-368.

147 *D.R.Hackathorn and D.C.Eberhart*, 1985, Data-base proposal for use in predicting mixer-loader-applicator exposure, in Dermal Exposure Related to Pesticide Use (R.C.Honeycutt, G.Zweig and N.N.Ragsdale, eds.) ACS Symposium Series 273, 341-355.

148 *K.T.Maddy, R.G.Wang, J.B.Knaak, C.L.Liao, S.C.Edmiston and C.K.Winter*, 1985, Risk assessment of excess pesticide exposure to workers in Calfornia, in Dermal Exposure Related to Pesticide Use (R.C.Honeycutt, G.Zweig and N.N.Ragsdale, eds.) ACS Symposium Series 273, 445-461.

149 *C.A.Franklin*, 1985, Occupational exposure to pesticides and its role in risk assessment procedures used in Canada, in Dermal Exposure Related to Pesticide Use (R.C.Honeycutt, G.Zweig and N.N.Ragsdale, eds.) ACS Symposium Series 273, 429-444.

150 *R.Grover, A.J.Cessna, N.I.Muir, D.Riedel and C.A.Franklin*, 1988, Pattern of dermal deposition resulting from mixing/loading and ground application of 2,4-D dimethylamine salt, in Performance of Protective Clothing: Second Symposium, ASTM STP 989 (S.Z.Mansdorf, R.Sager and A.P.Nielsen, eds.) p. 625-629, American Society for Testing and Materials, Philadelphia, USA.

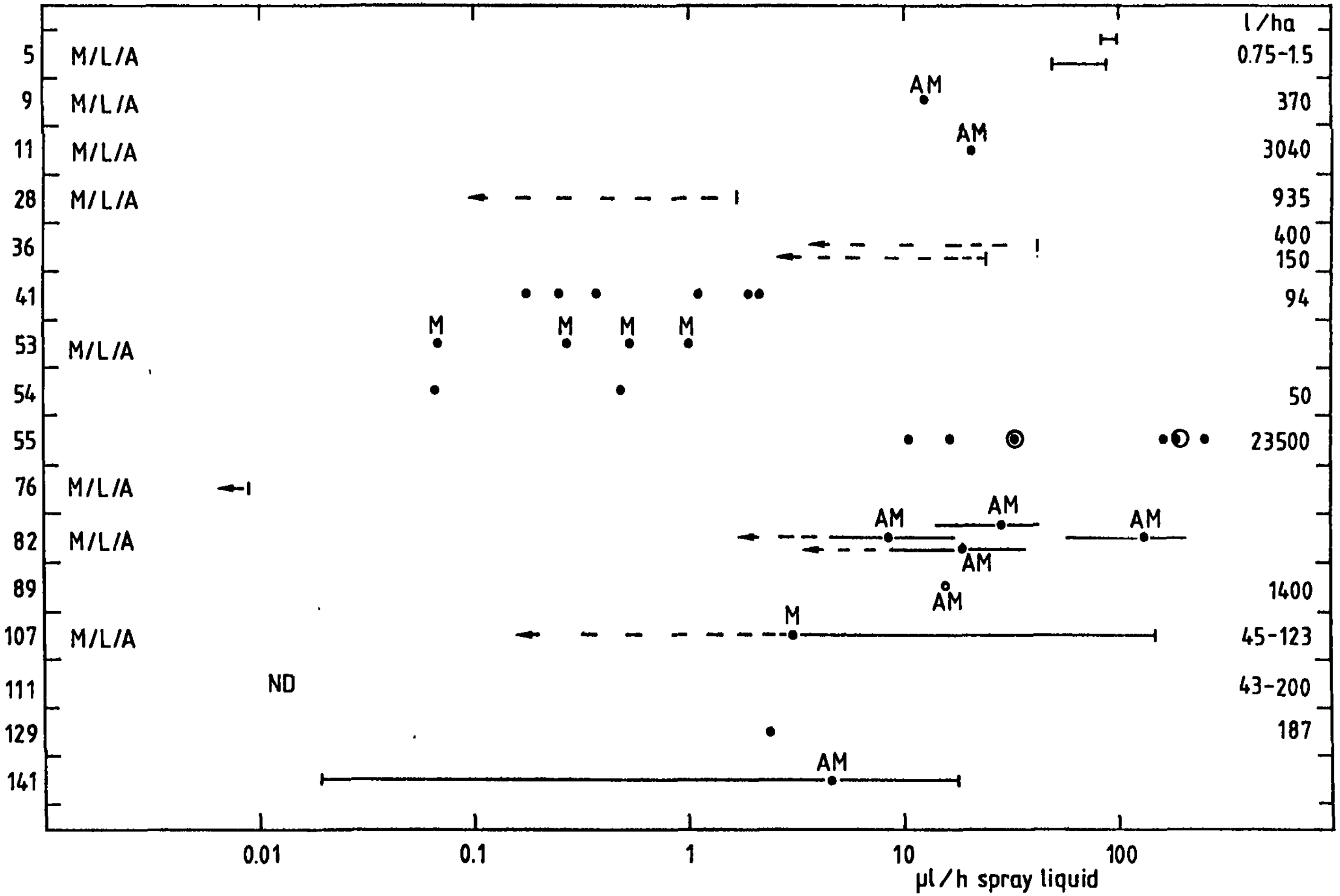

Figure 1 Inhalation exposure (µl/h spray liquid) during application with a tractor mounted downward spraying technique {1a}. References are given by numbers at the left-hand side. M/L/A indicates a combination of mixing, loading and application. ND: no detectable exposure. M: median. AM: arithmetic mean. | | : range. |: upper range with arrow indicating from highest observed exposure downwards to undetectable. —— —— : arithmetic standard deviation. The values on the right-hand side of the graph indicate the amount of liquid sprayed per hectare (l/ha).

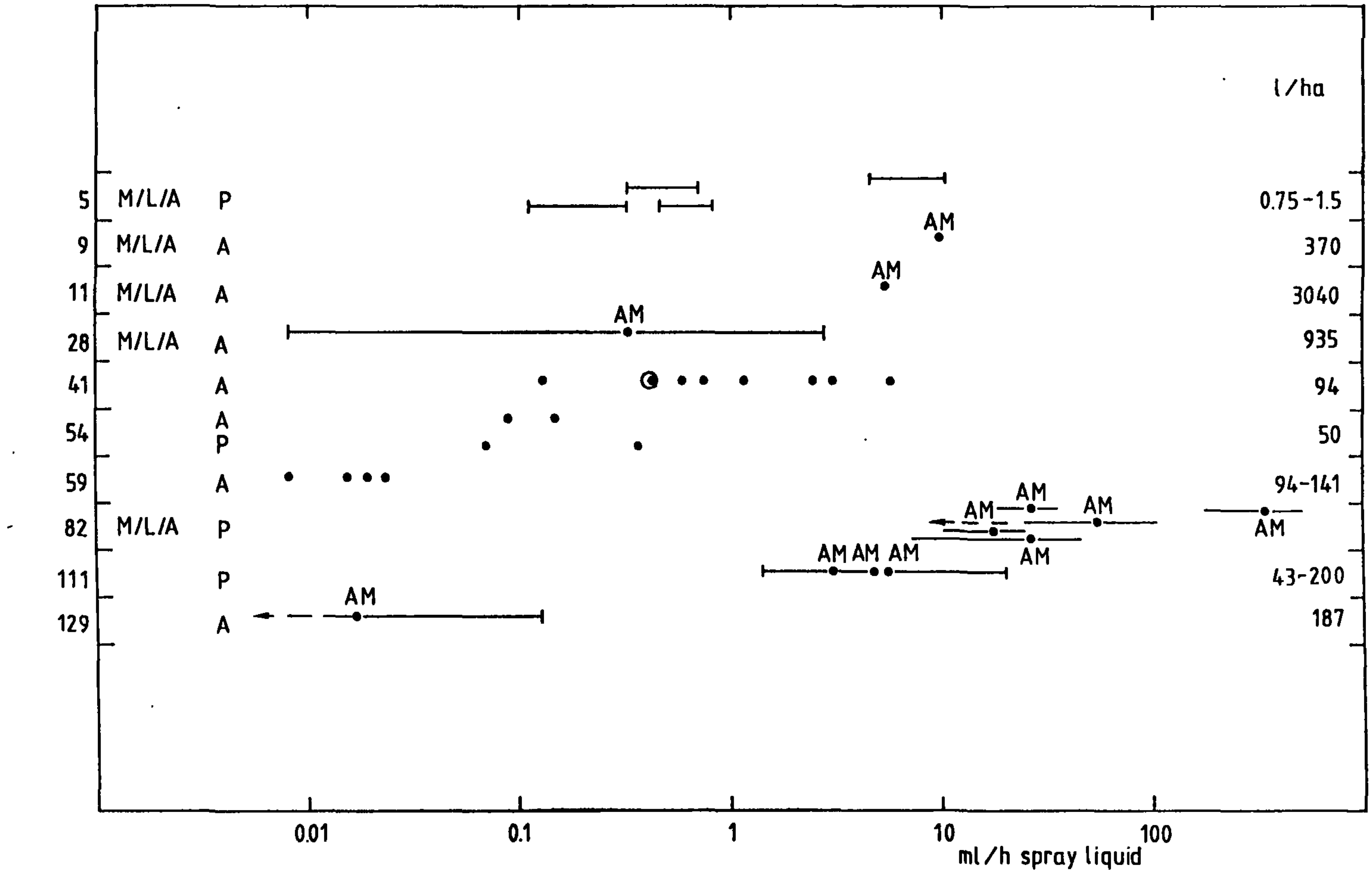

Figure 2 Dermal exposure (ml/h spray liquid) during application with a tractor mounted downward spraying technique {1a}. References are given by numbers at the left-hand side. M/L/A indicates a combination of mixing, loading and application. A: actual exposure. P: potential exposure. ND: no detectable exposure. AM: arithmetic mean. | | : range. |: upper range with arrow indicating from highest observed exposure downwards to undetectable. —— ——: arithmetic standard deviation. The values on the right hand side of the graph indicate the amount of liquid sprayed per hectare (l/ha).

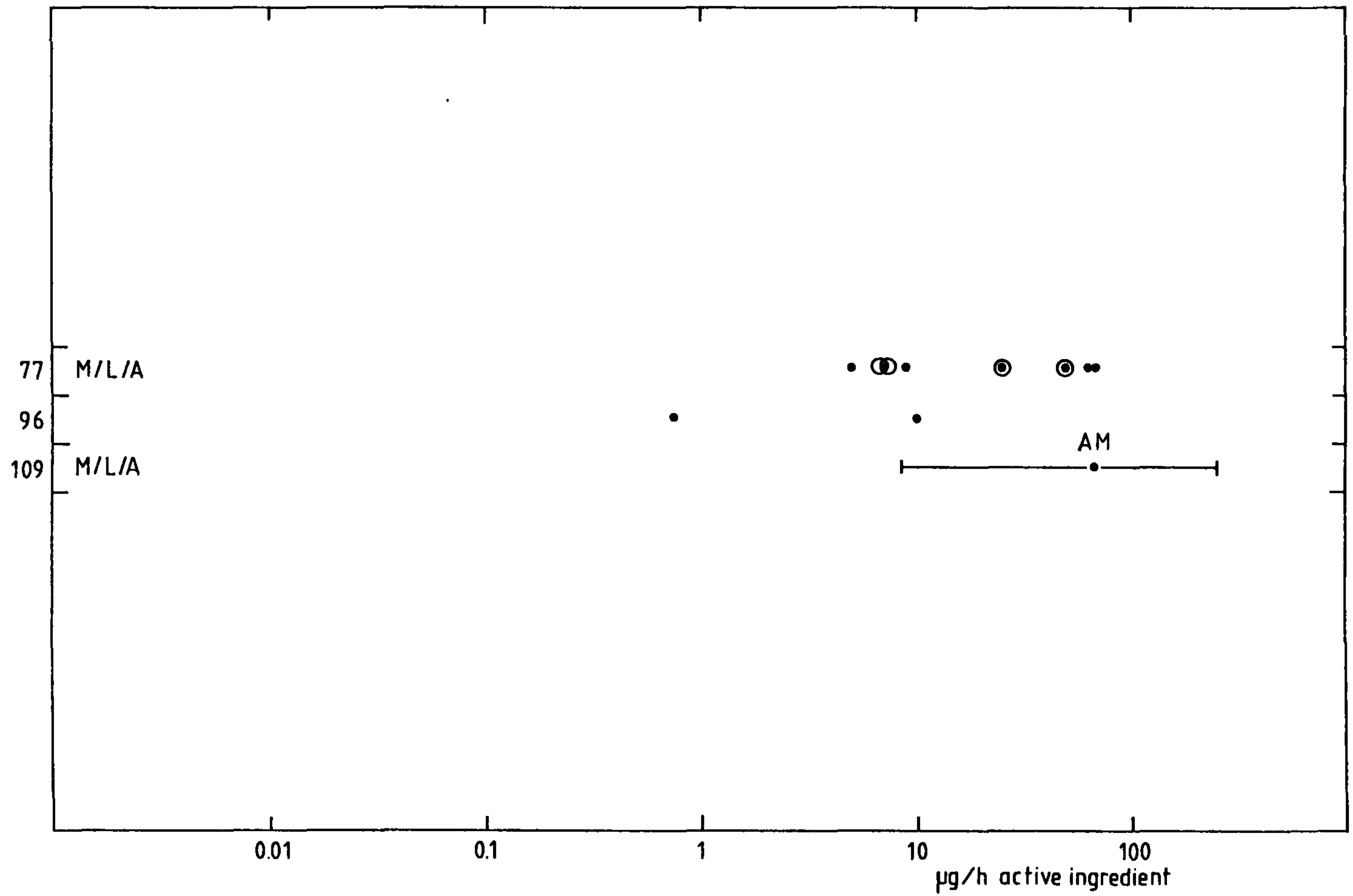

Figure 3 Inhalation exposure (μg/h active ingredient) during application with a tractor mounted downward spraying technique {1a}. For further description see legend to figure 1.

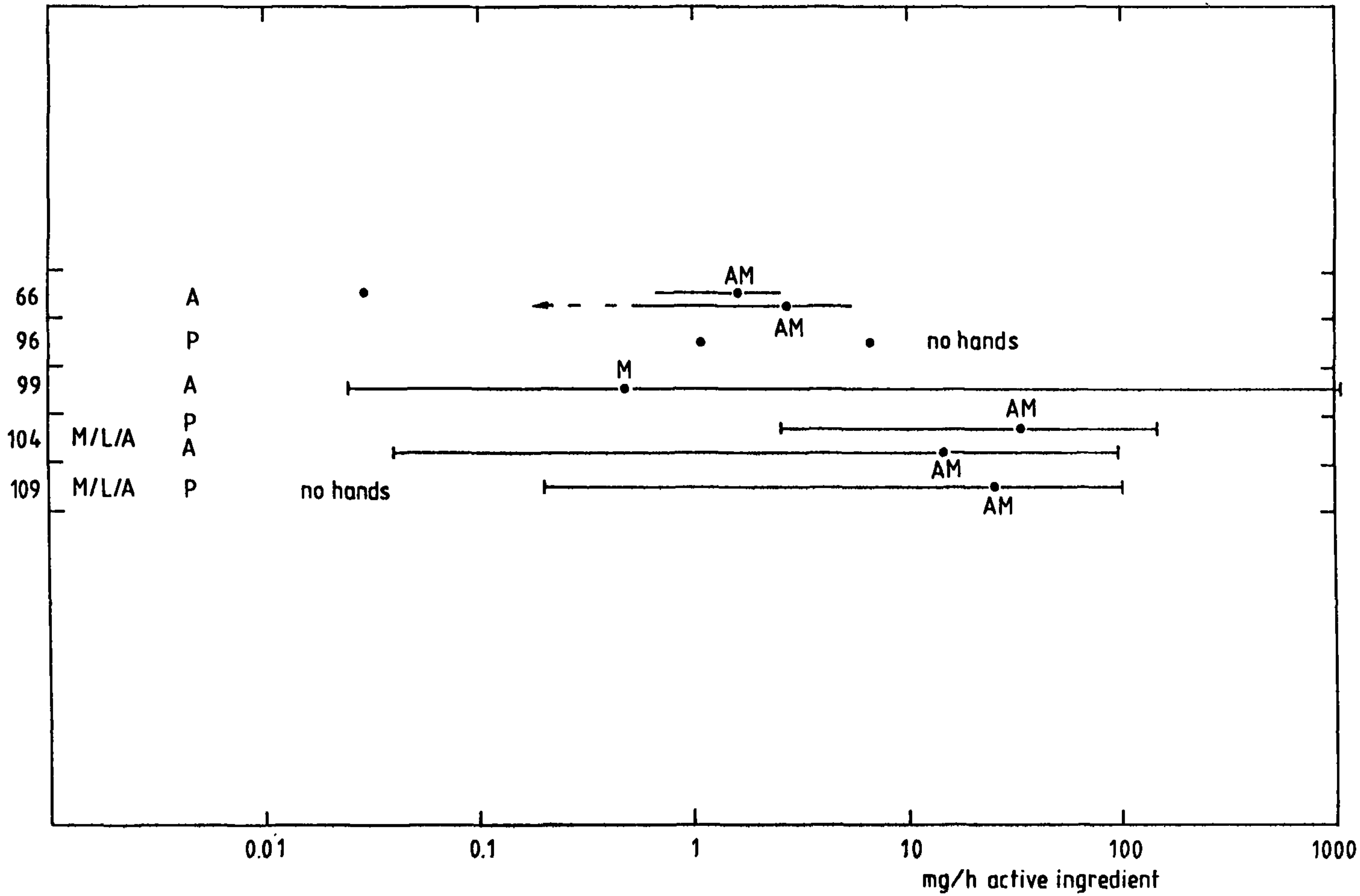

Figure 4 Dermal exposure (mg/h active ingredient) during application with a tractor mounted downward spraying technique {1a}. For further description seen legend to figure 2.

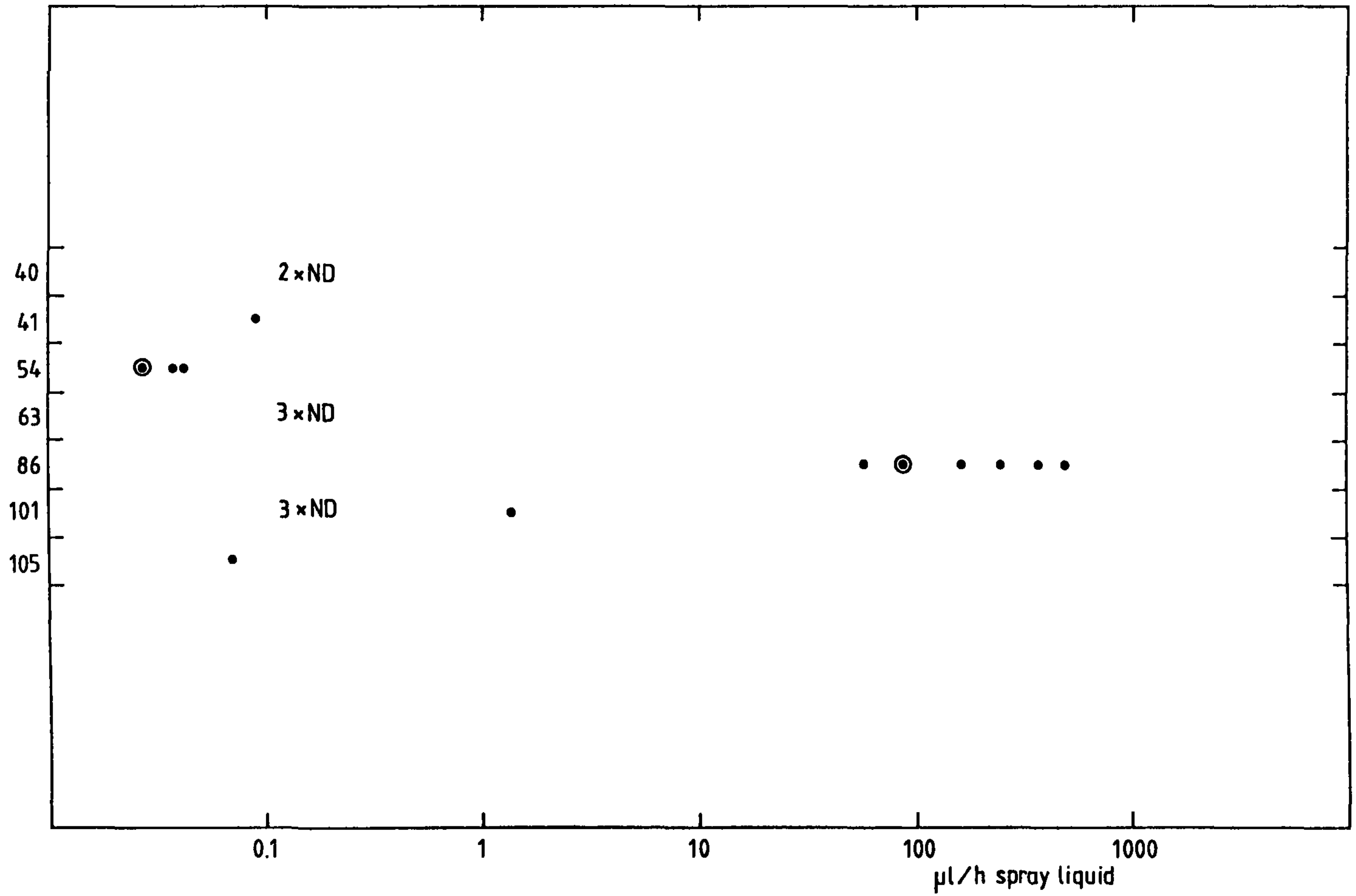

Figure 5 Inhalation exposure (μl/h spray liquid) during aircraft spraying {1b}. For further description see legend to figure 1.

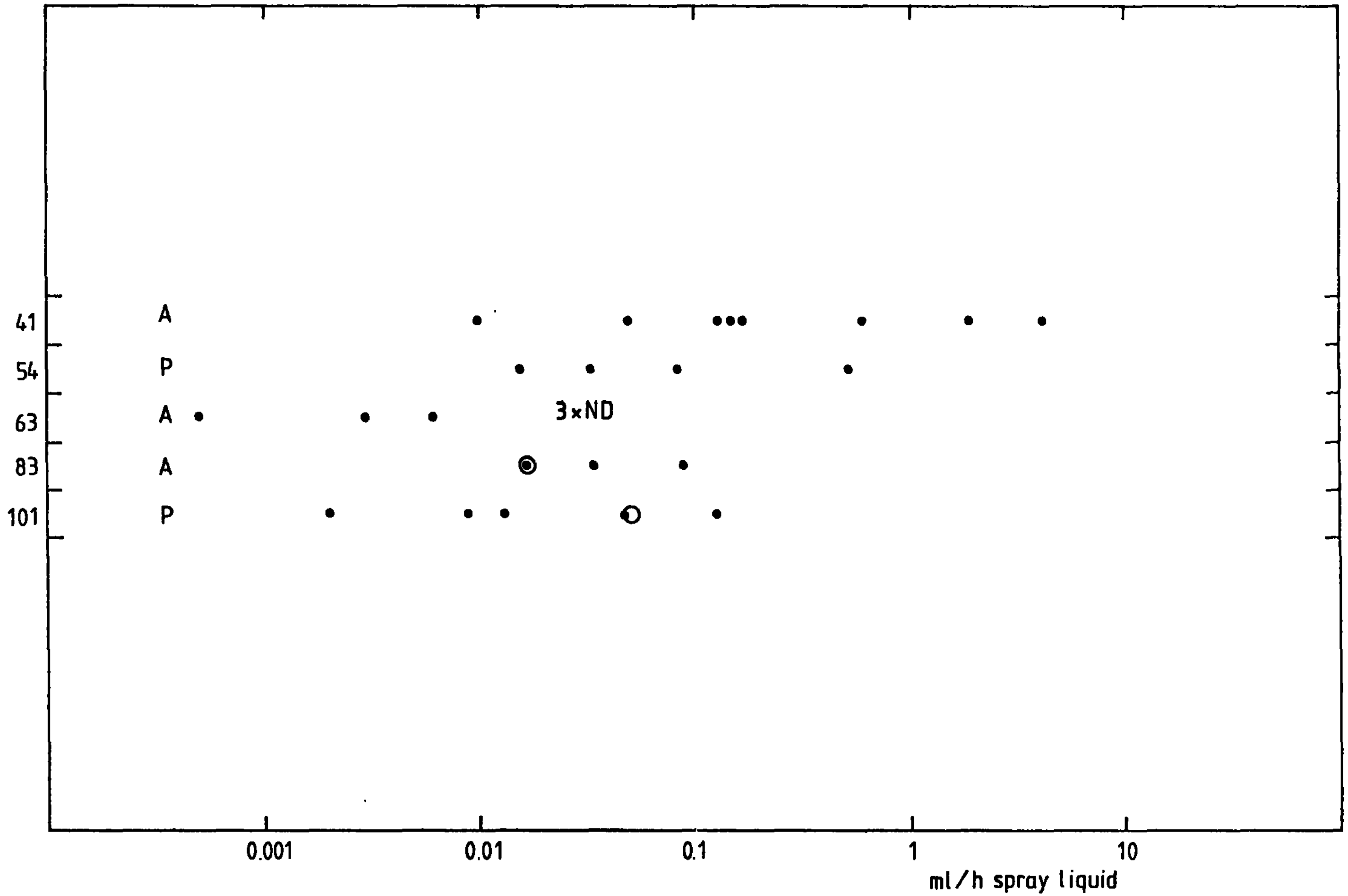

Figure 6 Dermal exposure (ml/h spray liquid) during aircraft spraying {1b}. ND: no detectable exposure. For further description see legend to figure 2.

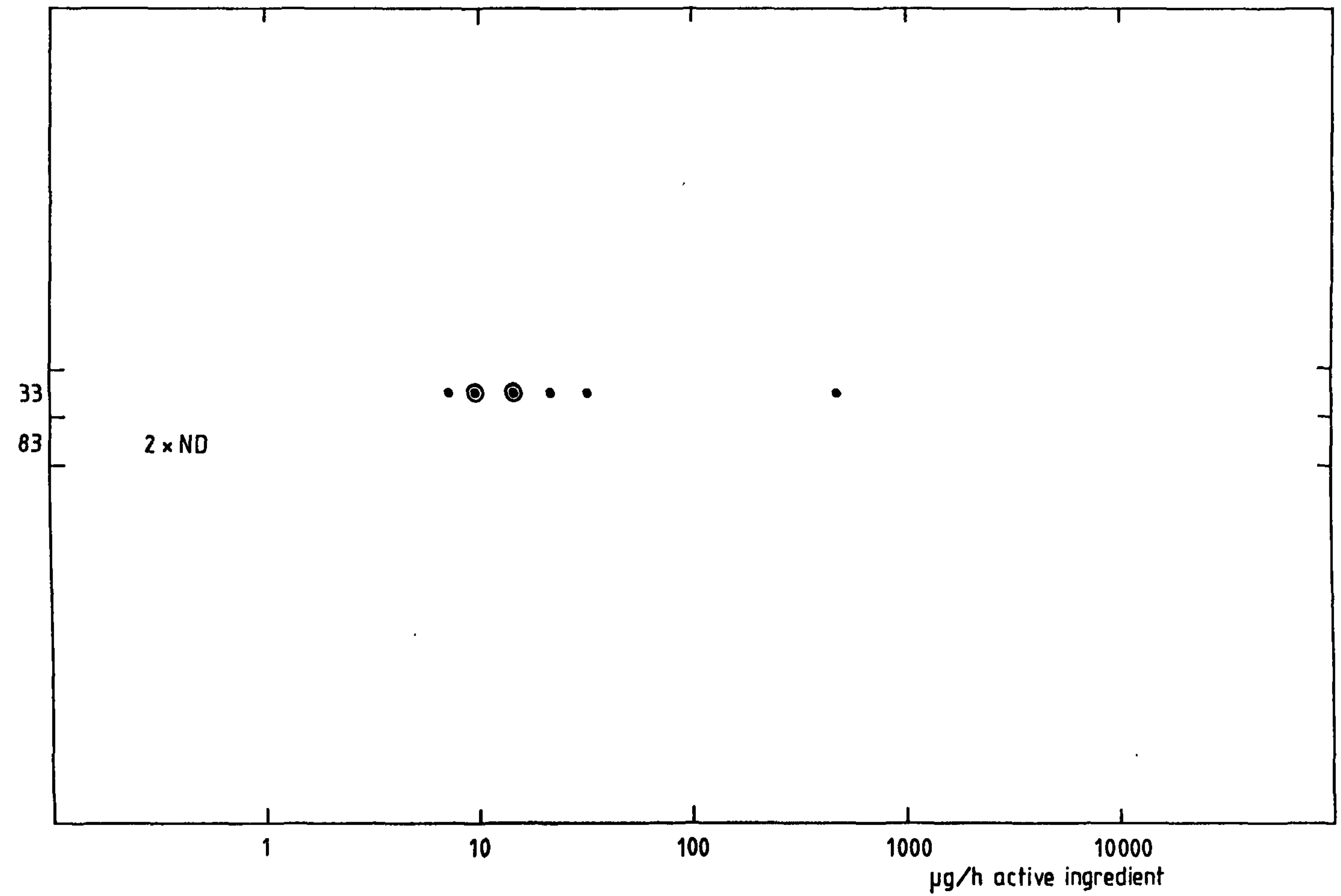

Figure 7 Inhalation exposure (μg/h active ingredient) during aircraft spraying {1b}. For further description see legend to figure 1.

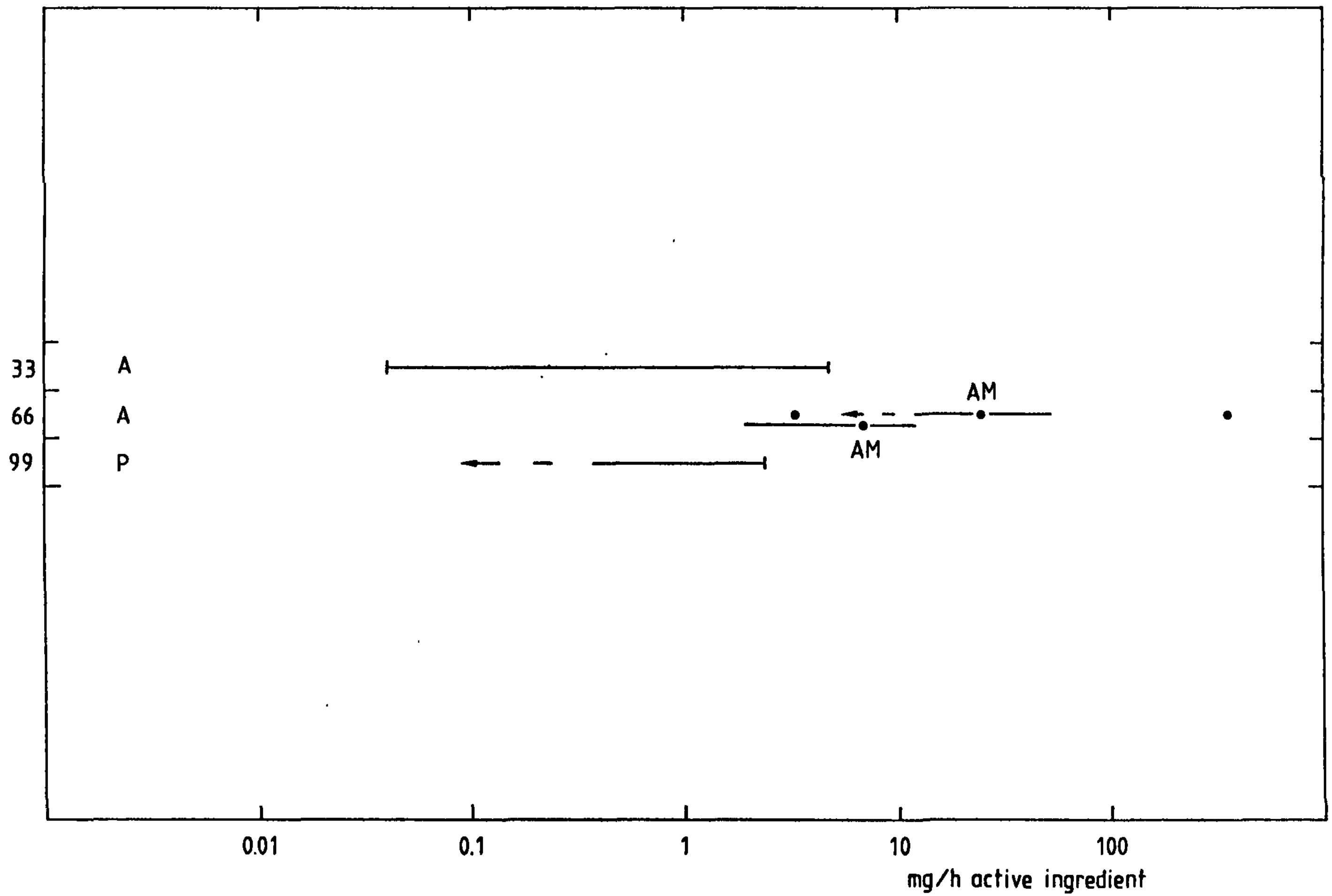

Figure 8 Dermal exposure (mg/h active ingredient) during aircraft spraying {1b}. For further description see legend to figure 2.

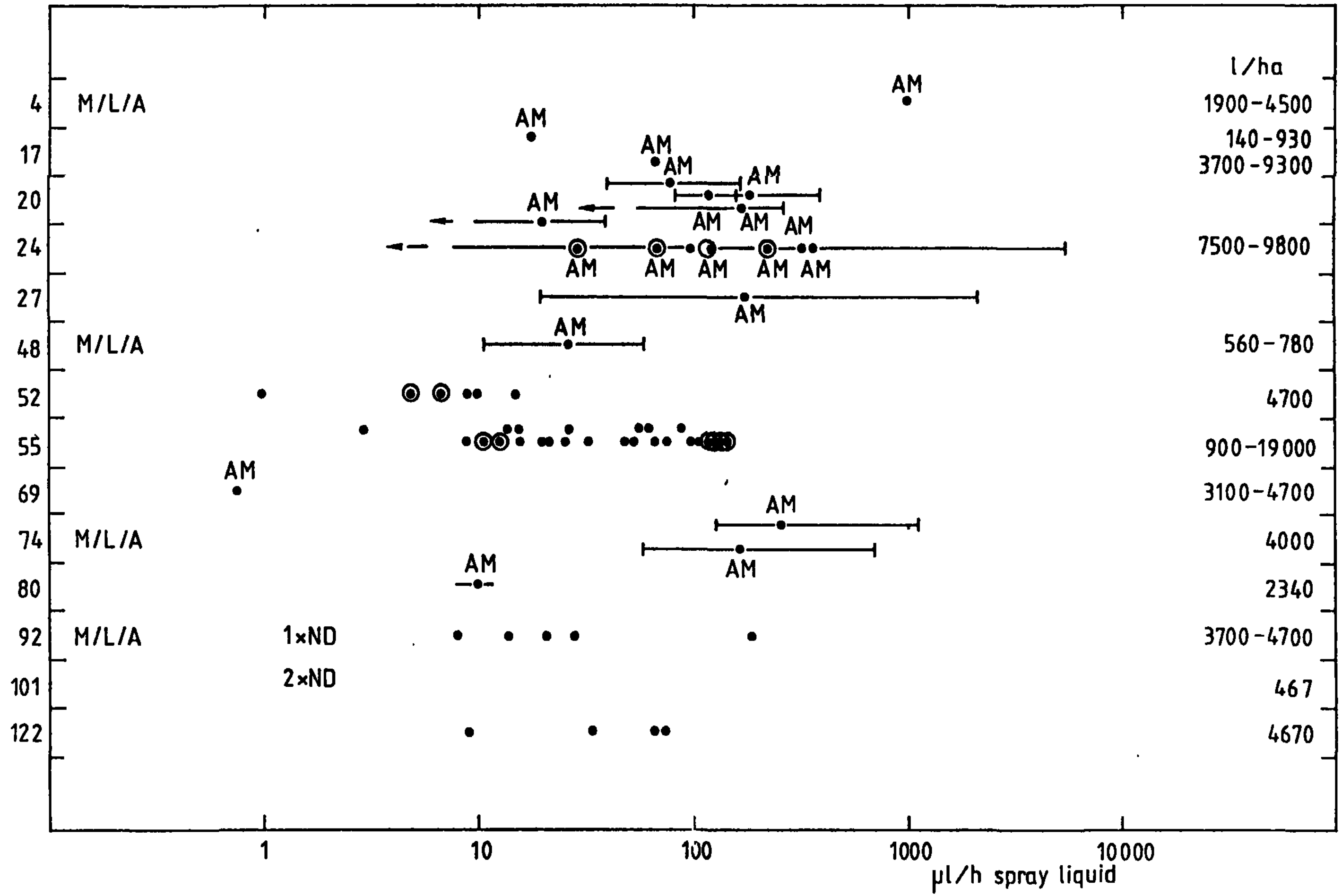

Figure 9 Inhalation exposure (µl/h spray liquid) during tractor mounted equipment upward spraying {4}. For further description see legend to figure 1.

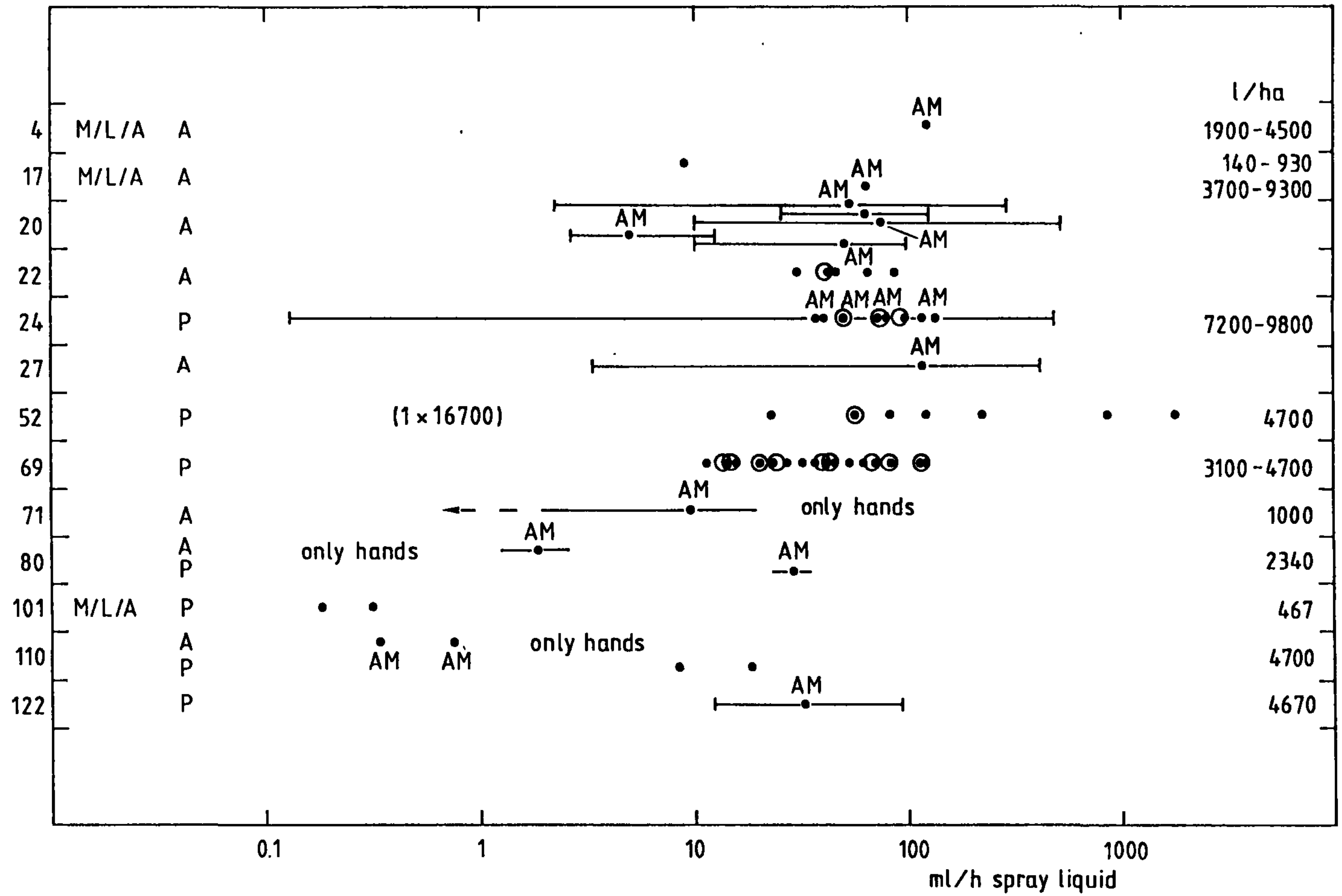

Fig. 10 Dermal exposure (ml/h spray liquid) during tractor mounted equipment upward spraying {4}. One extremely high value has been given as the actual figure. For further description see legend to figure 2.

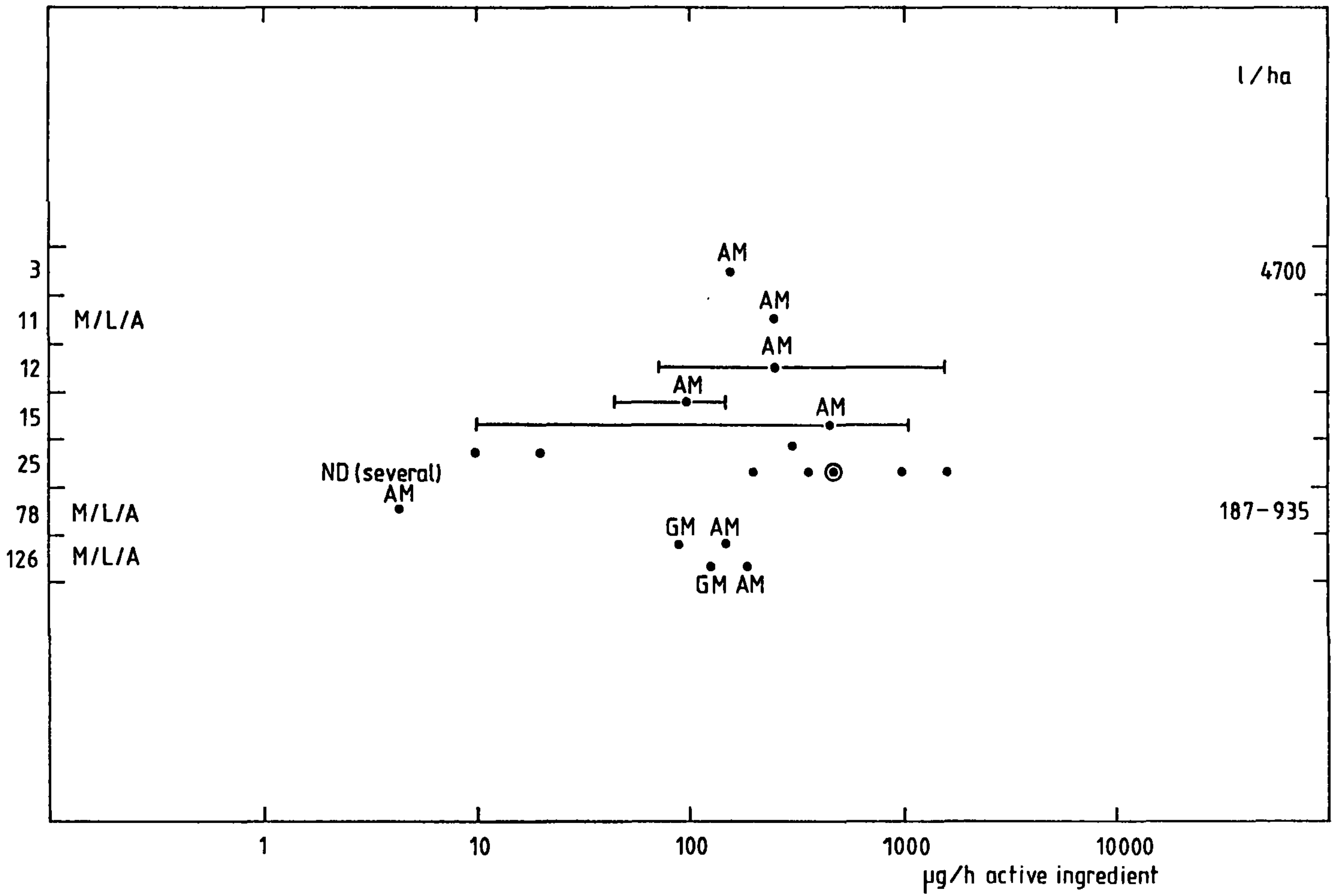

Fig. 11 Inhalation exposure (µg/h active ingredient) during tractor mounted equipment upward spraying {4}. GM: geometric mean. For further description see legend to figure 1.

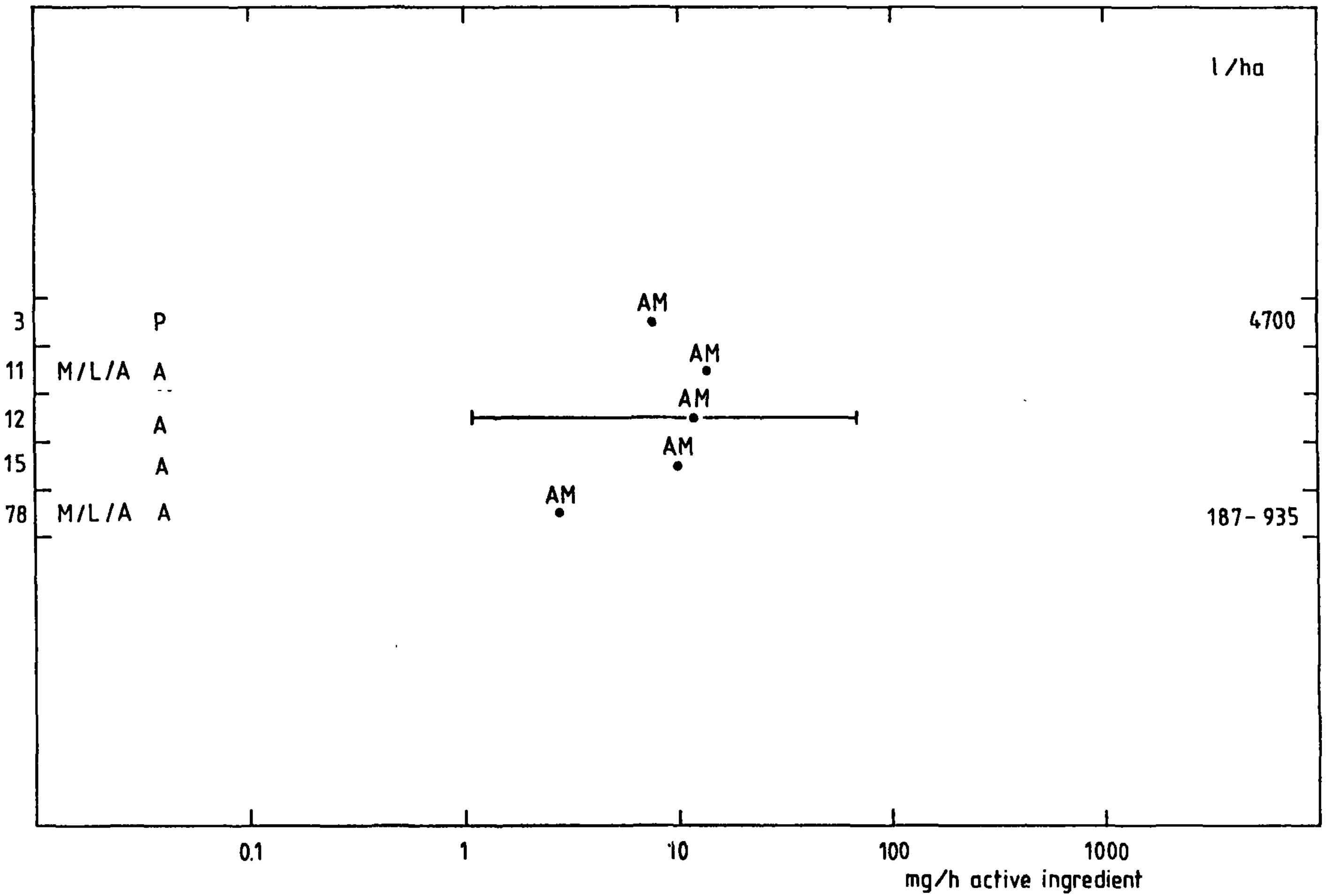

Fig. 12 Dermal exposure (mg/h active ingredient) during tractor mounted equipment upward spraying {4}. For further description see legend to figure 2.

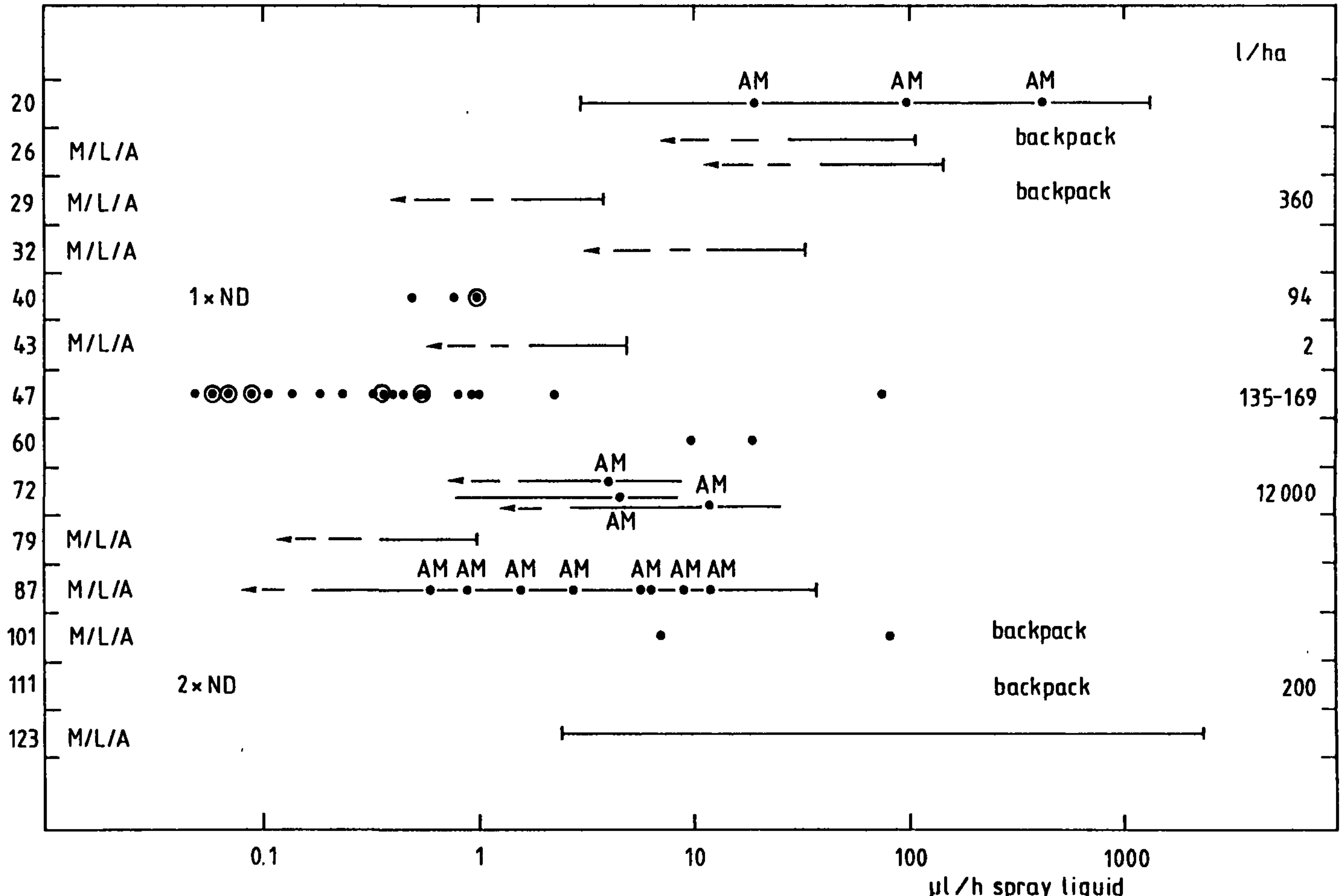

Fig. 13 Inhalation exposure (µl/h spray liquid) during manual spraying (upward and downward) outdoors {5}. All values are related to hand gun spraying, unless indicated as backpack spraying. For further description see legend to figure 1.

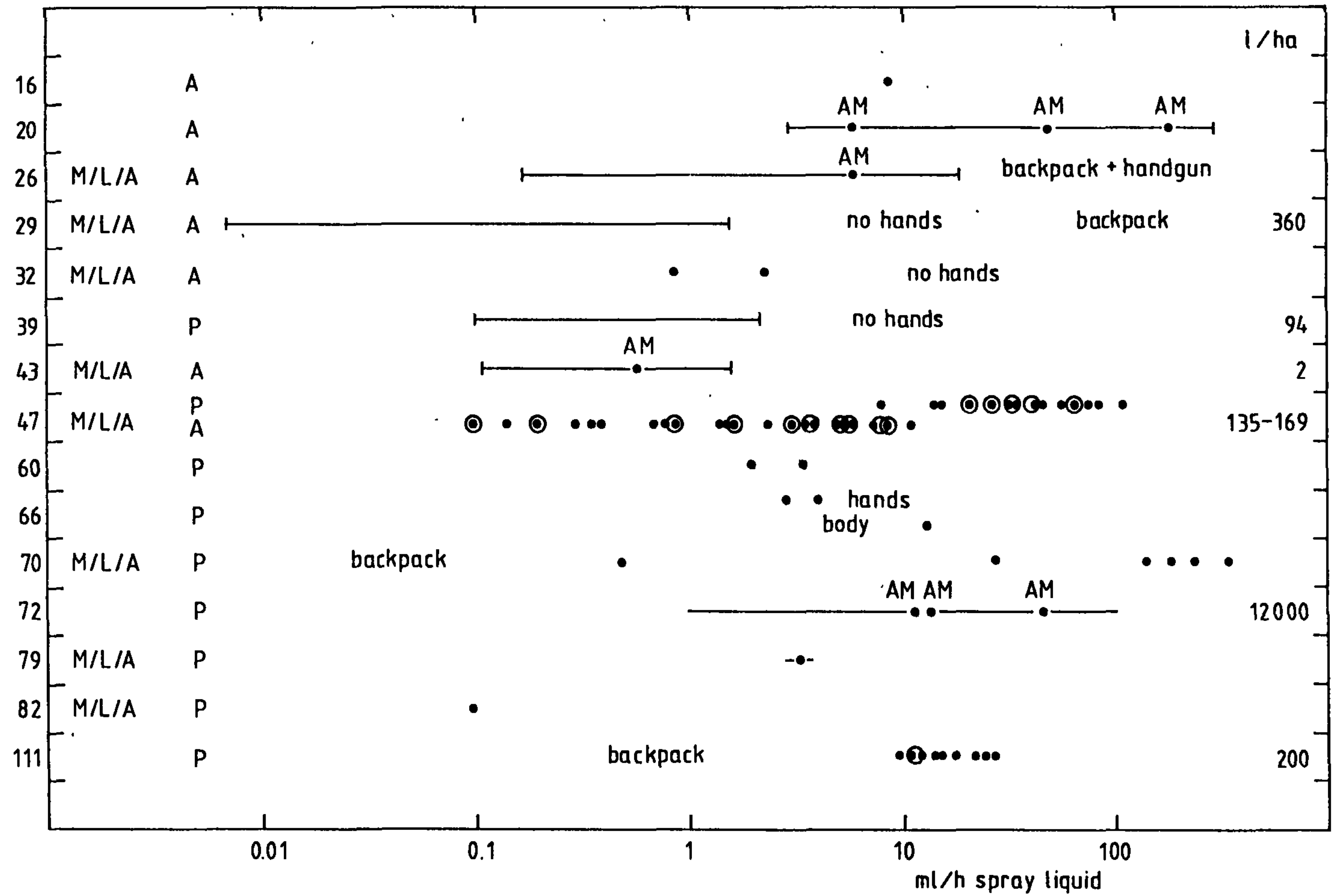

Fig. 14 Dermal exposure (ml/h spray liquid) during manual spraying (upward and downward) outdoors {5}. All values are related to hand gun spraying, unless indicated as backpack spraying. For further description see legend to figure 2.

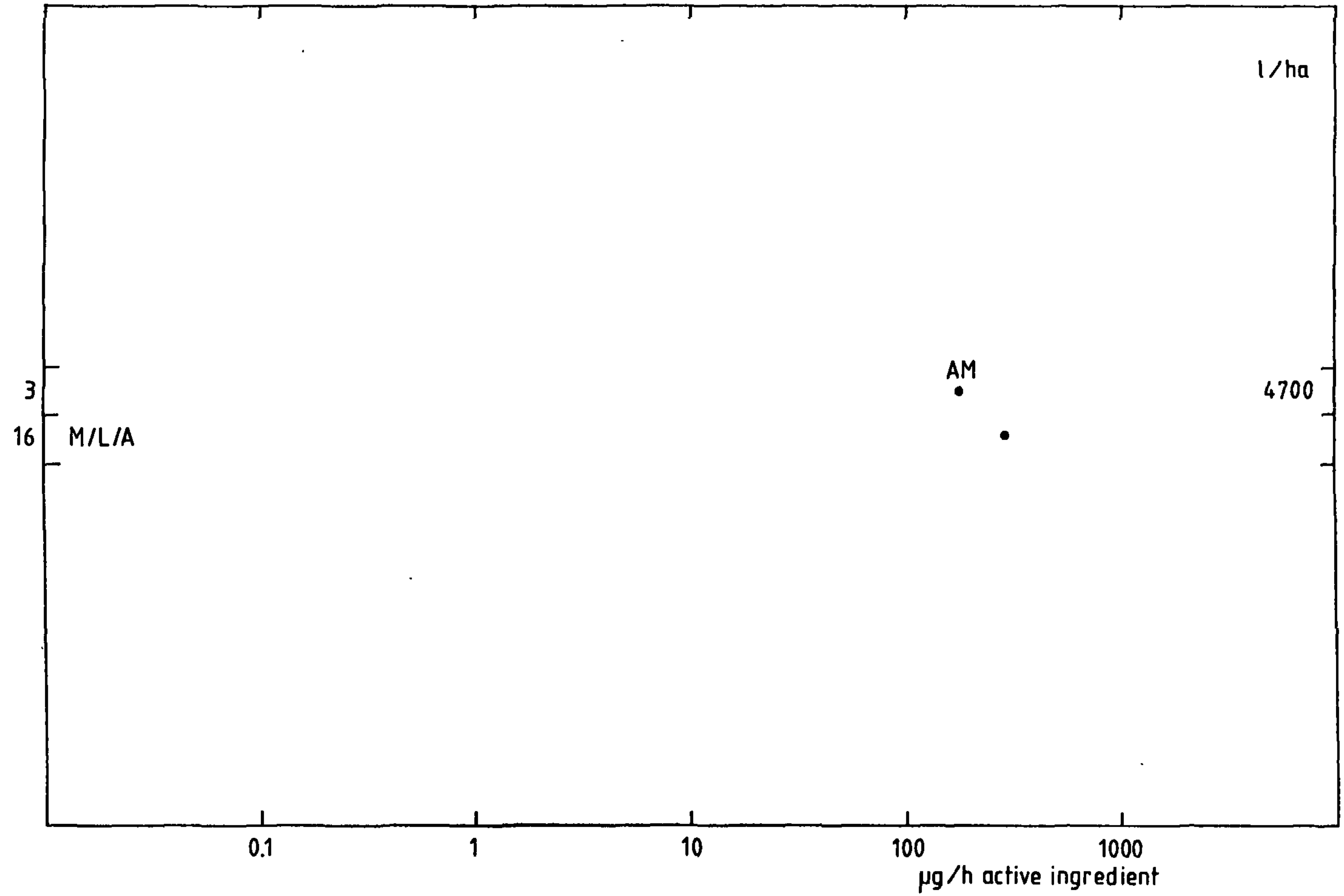

Fig. 15 Inhalation exposure (µg/h active ingredient) during hand gun spraying (upward and downward) outdoors {5}. For further description see legend to figure 1.

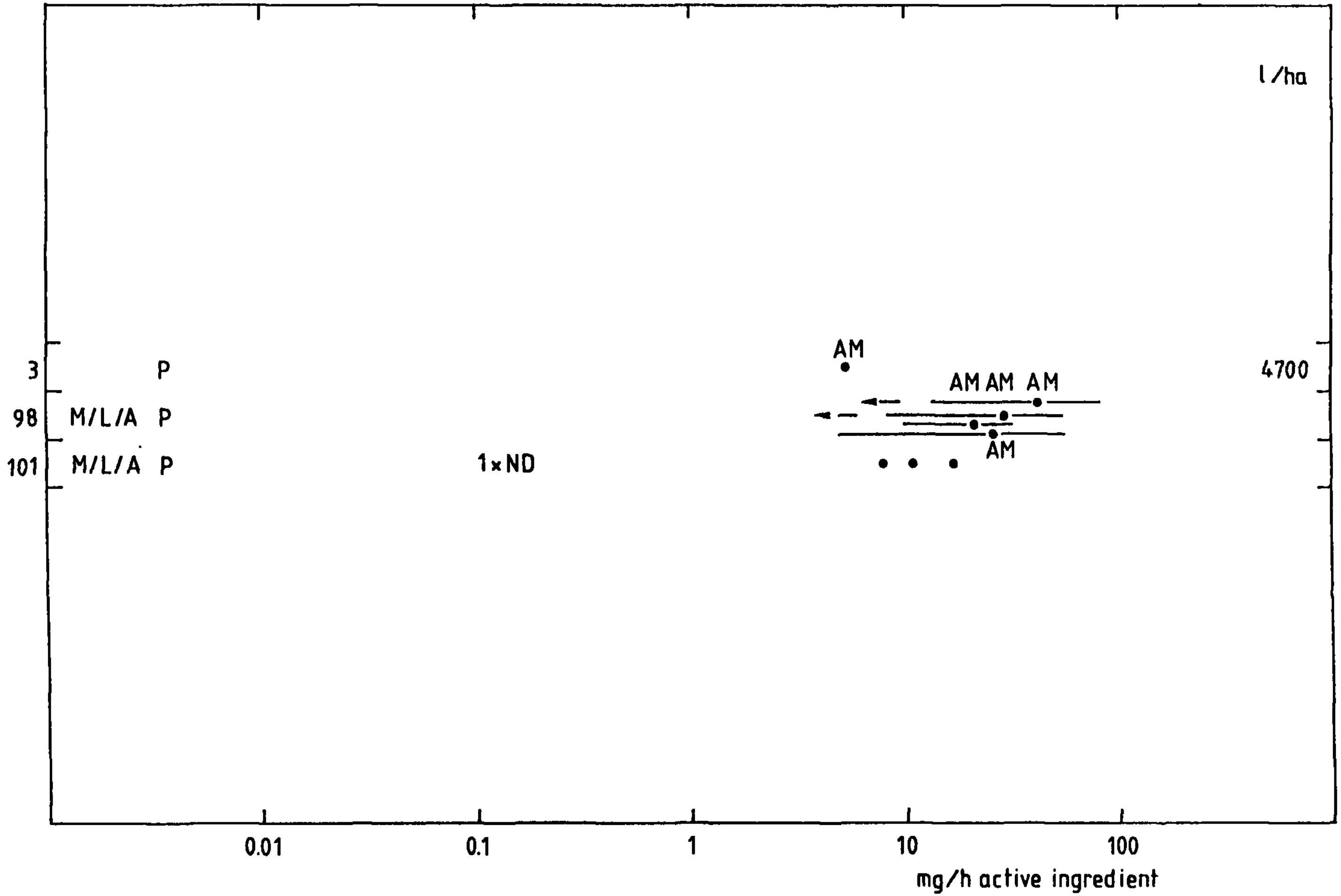

Fig. 16 Dermal exposure (mg/h active ingredient) during hand gun spraying (upward and downward) outdoors {5}. For further description see legend to figure 2.

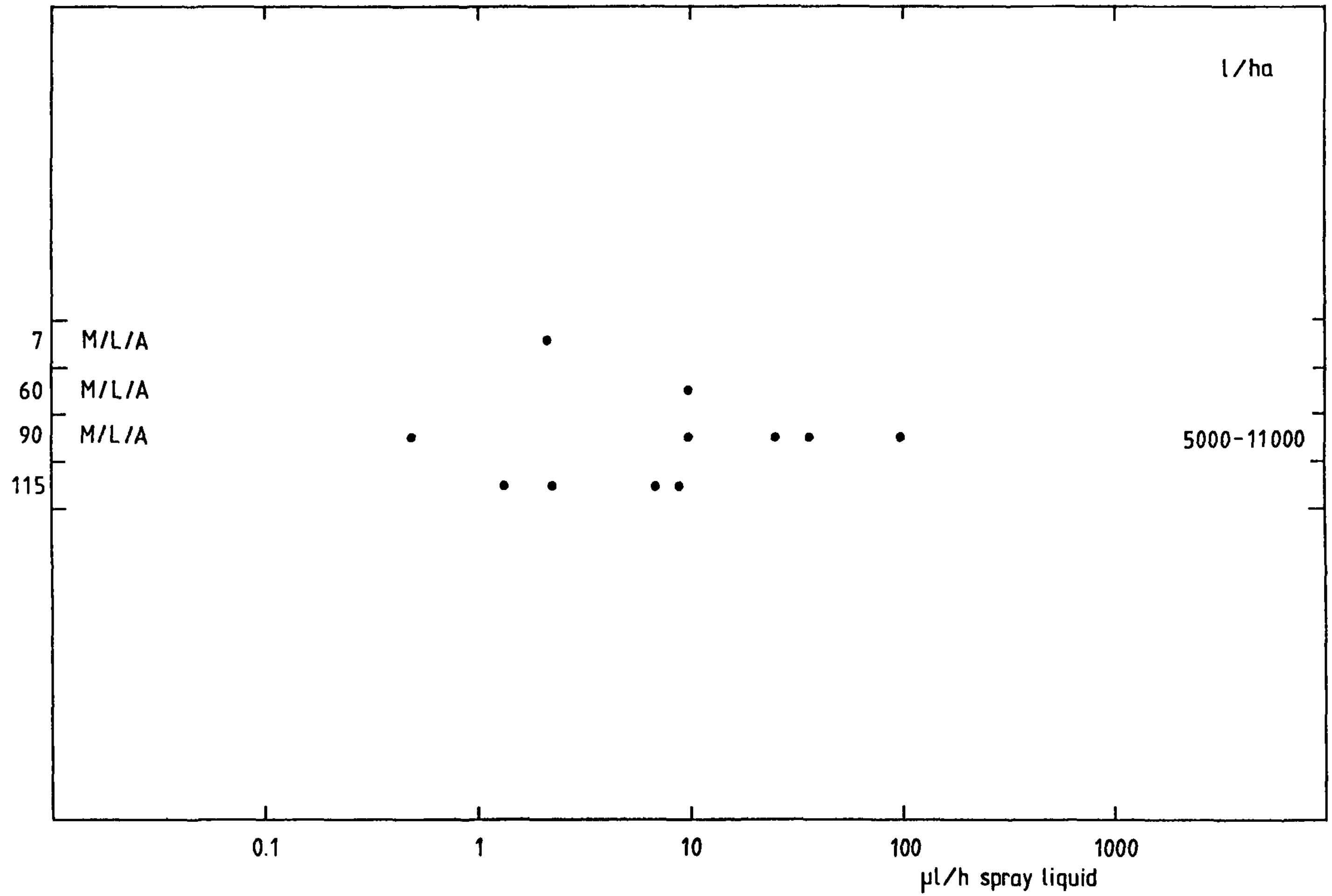

Fig. 17 Inhalation exposure (μl/h spray liquid) during spraying indoors {6}. For further description see legend to figure 1.

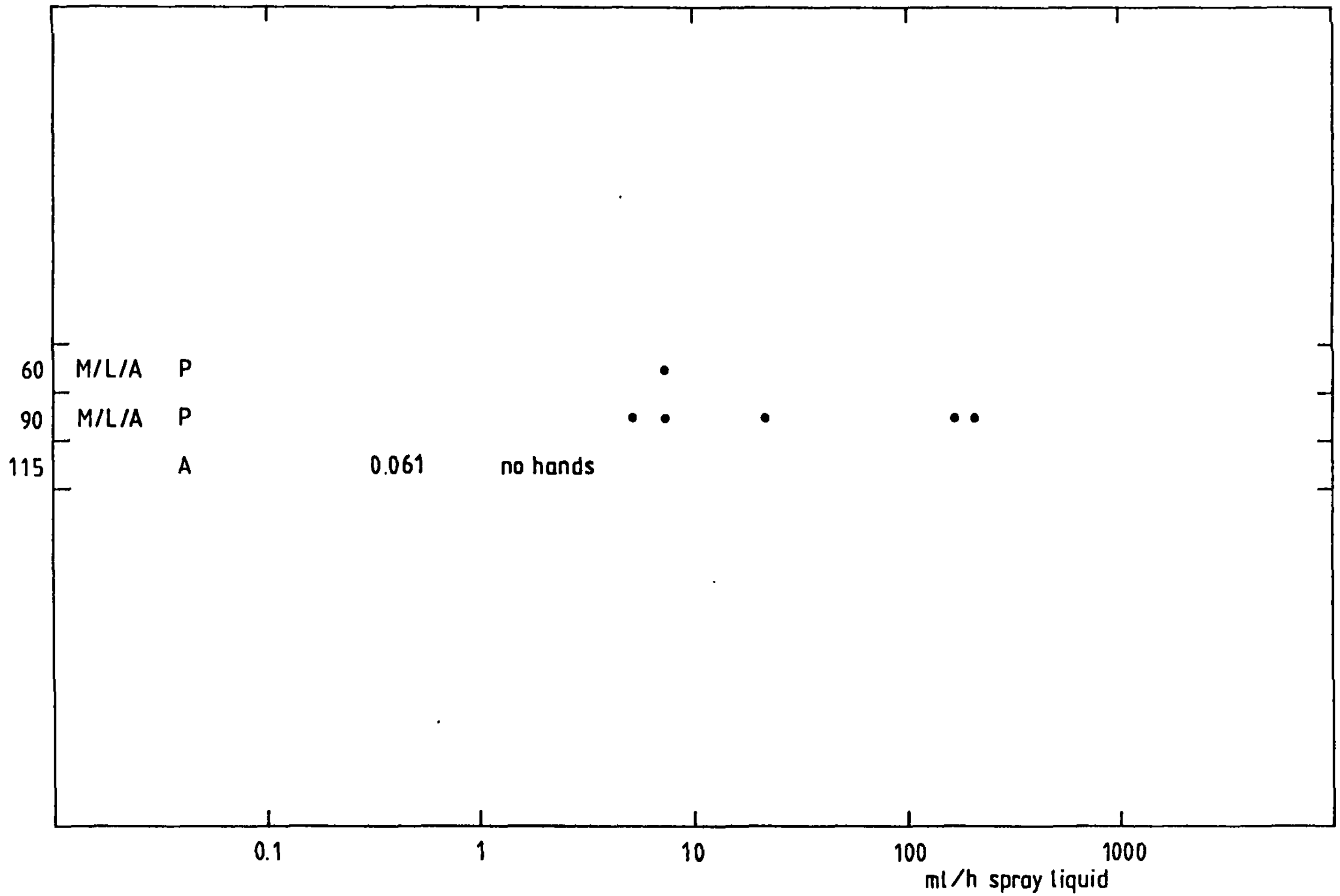

Fig. 18 Dermal exposure (ml/h spray liquid) during spraying indoors {6}. In one case an extremely low value has been indicated by the number itself. For further description see figure 2.

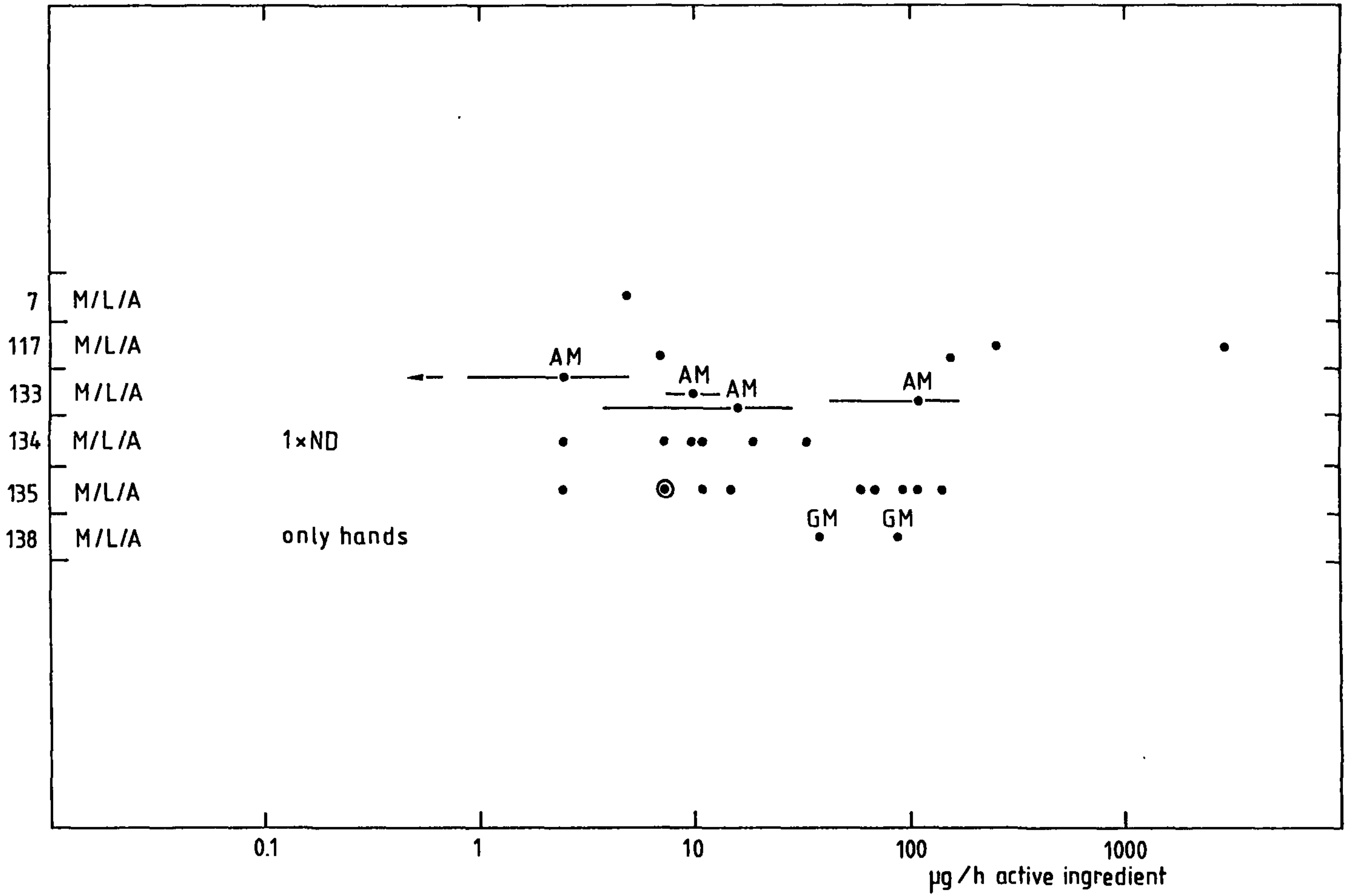

Fig. 19 Inhalation exposure (µg/h active ingredient) during spraying indoors {6}. GM: geometric mean. For further description see legend to figure 1.

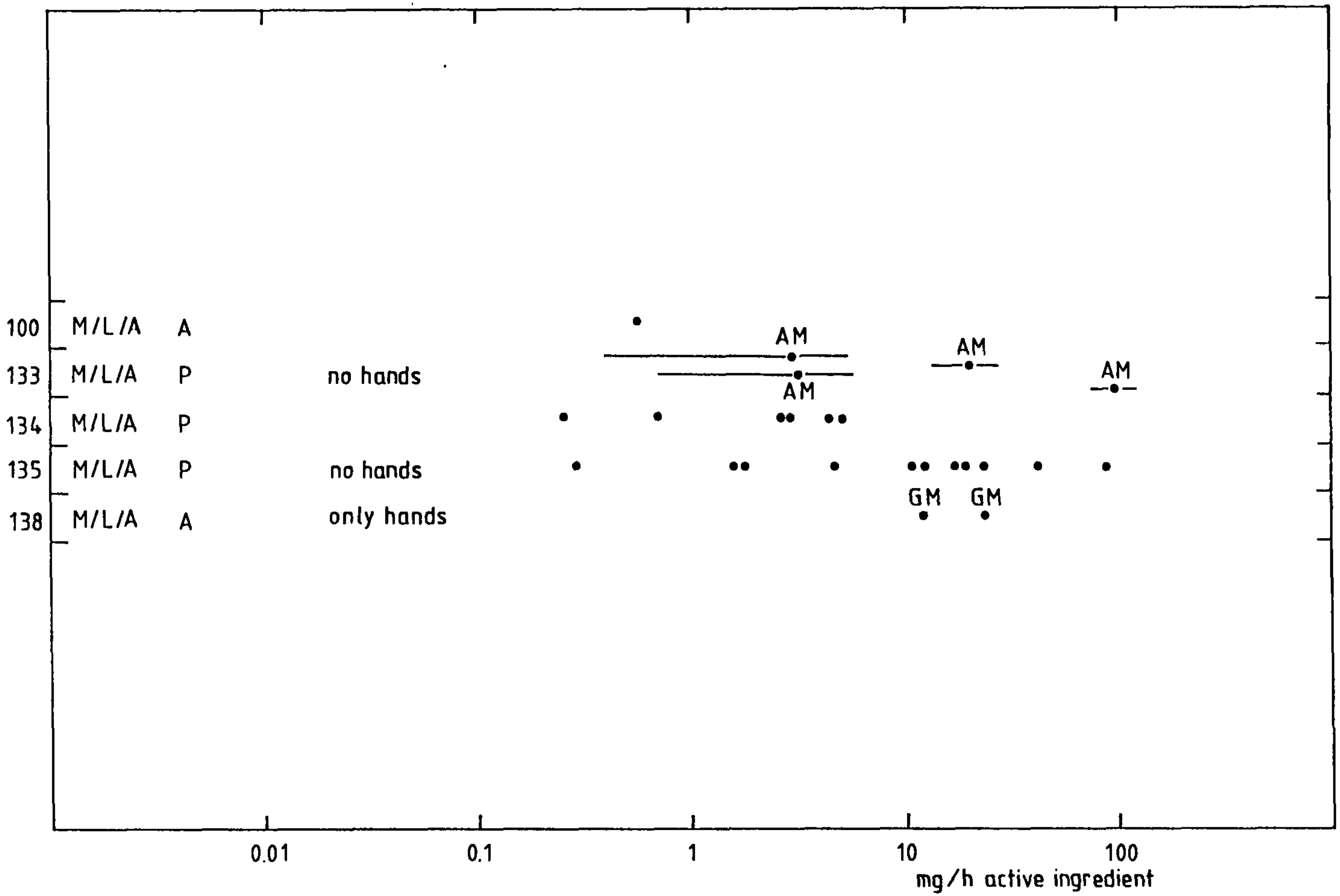

Fig. 20 Dermal exposure (mg/h active ingredient) during spraying indoors {6}. GM: geometric mean. For further description see legend to figure 2.

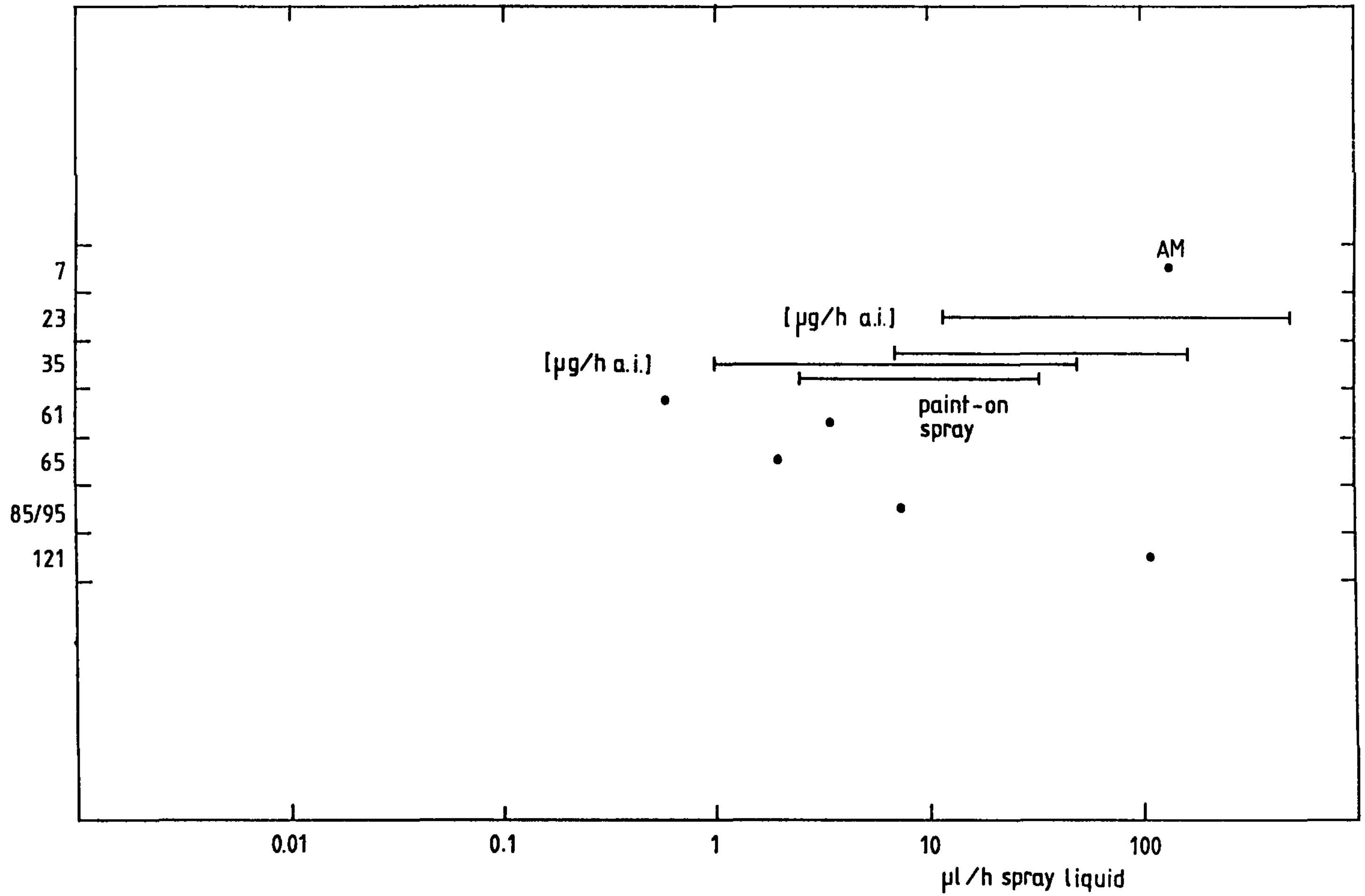

Fig. 21 Inhalation exposure during fumigation of enclosed locations {11}. The exposure is given as µl/h spray liquid unless stated otherwise (active ingredient). In one case the exposure levels were compared for the use of a paint-on and a spray formulation. For further description see legend to figure 1.

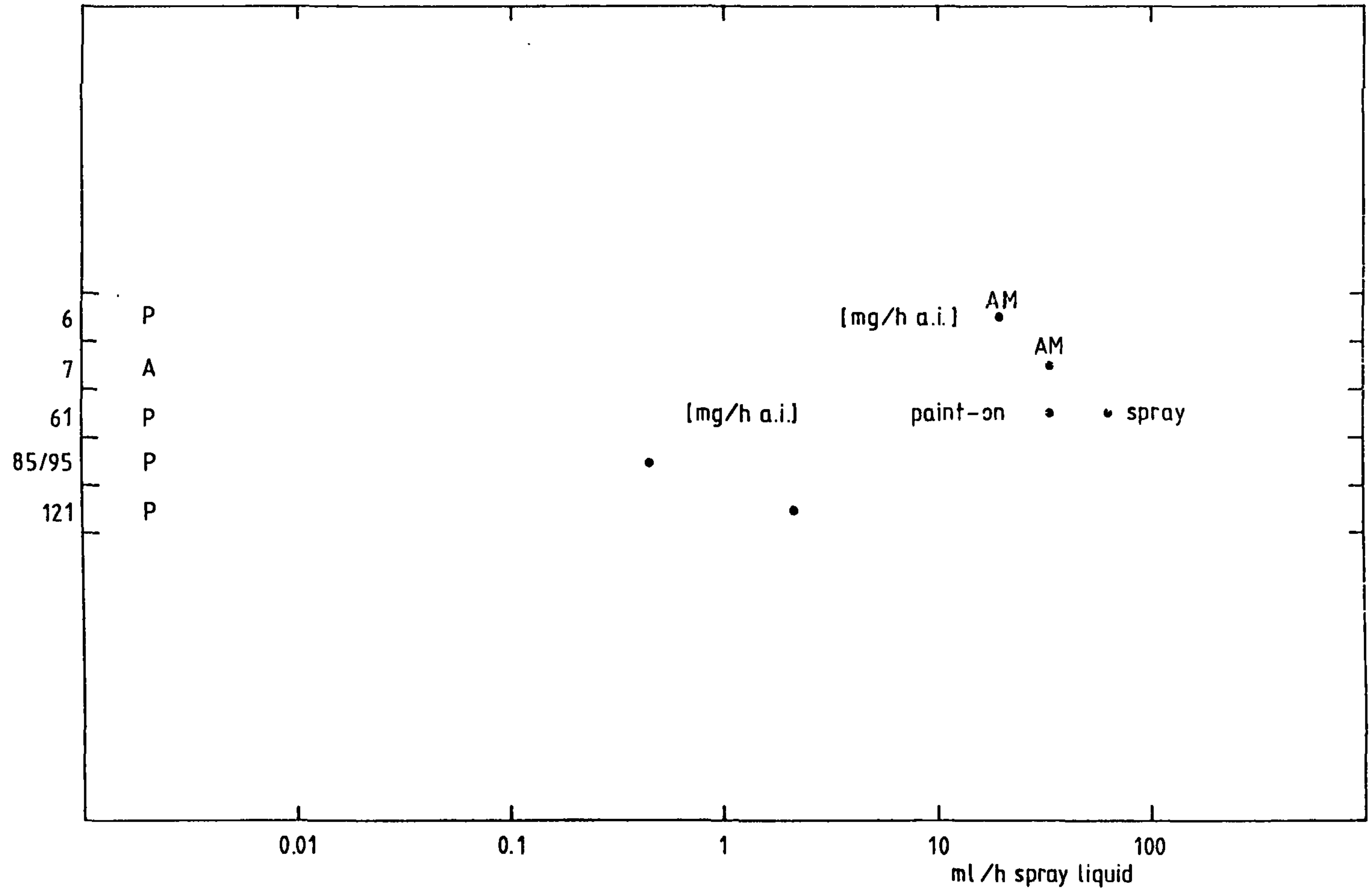

Fig. 22 Dermal exposure during fumigation of enclosed locations {11}. The exposure is given as ml/h spray liquid unless stated otherwise (active ingredient). In one case the exposure levels were compared for the use of a paint-on and a spray formulation. For further description see legend to figure 2.

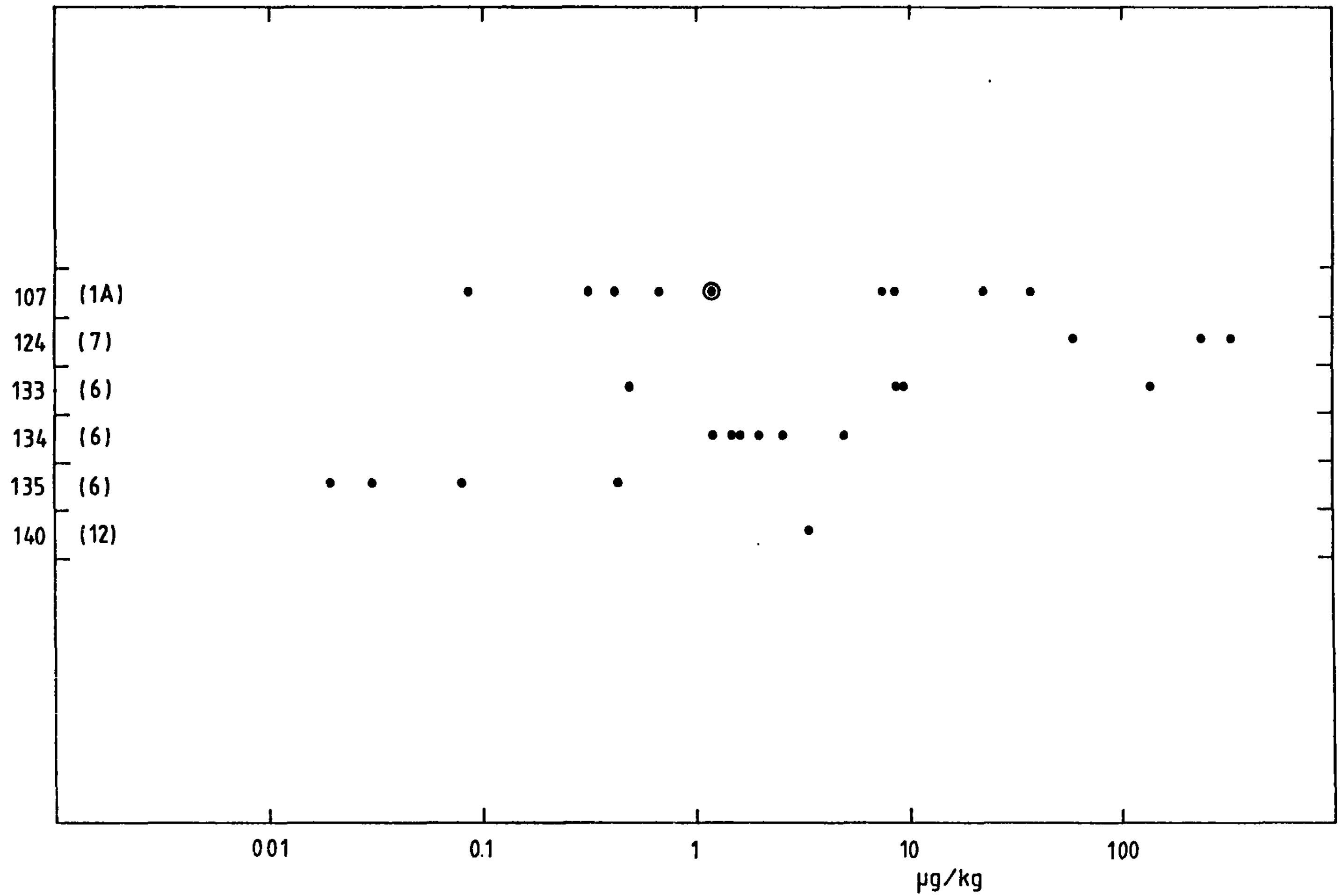

Fig. 23 Inhalation exposure per amount of pesticide handled (µg/kg) for various application techniques indicated by (x), conform table 1. For further description see legend to figure 1.

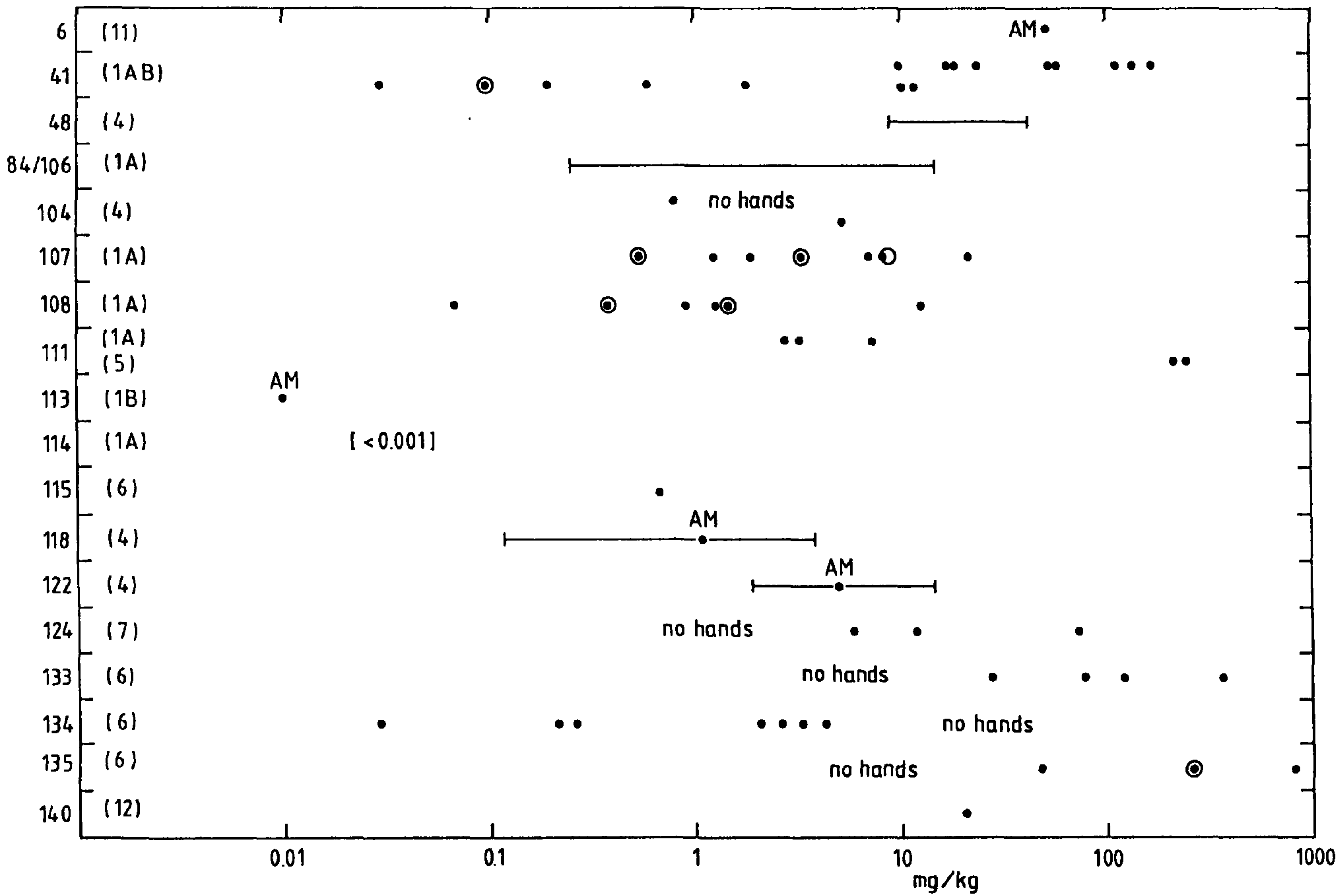

Fig. 24 Dermal exposure per amount of pesticide handled (mg/kg) for various application techniques indicated by (x), conform table 1. In one case an extremely low value has been indicated by the number itself. For further description see legend to figure 2.