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Assessment of occupational exposure to pesticides in agriculture

Part II Mixing and loading

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Labour Inspectorate

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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 second part of the series, the published data on exposure due to mixing and loading are summarized and evaluated. It may be concluded that there is a large spread in the levels of exposure. From the data indicative 90-percentiles of exposure in amount of formulated product per hour of mixing and loading have been estimated for liquid and solid formulations :

potential dermal exposure	
liquid formulations	300 mg/h
solid formulations	2 g/h
inhalation exposure	
liquid formulations	20 μg/h
solid formulations	15 mg/h

It is to be noted that these levels are based on a professional judgement of the available literature and pertain to conditions which are considered relevant for Dutch agriculture.

In cases where relatively small amounts of pesticide are handled, *e.g.* up to one or two kg of active ingredient, the levels of exposure to be used for registration procedures should be lower. Although only a few data are available, it appears that the level of exposure correlates well with the amount of pesticide handled. Data on the distribution of exposure over the body show relatively large differences. Deposition occurs mainly on hands and forearms. A general approach to risk assessment using the indicative 90-percentiles is described.

CONTENTS

1 INTRODUCTION

Data on exposure to, together with data on toxicity of a particular compound can be used to estimate possible health risks of working methods which involve that compound. Exposure to pesticides during mixing and loading forms an important part of the total exposure during the application of pesticides in agriculture.
In this paper relevant articles in the open literature which contain exposure data on mixing and loading of pesticides will be reviewed for possible inclusion in a generic/surrogate data base. This inclusion is based on an evaluation of the data according to criteria which have been described in part I of this series [1] and which are thought to be relevant for occupational exposure to pesticides in The Netherlands.
The liquid and solid formulations (powders and granules) which are used in the process of mixing and loading will be considered separately. Mixing and loading may be done indoors or outdoors.
From the data bases finally obtained, conclusions can be drawn which are considered to be relevant for surrogate exposures to be used in a first step in risk assessment for registration procedures.

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 several variables that may affect the dermal and inhalation exposure under field conditions. First of all, one should consider the methods for obtaining exposure values as well as the sampling strategy. The analytical chemical data should be 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 type of formulation, type of package and working methods need to be presented, as well as data on the amounts of pesticide handled. Thirdly, data are required on agricultural conditions, *i.e.* techniques and working methods, and on climatic conditions such as temperature and wind conditions.

In the present study the publications will be considered according to the physical nature of the formulations, *i.e.* powders, granules and liquids (see [1]). A further differentiation was intended to be made with regard to the actual surroundings, *e.g.* indoors and outdoors, but this has not been possible since almost all published exposure data were collected outdoors. The data on closed transfer systems will not be discussed separately, since the number of publications is very small and the data may not be relevant here, due to lack of use in the present agricultural practice in The Netherlands.
In The Netherlands mixing and loading is generally done by the applicator. This means that the operations related to mixing and loading will only take a relatively small part of the day. It has been estimated by a group of agricultural experts (data not shown) that for general use in registration procedures the duration of mixing and loading may be taken as one hour per day unless specific knowledge is available which indicates a different duration. For this reason exposure data will be presented for one hour of mixing and loading.
The data on exposure during mixing and loading will be considered separately for dermal and inhalation exposure. It should be noted that especially with relatively high dermal exposure oral absorption of pesticides can be expected, due to secondary ingestion. Under dusty conditions this may also be true for inhaled particles. The total amount absorbed into the body may be measured

using biological monitoring. For reasons already given [1], results of biological monitoring are not suitable for the present purpose.
Studies that consider exposure during mixing, loading and application of pesticides in a single sample will not be reviewed. These data may be very relevant for the actual work conditions, especially for work in enclosed spaces, such as greenhouses, where only relatively small amounts of pesticides are handled, but they cannot be dissected for the present review.

The collection of data from different sources leads to the statistical problem that these data cannot be considered as a homogenous 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 pertaining 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 figure 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 exposures levels are not very likely to occur under field conditions in normal practice, *i.e.* in the absence of calamities, (see also [1]).

3 RESULTS AND DISCUSSION

In total about thirty-five references have been found that present original exposure data [2-40] (*for easy reference these papers have been listed in chronological and alphabetical order*). These references will be reviewed, considering the different aspects mentioned in chapter 2. The actual data on inhalation and dermal exposure will be presented in graphs, in order to present an overview. The data will be presented in amount of formulated product per unit of time (mg/h). The dermal exposure data will be presented as given by the authors as potential (total body, covered and uncovered skin) or as actual (uncovered skin) dermal exposure. The actual dermal exposure is generally defined as the exposure of hands, forearms, head, neck and "V" of the chest. When estimating actual exposure from data on potential exposure many authors in the literature assume that the 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 is measured and included in the data on actual exposure. Whether penetration of the clothing is significantly increasing the actual exposure, depends largely on the distribution of exposure over the body and the type of clothing. Further, it should be noted that due to 'pumping' of the clothing during movements, contaminated air may be sucked in through the openings in the clothing, which may lead to deposition of pesticide on the skin under the clothing [41].

3.1 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 amounts of liquid or solid aerosols (see [1] for some comments). Some overestimation may occur. The use of stationary air sampling is considered inadequate to assess personal exposure for the present goal. This means that data on inhalation exposure from some references [2, partly 3,4,10,11,38,40] will not be included in the present review. The data from Dubelman *et al.* [19] will be included, since the authors state that they tried to measure in the breathing zone of the workers. The inhalation data from Lavy *et al.* [13] will not be used because of inadequate presentation: no sampling time is given. The data from Kilgore *et al.* [26] cannot be used since the format is inadequate: the data are presented per unit of surface filter in the respirator pad. Van Emon *et al.* [29] have presented a single figure. This figure is not considered, since no details are given. The authors apparently did not aim at presenting occupational exposure data.
In the following papers [3,5-7,9,14-17,19-21,23-25,27,28,31,34,35,37,39] data are

presented that can be used in a data base for inhalation exposure. Only in part of these publications [3,5,9,14-17,19-21,23-25,27,28,31,34,39] data can be found that indicate exposure in amount of formulated product used per unit of time (*e.g.* mg/hr formulated product). The calculations that were necessary to obtain this format were done with the assumption that the exposure during mixing and loading can be completely expressed in the amount of undiluted formulated product, although some exposure will result from work with the diluted formulation when preparing a spray liquid. Furthermore, an average ventilation rate of 1.25 m^3/h is assumed for transformation of data from mg/m^3 to mg/h.
The data from Kangas *et al.* [9] are considered with the (likely) assumption that the formulation contains almost 100 % active ingredient. Stevens and Davis [15] state that exposure during mixing and loading may be affected by other work with the active ingredient in the vicinity. Therefore, data from this publication have not been included. The data for mixing and loading of liquid formulations [14,16,17,19,21,23-25,27,31] are presented in figure 1 and those for solid formulations [3,5,9,20,27,28,34,39] in figure 2.
It should be noted that Chester and Ward [25] state an undetectable inhalation exposure. Abbott *et al.* [31] have attempted to measure inhalation exposure, but found it to be not detectable. In a single case exposure during an application operation was found to be below 36 μg/h active ingredient (80 μg/h formulated product). This number is included in the figure as a measure for the not detectable amount during mixing and loading.
The data from exposure studies that could not be transformed to units of formulated product are summarized in figure 3 as mg active ingredient per hour. In neither of the three publications [6,7,35] data on liquid formulations and solid formulations are described separately.

In most papers the presentation of the analytical chemical aspects is 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. Possible exceptions are the analytical chemical data given in [16,17,19,25,30-33,39]. Details on the machinery which was loaded have been omitted in almost all published reports, neither are details given on type and size of package. Details on climatic conditions are given in a general way in most papers, but no relation is suggested or commented upon between inhalation exposure and *e.g.* wind speed. Nevertheless, data are not excluded from the data bases for these shortcomings alone.
It should be noted that almost all data have been have been collected in the USA. There is only one study available which was conducted in the United Kingdom [31], along with one study from The Netherlands [39].

It can be seen in figure 1 that for liquid formulations all observed exposures were below 100 μg/h of the formulated product. Although the data base presented in figure 1 cannot be analysed statistically without introducing various assumptions, such as weight factors for the various numbers, it seems quite straightforward to estimate that the 90-percentile for this data set amounts to about 20 μg/h.

For solid formulations (mainly wettable powders), the exposure data vary considerably more. The highest exposure is given by Wolfe *et al.* [5], an observation made already in 1967 and which pertains to a 1% dust. More recently (1990) high exposures have been observed in The Netherlands [39]. From the data it is concluded that an estimate of the 90-percentile will probably be around 15 mg/h. The data in figure 3, which could not be included in the data sets of figures 1 and 2, give no reason to amend the above conclusions on the figures for indicative 90-percentiles.

Exposure data that can be correlated to amounts of pesticide handled are only provided by a few studies [20,34], so any form of correction for the amount handled cannot be applied to the data in figures 1 and 2. The very small amount of pesticides handled (Fenske *et al.* [34], work in greenhouses) in comparison to those described by Everhart and Holt [20] may explain at least part of the differences between the data given in figure 2. Everhart and Holt [20] have observed values between 0.54 and 32.4 μg/kg. Fenske *et al.* [34] found values between 8.6 and 282 μg/kg. In view of the small number of papers, no further conclusions can be adhered to these observations.

The indicative 90-percentiles for exposure during handling of liquid or solid (powder) formulations can be compared with conclusions that other researchers have drawn from similar or other data bases. These data bases have been given [1] and pertain to the publications [42-48]. For convenience the relevant table in [1] is reproduced here.

As can be seen from the format of the data in table 1, a comparison is extremely difficult. The only data given for the formulated product are those from Turnbull *et al.* [45] and these authors have only given the range of the data. The very high upper limit of the inhalation exposure given pertains to an exposure study by Lloyd and Tweddle [4] which is not included in the present data set. The high exposure is probably due to the extremely high volatility of the compound under study, *i.e.* dimefox. This is a warning for careful use of data sets if volatile compounds are considered. Exposure to gases should not at all be considered in the present framework.

The 90-percentile for powders appears to be consistent with the data from the United Kingdom [43] and with the 90-percentile taken from data from Germany [44], if allowance is made for a reasonable amount of formulated product loaded per day (*e.g.* up to 50 kg active ingredient). The same is true for exposure during loading of liquid formulations. Unfortunately, the data on which the numbers are based have not been published. Comparison with the numbers taken from Batel and Hinz [42] can only be done for powder

Table 1 Data bases for exposure during mixing and loading

Dermal* exposure	Inhalation* exposure	Comments	Reference
		Outdoors (powders)	
Actual exposure			
15 (1-40) mg/h	0.03 mg/h (0.003-0.3)	mean (range) liquids and powders	[42]
considered 0	0.09 mg/kg	geometric mean	[44]
	0.44 mg/kg	90-percentile	[44]
10.6-624 mg/h f.	<0.22-12.5 mg/h f.	range	[45]
10-100 mg/h	no data	range liquids and powders	[46]
510 mg/h (39-3000)	no data	mean (range)	[47]
Potential exposure			
no data	<1 mg /oper.	75-percentile	[43]
5.8 (0.3-94.5) mg/day (7 h)	no data	median (range) liquids and powders	[48]
		Outdoors (liquids)	
Actual exposure			
15 (1-40) mg/h	0.03 mg/h (0.003-0.3)	mean (range) liquids and powders	[42]
considered 0	0.0005 mg/kg	geometric mean	[44]
	0.0014 mg/kg	90-percentile	[44]
0.70-615 mg/h f.	0.004-0.6 mg/h f.	range	[45]
10-100 mg/h	no data	range liquids and powders	[46]
7800 mg/h (27-32000)	no data	mean (range)	[47]
Potential exposure			
<1 ml /oper.	undetectable	75-percentile (10-20 l containers)	[43]
5.8 (0.3-94.5) mg/day (7 h)	no data	median (range) liquids and powders	[48]
		Indoors	
no data base available			

* active ingredient, unless stated otherwise;
oper. = handling of a single product pack;
f. = formulated product.

formulations. The 90-percentile of 15 mg/h formulation is most likely higher than the upper value of 0.3 mg/h active ingredient. The data base of Batel and Hinz [42] is not known (see [1]).

3.2 Dermal exposure

Dermal exposure can be measured in several ways [1]. As has been indicated before a distinction is made between potential exposure and actual exposure. Jegier has measured exposure of the hands by wrist pads [3]. This is considered an inadequate way and therefore the data will not be presented. For data from Soliman *et al.* [8] and Atallah *et al.* [17] it is assumed that daily exposure took place in about an hour of mixing and loading, according to Crome [43]. For the data from Abbott *et al.* [31] and Brouwer *et al.* [39] it is concluded from their descriptions that six mixing/loading operations can be carried out in an hour. Data from Lavy *et al.* [12] are not included in the data set, because data on mixing and loading and application are measured separately but not presented as such. The exposure data from Lavy *et al.* [13] are not useful, since the sampling time has not been given and the location of the pads on the body was not adequate. Imperfect sampling strategy may also have affected the data of Davies *et al.* [18]. Furthermore, these authors indicate that the observed exposure may be affected by contamination from other sources than mixing and loading. Kilgore *et al.* [26] have only sampled exposure of the chest and the back, since they were interested in penetration of clothing. The data from Van Emon *et al.* [29] have not been included for reasons already given in section 3.1. Data from [15,25,34] have not been considered for hand exposure, since measurements were done underneath protective gloves. These data may be very important for estimating exposure risks, but are not suitable for inclusion in a data set for the present goal. In three cases data are presented per unit of pad area, which cannot be transformed and thus have not been included [11,38,40]. Fenske [36] presented data as a ratio of exposure and amount of pesticide handled.
Dermal exposure data from [5,7,8,14-17,19-25,27,28,30-32,34,39] will be presented. The data from [5,8,14-17,19-25,27,28,30-32,34,39] are already expressed in amount of formulated product per unit time given or can be transformed to this unit of exposure. The exposure data on mixing and loading for liquid formulations [8,14,16,17,19,21-25,27,30-32] are given in figure 4 and for solid formulations [5,15,20,22,27,28,34,39] in figure 5. The exposure data that could not be transformed are given in figure 6. These data are taken from Cohen *et al.* [7]. Cowell *et al.* [33] presented data on a liquid formulation and on a micro-encapsulated formulation. The data cannot be separated from each other and are therefore also plotted in figure 6. For these data it is assumed from the description that four mixing/loading operations can be done in one hour.
From the data on liquid formulations in figure 4 it is obvious that a large

range of levels of exposure has been observed. The highest levels are given by Wojeck *et al.* [16] and Abbott *et al.* [31]. Especially the data in [16] are considered high, since they reflect exposure of the hands only (according to the authors about 75% of the total exposure), whereas in [31] the potential exposure of the whole body has been measured. A possible explanation for these high values is the fact that for the estimation of exposure of the hands gloves were used. It may well be that for assessing exposure of the hands to liquids the use of gloves is inappropriate since they may act as a sponge. This notion is mentioned by many authors in reviews of monitoring techniques, but it has not been studied in detail. From an indicative comparison of the papers considered in figure 4 it is clear that the high levels of hand exposure have been observed in studies in which gloves were used [16,23,31] as compared with the studies in which hand washings were used [17,22,24,30]. For these reasons, data on exposure by using glove monitoring will not be considered for the estimation of the indicative 90-percentile.
Wojeck *et al.* [16] noted considerable differences in exposure among individuals. They give no explanation but mention the possibility of effects of wind direction, temperature and relative humidity. Data on these environmental conditions are not presented, however, neither are data on the amount of formulated product handled.
On the lower side of the exposure range the papers [17,30] are to be noted. In both exposure of the hands is very low in comparison to exposure of the body. The exposure of the hands was measured by washing. Atallah *et al.* [17] mention that the washing liquid was poured over the hands. No data are presented on the efficiency of this procedure. Nigg *et al.* [30] describe also that the exposure of the hand was determined by a rinsing procedure, which is not further specified. Possibly, these methods are not effective for removing the pesticides under consideration completely from the hands.
From the data in figure 4, an indicative 90-percentile can be deduced of about 2 g/h formulated liquid product for all data and about 300 mg/h for the accepted data (glove monitoring not included).
The data on solid formulations in figure 5 show a relatively small range, excepting the data of Fenske *et al.* [34] at the lower size and those of Brouwer *et al.* [39] at the higher side. The data in [34] were obtained for handling a very small amount of active ingredient (<1 kg) and may therefore be very low. This suggests the necessity to treat mixing and loading of relative small amounts of active ingredient (*e.g.* in greenhouses) separately. The exposure data in [39] are relatively high, even when corrected for the amount of pesticide handled. From the data in figure 5 an indicative 90-percentile can be deduced of about 2 g/h.

General remarks on the presentation of relevant analytical chemical and agricultural aspects have already been made in 3.1.1 and will not be repeated here. The same holds for the origin of the exposure data : mainly from the

USA and only two from Europe ([31,39]).
The indicative 90-percentiles for dermal exposure may be compared with data presented in table 1. Such a comparison is difficult due to differences in the format of the data. For exposure to solids, only the data from Reinert and Severn [47] are higher, even much higher; all other data bases indicate a somewhat lower exposure. For the case of liquids, the same conclusion can be reached.

In a few papers [14,20,32,34,36] data on dermal exposure are presented as a ratio to the amount of pesticide handled. According to Miller *et al.* [14] these data vary between 0.2 and 17.5 μg/kg, Everhart and Holt [20] found 0.71 to 7.97 mg/kg, Chester *et al.* [32] 0.07 to 0.27 mg/kg and the data presented by Fenske *et al.* [34] amounted to on average of 1.18 mg/kg. In another study Fenske [36] observed an average dermal exposure of 0.31 mg/kg during mixing and loading. As can be seen the values vary considerably between the various reports. This is partly due to the type of formulation handled (solid or liquid) and the method of exposure assessment. No further conclusions can be drawn from these data in the context of the present goal.

3.3 Distribution of dermal exposure over the body

The indicative 90-percentiles for dermal exposure pertain to potential exposure and it is therefore important to consider the distribution over the body. It has been mentioned before that for risk assessment it is necessary to use data on the level of actual exposure of the skin. This amount will depend largely on the use of protective clothing such as impermeable gloves, although personal hygiene is also very important in this respect. A major factor is the use of clean protective garments and their proper use, *e.g.* use of gloves throughout the mixing and loading operations. It has been shown by Nigg *et al.* [30] that (improper) use of impermeable gloves during mixing and loading may lead to higher exposure of the hands than working without gloves.
Data from the literature on the distribution of dermal exposure are presented in table 2. Data obtained in studies where protective gloves were used and exposure was measured underneath the gloves have been omitted since this procedure may affect the distribution considerably.
As can be seen in table 2, exposure of the hands may vary considerably. Especially Knarr *et al.* [27] and Nigg *et al.* [30] observed relatively low levels of exposure. This has been noted by the authors, but no easy explanation can be offered. In reviews, it is generally stated that hand exposure is important. Franklin [49] states that it is in general much higher than 50 % of the total exposure. According to the analyses of the British data base [43] dermal exposure during mixing and loading is virtually confined to the hands. The skin exposure is considered to be completely prevented by the proper use of protective gloves by the German data base [44]. Maddy *et al.* [48] show that

Table 2 Distribution of exposure over the body (percentage of total exposure)

Arms (a) hands (h)	Body (b) head (h)	Legs	Comments formulation	Reference
76 (h) 3 (a)	11 (b) 1 (h)	10	liquid (hw)	[16]
hands and trunk highest			no data liquid (hw)	[17]
> 99	1		liquid (g)	[19]
> 95			powder (hw)	[20]
76			powder/liquid (hw)	[22]
57 (h) 10 (a)	1	41	liquid (g)	[23]
20 (h) 4 (a)	5 (b) 5 (h)	65	liquid (hw)	[27]
8 (a) 2 (h)	9 (b) 5 (h)	76	granules (hw)	[27]
2	--------- 98 ---------		liquid (g)	[30]
76-94			liquid (g)	[31]
27 (h) 9 (a)	34 (b) 2 (h)	29	liquid (g)	[51]

(hw) : exposure of the hands measured with washings
(g) : exposure of the hands measured with gloves

even when using protective gloves, in practice exposure of the hands is on average 40 % of the total dermal exposure.
According to Fenske [50], who used the video-imaging technique (see [1]),

exposure of the hands of mixers was 42 % of the total despite the use of chemical-resistant gloves and 37 % of the exposure of the skin was found underneath a protective coverall. Chester and Hart [51] showed that for potential dermal exposure the trunk, the legs and the hands are the most exposed parts of the body.

It may be concluded that in most cases exposure of the hands will constitute the largest part of the potential dermal exposure. For the present state of the art it seems reasonable to consider the use of normal clothing as providing such a degree of protection of the trunk, that the actual dermal exposure during mixing and loading is 50 % or more of the potential dermal exposure. For risk assessment of current practices in The Netherlands (in general no proper use of impermeable gloves) this is a sufficient proposition for registration procedures. It should be noted that proper use of protective gloves will prevent contamination of the skin to a large extent. A quantificati- of this extent cannot be given on the basis of the data presented in this review.

4 USE OF SURROGATE EXPOSURE DATA FOR REGISTRATION PROCEDURES

For registration procedures, data on potential exposure must be transformed to actual exposure and subsequently to uptake into the body. The result must be compared with toxicological data. This is a difficult process. It requires as much specific knowledge about the compound and its use in practice as can be obtained.

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 section 3.1 on inhalation exposure is relatively simple and straightforward, using available knowledge on the percentage active ingredient in the formulation. 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 mixing and loading processes 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 to lower the exposure with regard to aspects of formulation, packaging, mixing/loading techniques, personal hygiene and finally, use of specific protective measures.
If no inhalation 'no-effect' level is available, the oral 'no-effect' level may be considered for comparison, using data on differences in percentages of oral and inhalation absorption (the latter taken as 100 %, if no data are available) and data on possible differences in toxicokinetics for these different routes of exposure.

For dermal exposure the situation is more complex. First of all, the actual exposure has to be estimated from the potential exposure. In practice this means for mixing and loading with unprotected hands that the actual exposure is generally between 50 and 100 % of the potential exposure. From here, the analysis is straightforward unless a dermal 'no-effect' level (mainly for hands and forearms) is not available. In this case a strategy may be followed as is indicated above for inhalation. This will always mean that data are required on dermal penetration. If these data are not available, it may be assumed, for safety reasons, that the amount of the compound under consideration which is deposited on the skin will be completely absorbed. For most compounds complete absorption is unlikely to happen in practice, especially for the amounts (two grams) given as indicative 90-percentiles. In the British and German procedures [43,44] an absorption of 10 % is used in the calculations if no data are available indicating higher or lower dermal absorption. 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

It has been shown that exposure varies to a large extent between different situations. Possible reasons for this variation are differences in formulations, equipment, weather conditions, working methods, personal hygiene and in the amounts of product that are handled. The specific effects of several of these factors are unknown, but it is assumed that the available data bases constructed from data in the literature, which will increase further in the future, are at present already large enough to include the most important consequences of these factors. With this assumption in mind it seems possible to extract some surrogate exposure data from these data bases for risk assessment in registration procedures. Nevertheless, one should be very careful in using these data, since not all effects of varying conditions on exposure are known. This is a major reason for using indicative 90-percentiles in a first step in risk assessment. On the basis of specific knowledge about a formulation of a pesticide and the conditions it may be possible to use other figures. This may be important for instance when relatively small amounts of formulations will be handled. Other data bases, constructed from unpublished exposure data, should also be used to increase the validity of the surrogate exposure to be used in risk assessment for registration.

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, and generally not on exposure to vapours and gases.

It should be noted that relatively high levels of dermal exposure appear to occur with liquid formulations. This is in contrast with inhalation exposure, where exposure to solids (powders and dusts) is much higher than exposure to liquids. It is not certain, however, whether the estimated level of dermal exposure to liquids is affected by the technique of monitoring the hands. It is suggested that the use of gloves may overestimate the level of exposure to liquids.

The relation between the amount of active ingredient or formulation handled and the level of exposure during application is stressed by Batel (see [1]) and Reinert and Severn [47]. It has been observed for mixing and loading in the British and German data bases [43,44] 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 stress this aspect. Since exposure data for application in greenhouses are generally collected together with exposure during mixing and loading, this may, nevertheless, be a pragmatic reason not to use the present indicative 90-percentiles for exposure due to mixing and loading for the case of greenhouses or other situations where amounts below, say, one or two kg of active ingredient are used.

6 LITERATURE

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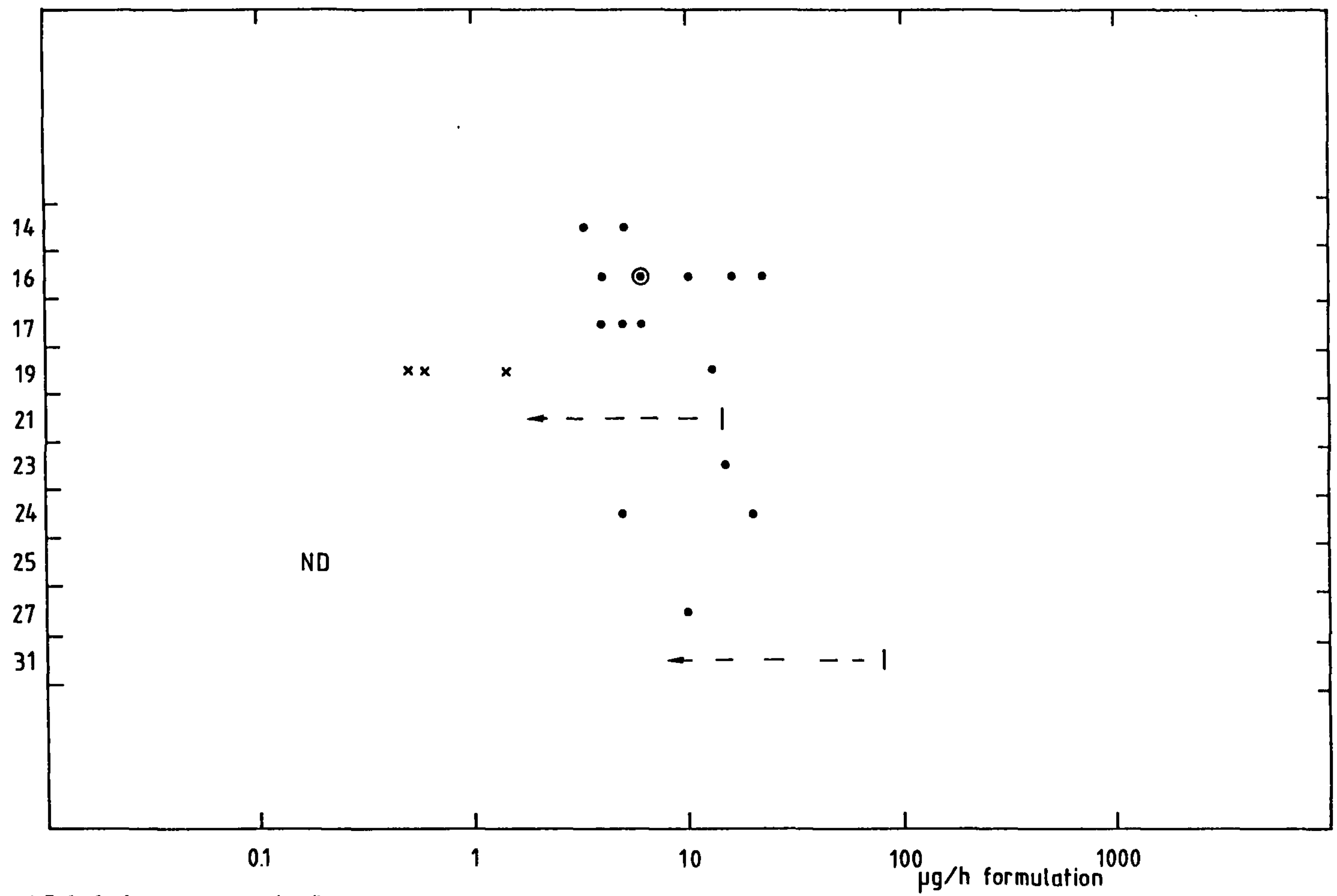

Figure 1 Inhalation exposure (μg/h formulated product) to liquid pesticide formulations during mixing and loading. References are given by numbers at left-hand side.
x: closed transfer system; ND: no detectable exposure; | : upper range; arrow indicates from highest observed exposure downwards.

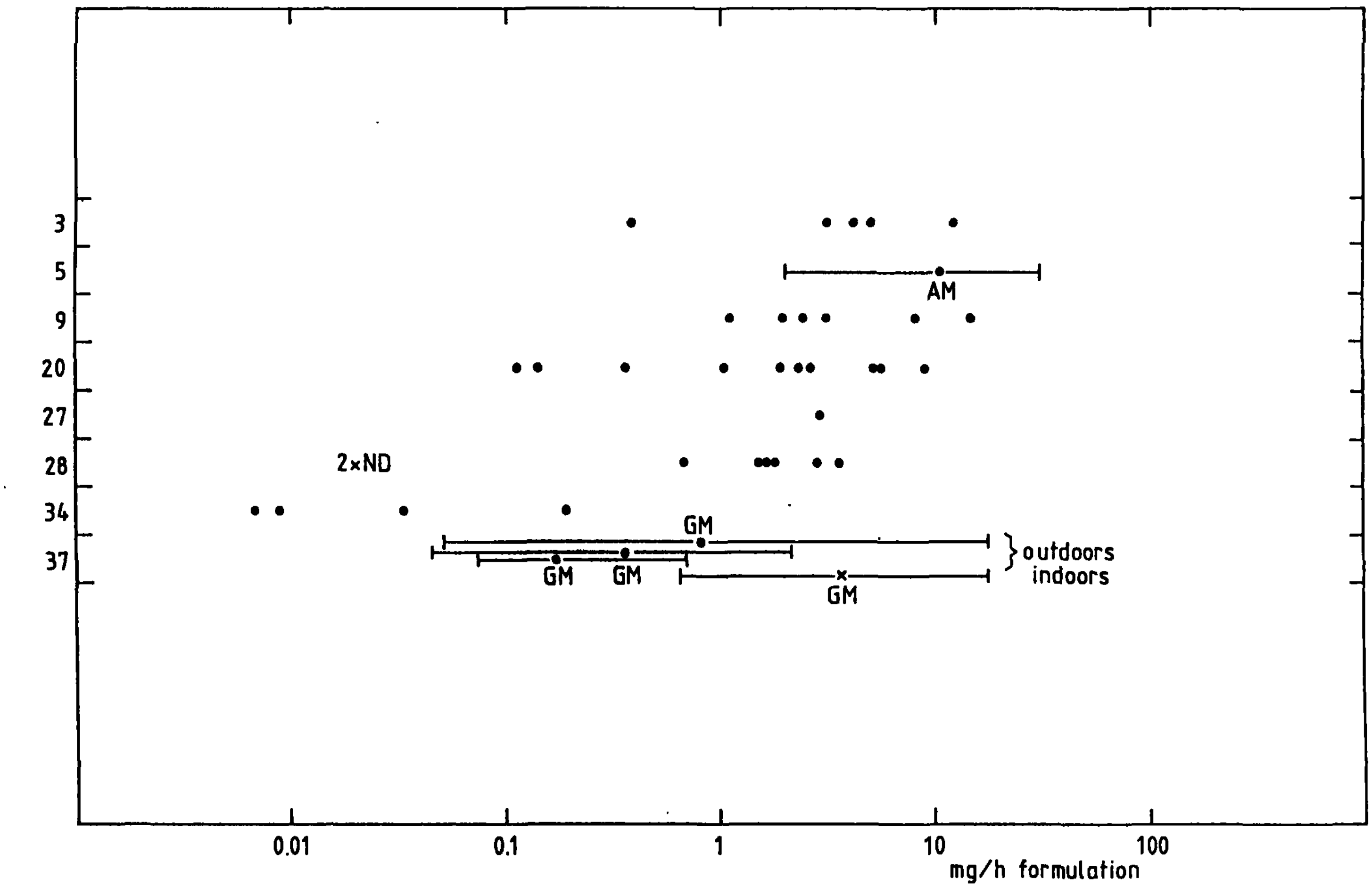

Figure 2 Inhalation exposure (mg/h formulated product) to solid pesticide formulations during mixing and loading. References are given by numbers at left-hand side.
AM : arithmetic mean; GM : geometric mean; ND : no detectable exposure; x : mixing indoors; | | : range.

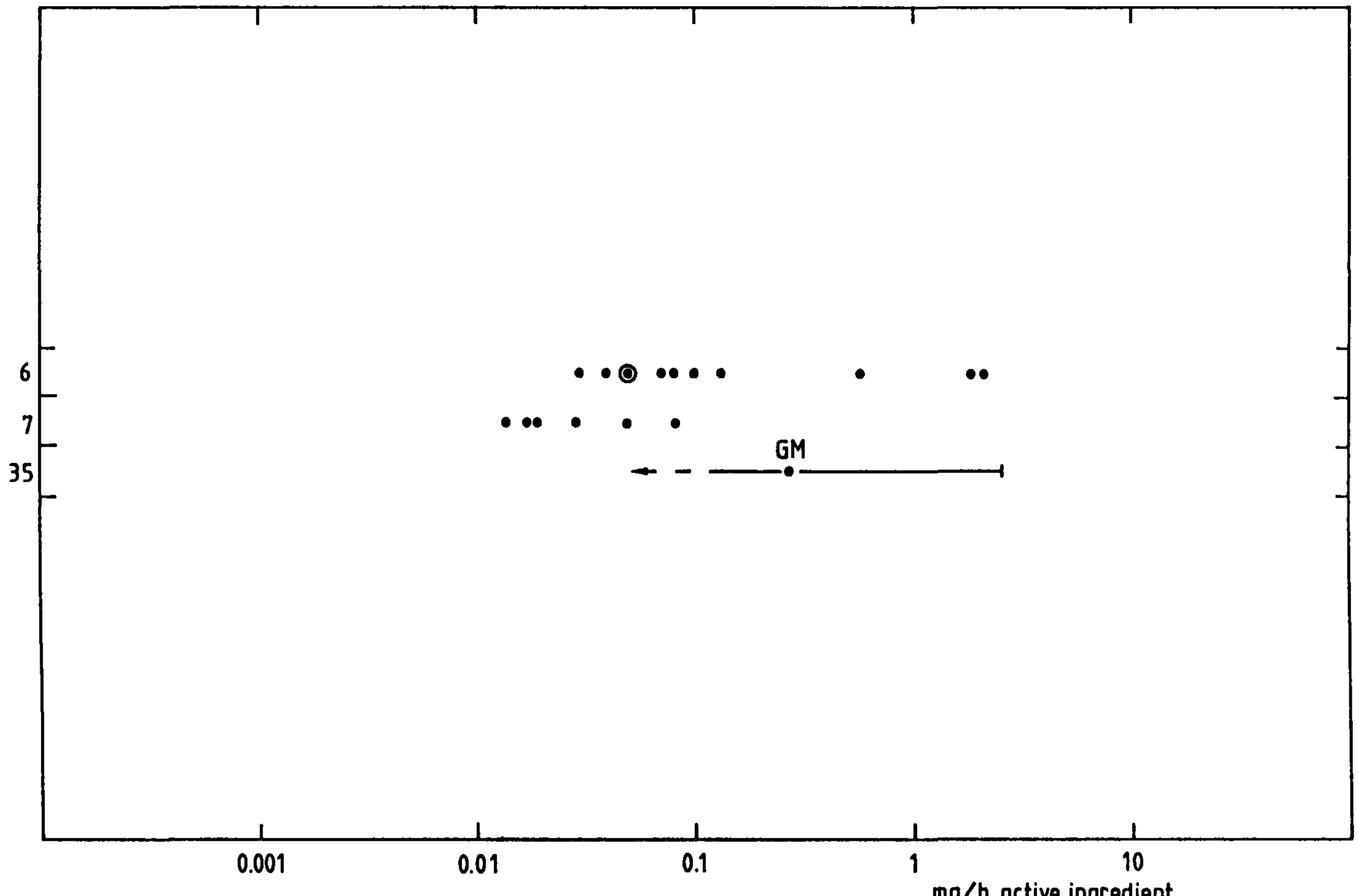

Figure 3 Inhalation exposure (mg/h active ingredient) during mixing and loading. References are given by numbers at left-hand side.
GM : geometric mean; | : upper range. Arrow indicates from highest observed exposure downwards..

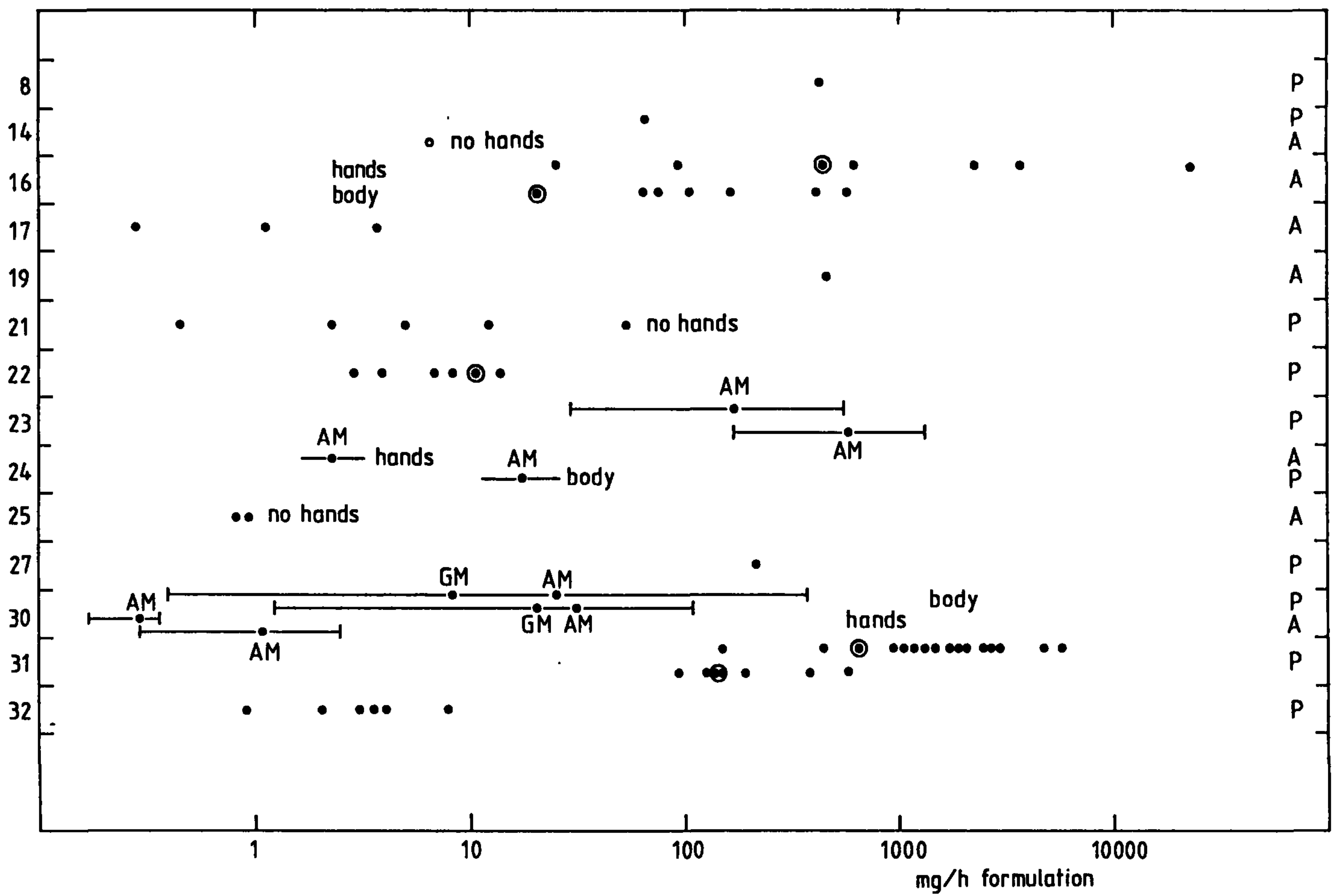

Figure 4 Dermal exposure (mg/h formulated product) to liquid pesticide formulations during mixing and loading. References are given by numbers at left-hand side.
P: potential exposure; A: actual exposure; AM: arithmetic mean; GM: geometric mean; | | : range; ——.—— : arithmetic standard deviation.

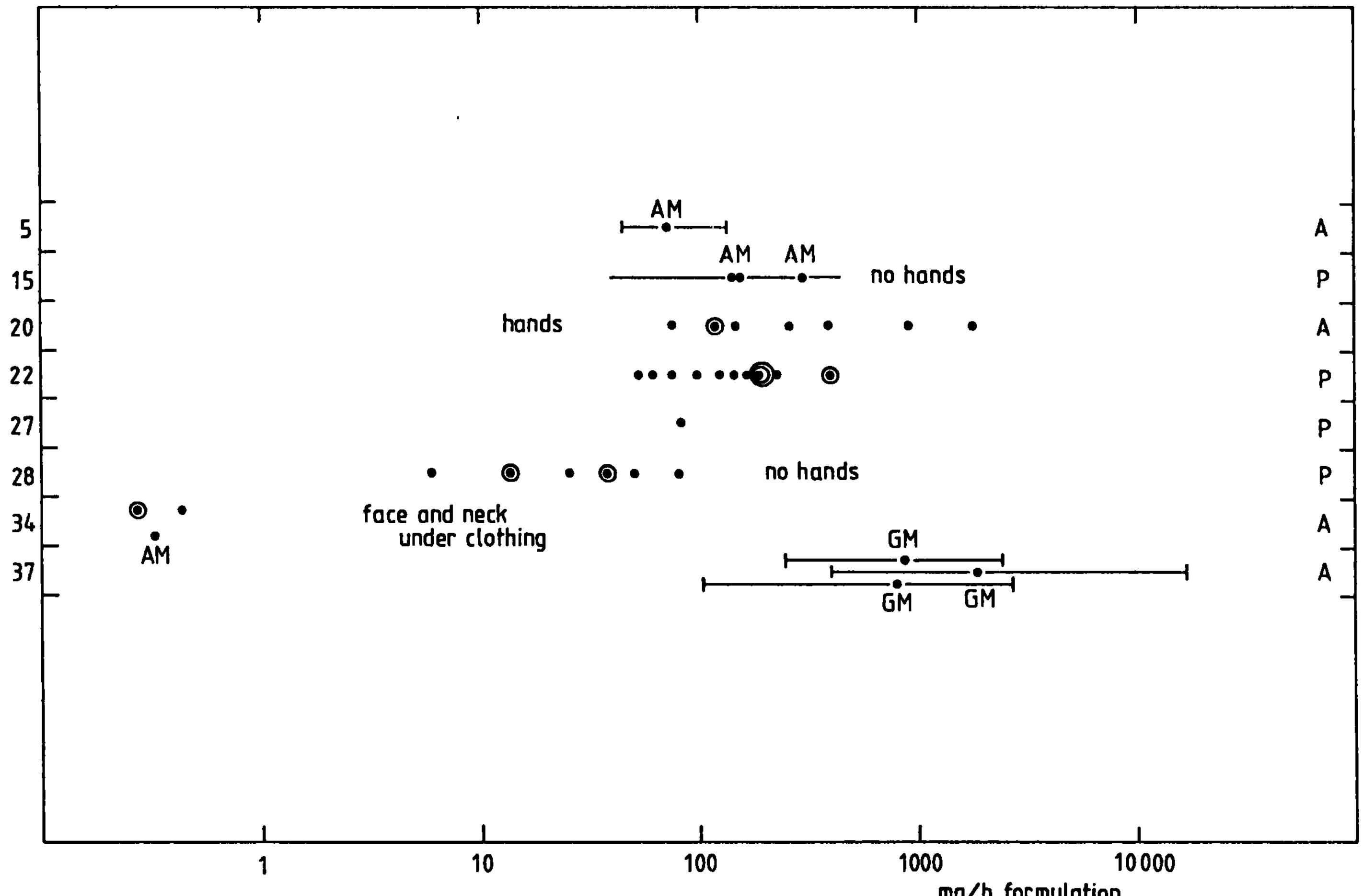

Figure. 5 Dermal exposure (mg/h formulated product) to solid pesticide formulations during mixing and loading. References are given by numbers at left-hand side.
P: potential exposure; A: actual exposure; AM: arithmetic mean; GM: geometric mean; | | : range; ——.—— : arithmetic standard deviation.

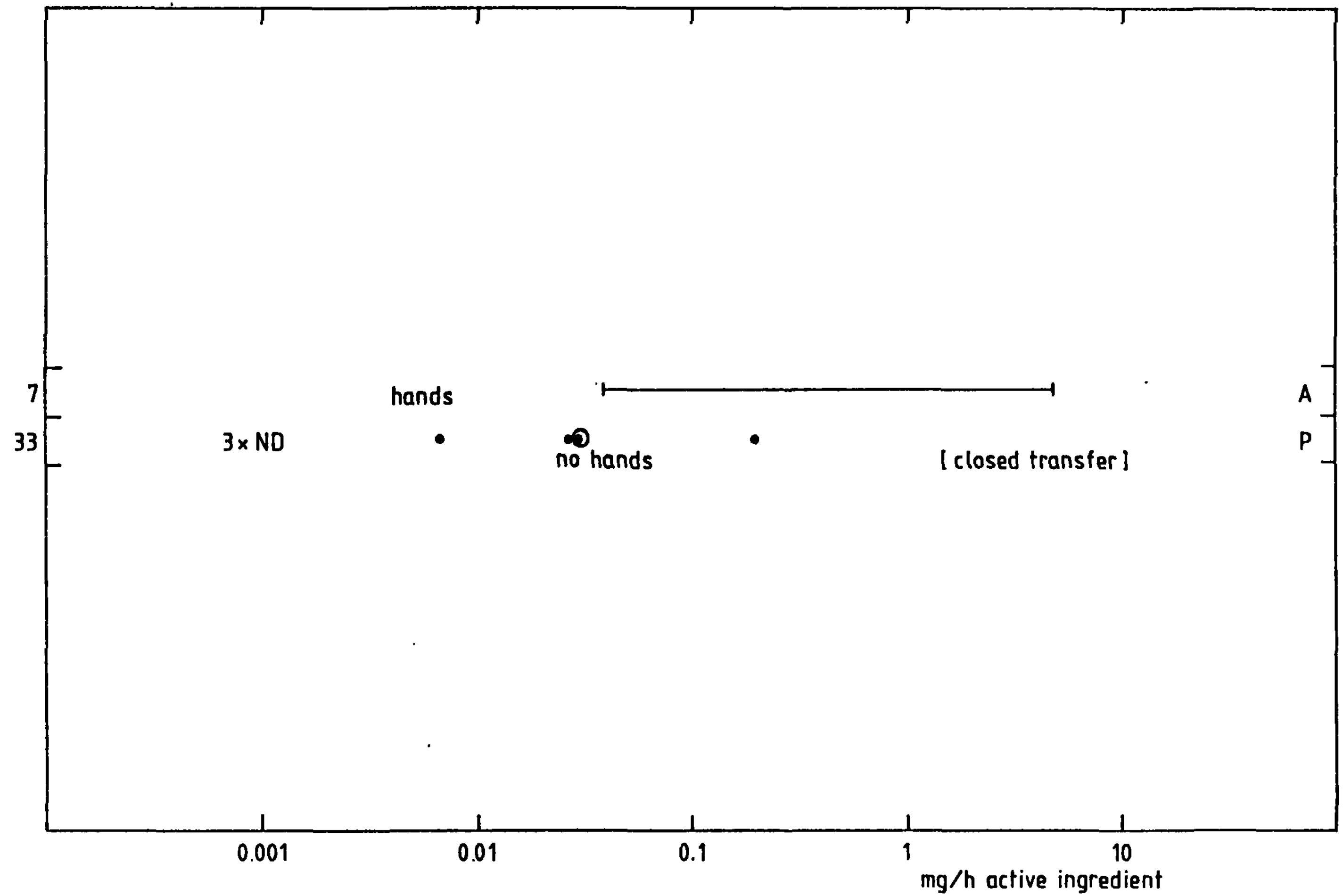

Figure 6 Dermal exposure (mg/h active ingredient) during mixing and loading. References are given at left-hand side. P : potential exposure; A : actual exposure; ND : no detectable exposure; | | : range.