

**GUIDANCE FOR THE PREPARATION OF HUMAN PESTICIDE EXPOSURE
ASSESSMENT DOCUMENTS**

by

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GUIDANCE FOR THE PREPARATION OF HUMAN PESTICIDE EXPOSURE ASSESSMENT DOCUMENTS

PURPOSE OF THE GUIDANCE

The human exposure assessment document contains essential information for the risk assessment process. Guidance for the preparation of this document was developed as an aid, particularly to new authors. It also provides some default values for the exposure assessment, including surface areas, body weights, ventilation rates, and clothing protection factors. The guidance should provide consistency in the format and contents of major subject areas needed for the exposure assessment process.

Exposure data together with some information, such as, dermal and inhalation absorption and time of work/employment, are used to estimate absorbed dosages for pesticide handlers (including mixer/loaders, applicators, flaggers, and maintenance workers), field workers (including harvesters, tree and fruit thinners, packers, and pest scouts), and home gardeners. These data are then used for the estimation of margins of safety and/or oncogenic risks. Other information, such as physical and chemical properties, usage, illness and injury data, dislodgeable foliar residues, and metabolism in animals (especially humans) are also necessary and are included.

After the risk has been estimated, mitigation measures may be required if exposure to a chemical is found to cause excessive risks. Thus, levels of exposure may be reduced to minimize risks. Engineering controls and/or protective clothing or equipment may be recommended in addition to requirements on the product label. Information from the exposure assessment, such as exposure of each body region, types of protection used in the study or residue dissipation data, may be used as a basis for developing mitigation measures.

The contents of a human exposure assessment document are listed below. In the following example, the exposure assessment document begins with a cover page (without page number) which includes an abstract. The following page is numbered page 2 and so forth. Suggested details of each section are listed as guidance. This guidance will be periodically updated if new information warrants changes.

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ESTIMATION OF EXPOSURE OF PERSONS IN CALIFORNIA
TO PESTICIDE PRODUCTS THAT CONTAIN (common name)

By

(Author, position)

(HS-No....Date....)

(Revised Date....)

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ABSTRACT

This report was prepared as part of the Department's risk characterization document for (common name of the pesticide).

(Includes a statement on toxicological concerns or adverse health effect(s) driving the risk assessment. Summary of worker illnesses/injuries, pertinent metabolic data, percent dermal absorption, worker exposure estimates, etc.)

HUMAN PESTICIDE EXPOSURE ASSESSMENT

California Environmental Protection Agency
Department of Pesticide Regulation
Worker Health and Safety Branch

(COMMON NAME OF PESTICIDE)

(Date.....)
(Revised Date.....)

INTRODUCTION

(An introduction is needed to inform the readers of the background and purpose of the exposure assessment document. The author(s) may use the following suggested information at their own discretion.)

Human exposure assessment is essential information for the risk assessment of pesticides (CDFA, 1987). This document will be an integral part of the Risk Characterization Document of the Department of Pesticide Regulation (DPR). It will also be used as the starting point for developing mitigation measures if exposure to this pesticide(s) is found to cause excessive risk.

Details related to the chemical under review are necessary for a better understanding of the nature, usage, and effects. These additional categories are: physical and chemical properties, U.S. Environmental Protection Agency (U.S. EPA) and California status, formulations, usage, label precautions, worker illnesses and injuries, dermal irritation/sensitization, animal metabolism, dermal and inhalation absorption, and dislodgeable foliar residues.

Worker exposure estimates may be derived directly from patches or other passive dosimeters. Biological monitoring can also be used when the pharmacokinetic profile of a pesticide is well understood. Exposure of field workers who come in contact with foliage may be estimated from dislodgeable foliar residues (DFR) with an appropriate transfer factor (TF). Inhalation exposure will be added to dermal exposure estimates to come up with absorbed daily dosage (ADD) and for subsequent calculations, such as annual average daily dosage (AADD) and/or lifetime average daily dosage (LADD).

(Note: Details in each of the following sections are suggested as a guide. Additional information if considered necessary is encouraged.)

PHYSICAL AND CHEMICAL PROPERTIES

1. Common name, empirical formula, molecular weight.
2. Physical and chemical characteristics: physical appearance, solubility in water/solvents, volatility (VP, mm Hg), stability in water/environment.

U.S. EPA AND CALIFORNIA STATUS

Status of the current registration or reregistration, reasons for special review or reevaluation, status report in the "U.S. EPA Position Document".

FORMULATIONS

Types and numbers of formulations of products registered in California for commercial or home/garden uses. (If there are inerts of concern, a report in a separate memo may be needed). Inert ingredients will not be disclosed in this document, unless they appear on the label.

USAGE

When was active ingredient (a.i.) first registered in California? Where is major use? Use going up or down? Use confined to one area of State? Information on the amount of a.i. used and sold in California from the latest available statistics. Label application rates (maximum and ranges) in major crops and home/garden uses of available formulations.

LABEL PRECAUTIONS

Identify the "Toxicity Category" of the product(s) for eye, dermal, oral, inhalation, brief precautionary statements including any requirements for protective clothing, equipment, or engineering controls.

WORKER ILLNESSES AND INJURIES

Records on worker illnesses summarized from the Worker Health and Safety Branch Pesticide Illness Surveillance Program (PISP) reports (the most five recent years). Give numbers of cases for each type of illness (excluding unlikely cases). Provide a tabulation of all illnesses with narrative description typically recorded in PISP giving details of exposure scenario and illness symptoms. If >20 cases, provide pertinent examples. For the purpose of this exposure assessment document, information on violation issues should not be included.

DERMAL IRRITATION/SENSITIZATION

Include the following information: information on skin irritation, dermatitis, or hypersensitivity (sensitization) as observed in experimental animals related to dose and skin irritation or dermatitis observed in humans. See U.S. EPA (1984) for general guidelines for the study.

ANIMAL METABOLISM

Include the following information: kinds of animals, numbers per dose, route of administration, carriers or vehicles for test materials, exposure period for dermal administration, formulation of chemical, radiolabeled information, collection and handling of samples, methods for identification or characterization of metabolites, kinds of major metabolites (show metabolic flow scheme), percent of major metabolites in tissue and excreta, the possibility of using major metabolites in urine as a means for biological monitoring in worker exposure study, and toxicity of metabolites. Provide your best estimate of oral bioavailability and document reasoning.

DERMAL AND INHALATION ABSORPTION

Dermal absorption rate is important in determining the availability of the dermal dose to produce biochemical or physiological effects in humans. The general guidelines for dermal absorption studies were written by Zendzian (1987, 1989). A proposal to revise the existing guidelines was also initiated (Zendzian, 1991; FR, 1991). Human dermal absorption data are preferable to animal data when available.

Dermal absorption

1. Animals: species, age, weight, handling of the animals, preparation of the application sites, size of application area, number of animals used per dose, treatment of animals during and after the administration of the chemical.
2. Doses of chemical: formulation and preparation of dosing solution (a.i. + formulation blank should be used), unlabeled or labeled compound, purity, method of application, range of doses, calculate dermal doses per unit area of skin (e.g., $\mu\text{g}/\text{cm}^2$). Acceptable dose levels should be close to actual worker exposure estimates. Suggested dosages for a dermal absorption study are 1-6, 10-25, and 50-100 $\mu\text{g}/\text{cm}^2$.
3. Exposure period: exposure time of chemical on the animal skin before being wiped or washed off. Suggested exposure time is 4 hours (for sacrifice time of 4 hours) and 10 hours (for sacrifice times of 10 hours or longer).
4. Methods of washing: methods of washing or wiping chemical off the surface of the skin after exposure, frequency of washing, types of materials used, samples collected and storage conditions. (Three to five cycles of washings or wipings with soap solution (2-4% liquid Ivory soap or equivalent) and distilled water is suggested).
5. Collection of samples: indicate time of collection after exposure, types of samples collected, treatment or storage of samples, frequency of collection. (Suggested sacrifice times are 4, 10, 24, and 96-168 hours or longer).
6. Analytical methods: methods used in the preparation of samples and methods of analysis, problems in analysis, mass-balance accountability.
7. Comparison of methods of study to that of Zendzian's: overall evaluation for the acceptability of the study, indicate any unusual circumstances or unacceptable methods.
8. Determination of dermal or percutaneous absorption: the general mass balance rule is normally used to determine dermal absorption of the chemical:

$$\% \text{ Dermal absorption} = \frac{\text{Applied dose} - \text{Unabsorbed dose}}{\text{Applied dose}} \times 100$$

or

Percent dermal absorption = percent sum of dose in excreta (urine, feces, cage washes), expired air, treated skin (or bound skin residues), blood and carcass. Percent dermal absorption is then corrected for dose lost during the study. Percent dose in urine, feces and treated skin in the calculation may be replaced by percent dose from best asymptotic plots

of the urine and fecal excretion. This can be done if excreta is collected at 24-h intervals for 4-7 days or longer after administration of the dose. These data are then used for asymptotic plots. Percent dermal absorption is the sum of percent dose at asymptote and percent dose recovered in carcass, blood and cage washes.

or

In some cases, a combination of intravenous (IV) and topical administration can be done in monkeys or humans. Dermal absorption is derived according to Feldmann and Maibach (1974) or Wester and Maibach (1985) as follows:

$$\% \text{ Dermal absorption} = \frac{(\text{Topical}) \text{ }^{14}\text{C in urine}^*}{(\text{IV}) \text{ }^{14}\text{C in urine}^*} \times 100$$

* If the majority of ^{14}C is excreted in urine.

Registrant should be informed if the results of the dermal absorption study are not acceptable and a new study is needed. A default dermal absorption of 100% will be applied if dermal absorption data are not available.

***In vitro* dermal absorption**

Occasionally, *in vitro* absorption studies using isolated human epidermal membranes are submitted. This is done under the contention that dermal absorption in rats or other animals is higher than that in humans (Allsup and Hubbell, 1983; Bartek and LaBudde, 1975; Grissom *et al.*, 1987; Maibach and Wester, 1989; Shah *et al.*, 1981; Yi-Lan, 1981; Wester *et al.*, 1989). It has also been shown that *in vitro* rat skin permeability is generally higher than that in human skin (Bronaugh *et al.*, 1982; Scott, 1989).

In light of some uncertainties and limited validation studies regarding the use of *in vitro* absorption of epidermal membranes in place of *in vivo* dermal absorption studies (Franklin, 1989; Zenzian, 1991), an equation indicated below has been used to derive *in vivo* human dermal absorption (Fong, 1989; Thongsinthusak, 1991). However, an *in vivo* validation study using humans or monkeys is needed.

$$\frac{\text{Rats}}{\text{Humans}} \frac{\text{Absorption rate}^a}{\text{Absorption rate}^b} = \frac{\text{Dermal absorption}^c}{\text{Dermal absorption}^d}$$

a,b,c are values obtained from the studies. *In vivo* dermal absorption in humans (d) is an unknown to be derived from the relationship of the known values.

At present, *in vitro* absorption results can not be used alone as an alternative to *in vivo* dermal absorption.

Inhalation absorption

The default inhalation absorption of vapor is 50% uptake (Raabe, 1988) and 100% absorption of chemical being retained in the lung tissue. Particulate <10 microns are

assumed to be 50% retained and particles larger than 30 microns are generally unavailable (Menzel and Amdur, 1986).

DISLODGEABLE FOLIAR RESIDUES

Elaborate on conditions observed in the dislodgeable foliar residue study (including application rates, sampling time post application, sample handling (kept on ice or dry ice), a brief summary of extraction method, field spiked recovery, correction for recovery) and report of unusual weather conditions, such as rain after application or strong winds during or after application. Guidelines outlined by U.S. EPA (1984a) and that from the work of Gunther *et al.* (1973) and Iwata *et al.* (1977) should be considered for the determination of acceptability of the study.

Residue dissipation rate: determine the dissipation rate or half-life of residue over time (also, point out the residue at legal harvest interval and earliest allowed reentry).

WORKER EXPOSURE

Worker exposure estimates are basically derived from worker exposure data submitted by the registrants. When studies or suitable exposure data for major uses are not available from the registrants, data generated by the Worker Health and Safety Branch, published literature or reports may be used at the discretion of the authors. However, if the acceptable studies are available from both the registrant and other sources, the exposure data submitted by the registrant has the priority to be used in the exposure assessment document. If exposure data is not available for any pesticide under evaluation, the author may use appropriate surrogate data (a.i. with similar formulation, physical and chemical properties and application rate and application method).

Acceptability of the worker exposure estimates should be carefully considered in regard to standards for study conduct. The U.S. EPA Subdivision U, Pesticide Assessment Guidelines for Applicators (U.S. EPA, 1987) or the U.S. EPA Subdivision K, Pesticide Assessment Guidelines for Reentry Exposure (U.S. EPA, 1984a) should be considered. As a matter of policy, some exposure studies involving human subjects conducted in California may be reviewed by the Worker Health and Safety Branch and approved by the Human Subject Committee (Krieger and Ross, 1991). In all cases, Good Laboratory Practices must be observed for all studies whenever applicable.

For consistency, the exposure terminology used should follow guidance by Thongsinthusak and Krieger (1993); the flow diagram for exposure assessment is reproduced in Figure 1. Some terms should be carefully used, especially **potential dermal** and **dermal exposure**. The definition of these two terms are as follows:

Potential dermal exposure: Total pesticide intercepted or from conversion of dislodgeable foliar residue using potential TF. It is assumed that there is no protection to workers; that is, potential dermal exposure is the exposure that would be experienced by naked persons.

Dermal exposure: Deposit of pesticide residues on the skin of workers wearing work clothing or protective equipment. Exposure to unclothed areas like head (including face), neck (including "V" of the neck), if there is no protection, is considered to be dermal exposure.

From past experience, characterizing potential dermal exposure to the workers according to route and body areas is very helpful in developing mitigation measures. Without this itemization, recalculation of the original data is unavoidable and is time consuming. Detailed information presented below for worker exposure is considered essential for this document. Therefore, exposure estimates should be elaborated in the text as follows:

Exposure according to the body regions:

1. **Head+Face+Neck** (including "V" of the neck). These areas are generally unclothed.
2. **Body** (excluding head, neck, and hands).
Chest/stomach, back, upper arms, forearms, thighs, lower legs, and feet.
3. **Hands**
4. **Inhalation**
5. **Dietary**
Dietary exposure is estimated by the Medical Toxicology Branch, DPR.

General information:

Exposure estimates to be used in the risk assessment process must represent the exposure of a worker after all protection provided by clothing, protective clothing and equipment or engineering controls specified on the product label are taken into consideration. Risk assessors may have to use a more conservative exposure estimate to determine the risk of acute exposure, e.g. reproductive effects. In order to satisfy this requirement, the mean (arithmetic or geometric depending on the normality of distribution) and the standard deviation of the mean will be used to report the worker exposure estimates. This will allow the risk assessor to apply the necessary degree of conservatism in using an exposure estimate for risk assessment.

Surface areas of adult male (total 19,400 cm²) and adult female (total 16,900 cm²) workers based upon the 50th percentile value (U.S. EPA, 1985) shown in Tables 1 and 2 are presently adopted by the Worker Health and Safety Branch, DPR. Body weight (50th percentile) of adult males is 75.9 kg and that of adult females is 61.5 kg. Heights of these adult males and adult females based upon the equation given by U.S. EPA (1985) are 5'11" for adult males and 5'6" for adult females. Ventilation rates of adult male and female workers shown in Table 3, either for light or moderate work activities depending on the type of work, should also be used. Exposure estimates from the registrants based upon surface areas, body weights, and ventilation rates which differ from the adopted numbers should be adjusted.

Monte Carlo analysis has been recommended by U.S. EPA (1992) as a technique in the exposure estimates. Use of the Monte Carlo simulation is currently under evaluation by the Worker Health and Safety Branch. From our preliminary review, exposure estimates using this technique are generally lower than that using a conventional method.

A 70-year lifetime has been widely used in the past for the calculation of LADD. Life expectancy for the U.S. population has gradually increased over the years. Preliminary data in 1989 showed that the life expectancy of the total population was 75.2 years (Bureau of the Census, 1991). Also, the projected life expectancies in 2010 are: total population 77.9 years, males 74.4 and females 81.3 years. It was suggested that 75 years would be a more

appropriate average value (U.S. EPA, 1990). In calculation of LADD, 40 years of exposure in a 75-year lifetime will be used for the purpose of exposure assessment.

Default values for percent protection shown in Table 4 (Thongsinthusak, *et al.*, 1991) for pesticide handlers may be used to calculate dermal exposure. A report by Brodberg and Sanborn (1993) for clothing protection for field workers should also be considered.

Whenever it is possible, actual clothing protection values determined from the study of pesticides under review are preferable to default values, especially pesticides with high vapor pressure. Exposure review and data should contain basic information as follows:

Handlers (including Mixer/Loaders and Applicators)

1. Types of crops, mixing/loading system, type of pesticide formulation, application equipment, work time, application time, pounds a.i. mixed/loaded or applied.
2. Methods of exposure evaluation for potential dermal and inhalation exposure.
3. Clothing worn by the workers, number of workers, and replicates.
4. Percent recoveries of field and/or lab spiked matrices, e.g. patches, air traps, hand wash solution, etc. Percent recoveries reflect extraction efficiency, stability of chemicals during storage and transportation.
5. Calculate percent clothing and glove protection if data are available.
6. Calculate (potential) dermal exposure of pesticide handlers. The exposure data must be corrected for percent recoveries. If the submitted data is calculated by using surface areas differing from that in Table 1 and 2, corrections are needed. The exposure must also be adjusted to reflect the label rate and protection requirements. Exposure data should be grouped as previously indicated.
7. Give recommendations as to study acceptability.

Field Workers (including harvesters and other reentry workers)

A. Exposure derived from work activities, such as harvesting, thinning, scouting:

1. Include the following information: crop, pesticide formulation, number of samples collected, pounds a.i. applied per acre, application method, days post application, application rate, frequency of application, and handling of samples.
2. Type of work clothing worn.
3. Methods of monitoring, number of workers, and number of replicates.
4. Tabulate exposure data into body regions mentioned previously.
5. Calculate percent clothing or glove protection if necessary.
6. Make corrections for percent recoveries, pounds a.i. applied per acre, weight, and surface areas.
7. Give recommendations as to the acceptability of the study.

B. Exposure derived from DFR:

1. Include the following information: crop, pesticide formulation, number of samples, days after an application of pesticide, pounds a.i. applied per acre, types of application equipment generating residues used for DFR, and environmental conditions.
2. Use an appropriate TF. A TF may be derived from potential or dermal exposure and is called potential dermal TF or dermal TF, respectively.
3. Calculate (potential) dermal exposure from the relationship of exposure, DFR and TF.

$$\text{TF (cm}^2\text{/h)} = \text{Exposure (ug/h)}/\text{DFR (ug/cm}^2\text{)}$$

4. Give recommendations as to study acceptability.

Notes: DFR is based on residues from two-sided leaf surface areas. TF (cm²/h) is simply used to indicate the "residue transfer index" as a function of "field worker work activity". It by no means indicates total transfer of DFR of the contacted surfaces, nor the actual surface contacted by the harvesters. The fact is, only a fraction of DFR of the contacted surface will be transferred to the harvester's skin (Maddy *et al.*, 1989). Values of some TFs for certain pesticides in different crops have been tabulated and published (Zweig *et al.*, 1984; Krieger *et al.*, 1990)

Exposure estimates of pesticide handlers, including maintenance workers, home gardeners, and pest control operators are also based on the suggested outlines shown above.

Indoor monitoring

If the pesticide is used indoors specify the manner of use i.e., crack and crevice, broadcast, fogger or bait; specify use rate, reentry interval and any precautions against children's exposure. Exposure monitoring studies should be conducted with human volunteers to achieve the most appropriate estimates of exposure. Exposure estimates generated exclusively from air and surface monitoring are not generally acceptable. Examples of acceptable indoor exposure estimates can be found in Ross, *et al.* (1990, 1991) and Vaccaro *et al.* (1991). Indoor exposure estimates must specify the exposure model used, daily exposure interval, level of activity, or surface contact, and contribution to exposure via dermal, inhalation and oral (hand to mouth) routes.

Summary:

In summary, exposure of pesticide handlers, field workers, and other population exposed to pesticides are then tabulated in terms of potential (dermal) exposure, daily dermal exposure, ADD, AADD, and LADD. Quarterly or seasonal absorbed daily dosage (QADD or SADD) may in some cases replace AADD depending on the nature of the time to onset of toxicity for the chemical. Some default values are applied in making the exposure estimates, unless an actual number from a field survey exists. Examples of the default values are: a normal workday of 8 hours and 40 years of exposure in a 75-year lifetime. A summary table incorporating exposure estimates for different work tasks is recommended.

Notes:

1. Application rates used in the worker exposure or related studies have to represent the maximum or nearest to the maximum rate recommended on the product labels.
2. After a human pesticide exposure assessment document is drafted, a memorandum should be issued to the Pesticide Registration Branch providing references used for the preparation of this document. The Pesticide Registration Branch will notify the registrant about this development and find out whether additional information is available to be incorporated in the exposure document.
3. If Human Exposure Assessment Document is revised, the original date should be retained; date of revision is added.

REFERENCE FORMAT

For consistency in citation, the reference format for the text and references is suggested. Author(s) and year should be cited in the text for the source of data or information. For example: Krieger (1990), (Krieger *et al.*, 1991). Reference style guides suggested follow that of *Journal of Toxicology and Environmental Health* (or styles for scientific references on pp. 438-447 of *A Manual of Style*, 13th ed., Chicago, University of Chicago Press). References are listed in alphabetical order. Examples of references for the REFERENCE section are as follows:

A. Periodicals

- Baser, M. E., Kennedy, T. P., Dodson, R., Rawling, W. R., Jr., Rao, N. V., and Hoidal, J. R. 1990. Difference in lung function and pneumoconiosis prevalence between workers in two kaolin processing plants. *Br. J. Ind. Med.*, in press.
- Wester, R. C., and Maibach, H. I. 1983. Cutaneous pharmacokinetics: 10 steps to percutaneous absorption. *Drug. Metab. Rev.* 14:169-205.

B. Books

- ACGIH. 1988. *Threshold Limit Values and Biological Exposure Indices for 1988-1989*. Cincinnati: American Conference of Governmental Industrial Hygienists.
- Miller, R. G., Jr. 1966. *Simultaneous Statistical Inference*, Chap. 61. New York: McGraw-Hill.

C. Chapter in Books

- Lavy, T. L., and Mattice, J. D. 1989. Biological monitoring techniques for humans exposed to pesticides: Use, development, and recommended refinements. In *Biological Monitoring for Pesticide Exposure: Measurement, Estimation, and Risk Reduction*, eds. R. G. M. Wang, C. A. Franklin, R. C. Honeycutt, and J. C. Reinert, ACS Symposium Series 382, pp. 192-205. Washington, D.C.
- Wester, R. C., and Maibach, H. I. 1985. *In vivo* model for percutaneous absorption. In *Percutaneous absorption*, eds. R. L. Bronaugh, and H. I. Maibach, pp. 251-266. New York: Marcel Dekker.

D. Thesis

Pan, J. C. 1985. Lindane metabolism: Epoxidation of polychloroalkenes and effects of route of administration on excretion. Ph.D. Thesis, University of Illinois, Chicago.

E. Report

Dybass, R. (or company names if authors are not listed). 1992. Dermal absorption of abamectin. Pesticide Registration Document Number 256-245, record number ER-2345. Pesticide Registration Branch, Department of Pesticide Regulation.

FR. 1988. Toxic chemical release reporting; Community right-to-know; Titanium dioxide. *Federal Register* 53:23108-23112.

WHO. 1982. Recommended Health Risk-Based Limited in Occupational Exposure to Pesticides. *World Health Organization Technical Report Series* 677.

Table 1. Surface areas for body regions of the adult males^a

Region of the body	Surface area (cm ²) of region	Location of pad (s) representing region	Percent of total
Head (exclude face)	630	Shoulder, Back, Chest ^b	3.25
Face	630	Chest	3.25
Back of Neck	107	Back	0.55
Front of Neck ^c	146	Chest	0.75
Chest/Stomach	3454	Chest	17.80
Back	3454	Back	17.80
Upper Arms	1479	Shoulder and forearms/ Upper arms	7.63
Forearms	1211	Forearms	6.24
Hands	915	---	4.72
Thighs	3663	Thighs	18.88
Lower Legs	2455	Shins	12.66
Feet	1256	---	6.47
Total	19400		100

^a Adapted from U.S. EPA (1985) and based on 50th percentile. Surface areas of head and trunk were subdivided based on the ratio used in U.S. EPA (1987). Weight of adult males (50th percentile) = 75.9 kg (U.S. EPA, 1985).

Note: Surface areas can be estimated by the equation that follows (U.S. EPA, 1985) if heights and weights are known. This equation was used in the estimation of the surface areas in Table 1. The parameters used are similar to that of Gehan and George (1970) for the estimation of surface area of all ages.

$$\text{Surface area (SA)} = a_0 H^{a_1} W^{a_2}$$

$$SA = 0.0239H^{0.417}W^{0.517}$$

(where H=cm, W=kg, SA=m²)

Or in logarithmic form: $\ln SA = -3.73 + 0.417 \ln H + 0.517 \ln W$

^b Exposure to the head may be estimated by using the mean of the shoulder, back and chest patches or by using a head patch.

^c Include "V" of the neck.

Table 2. Surface areas for body regions of the adult females^a

Region of the body	Surface area (cm ²) representing region	Location of pad (s) of region total	Percent of region total
Head (exclude face)	574	Shoulder, Back, Chest ^b	3.40
Face	574	Chest	3.40
Back of Neck	90	Back	0.53
Front of Neck ^c	123	Chest	0.73
Chest/Stomach	2888	Chest	17.09
Back	2888	Back	17.09
Upper Arms	1205	Shoulder and forearms/ Upper arms	7.13
Forearms	985	Forearms	5.83
Hands	778	---	4.60
Thighs	3367	Thighs	19.92
Lower Legs	2251	Shins	13.32
Feet	1177	---	6.96
Total	16,900		100

^a Adapted from U.S. EPA (1985) and based on 50th percentile. Surface areas of head and trunk were subdivided based on the ratio used in U.S. EPA (1987) and that of upper arms and forearms were based on the ratio used in U.S. EPA (1985). Weight of adult females (50th percentile) = 61.5 kg (U.S. EPA, 1985).

Note: Surface areas can be estimated by the equation that follows (U.S. EPA, 1985) if heights and weights are known. This equation was used in the estimation of the surface areas in Table 2. The parameters used are similar to that of Gehan and George (1970) for the estimation of surface area of all ages.

$$\begin{aligned} \text{Surface area (SA)} &= a_0 H^{a_1} W^{a_2} \\ \text{SA} &= 0.0239 H^{0.417} W^{0.517} \\ &\text{(where H=cm, W=kg, SA=m}^2\text{)} \\ \text{Or in logarithmic form: } \ln \text{ SA} &= -3.73 + 0.417 \ln H + 0.517 \ln W \end{aligned}$$

^b Exposure to the head may be estimated by using the mean of the shoulder, back and chest patches or by using a head patch.

^c Include "V" of the neck.

Table 3. Estimated ventilation rates by sex and activity level^a

	Ventilation rate (L/min)			
	Resting ^b	Light ^c	Moderate ^d	Heavy ^e
Adult male (n=454)	12	14	41	80
Approx. power (watts) ^f	<25	25	150	235
Adult female (n=595)	6	8	27	48
Approx. power (watts) ^f	<25	<25	75	165

Note: Pulmonary ventilation or the mass movement of gas in and out of the lungs (Astrand, 1960) is generally represented by ventilation rate or minute volume. The ventilation rate (L/min) represents the volume of gas expired in liters per minute (Astrand and Rodahl, 1977).

^a Adapted from U.S. EPA (1985).

^b Resting period includes watching television, reading, and sleeping.

^c Example of a light work activity for adult male workers: Continuous loading one bag at a time, seven bags of 50-pound bag granular formulation pesticide in one minute. The walking distance was one meter. The power was determined to be 26 watts which corresponds to ventilation rate of 14 L/min. This activity level is applicable to normal pesticide handling activities, including mixing/loading, application, and flagging. Light work activity is also applicable to adult female workers. However, ventilation rates used for any work activities should be justified in the exposure assessment document based upon the type of work conducted.

^d Moderate work activity represents approximately three times heavier work task than the light work activity. Power used can be estimated according to equation in (f).

^e Heavy work activity category is generally not applicable to occupational exposure to pesticides.

^f Approximate power (watts) shown in the Table 3 corresponding to ventilation rate in L/min (U.S. EPA, 1985). Power can be calculated by the following equation:

$$\text{Power (watts)} = \frac{\text{Weight} \times 9.80665 \times \text{Distance}}{\text{Time}}$$

(Weight = kg, Distance = meter, Time = second, 9.80665 is a conversion factor for kg to Newton)

Table 4. Default values for pesticide protection provided by engineering controls, protective clothing and equipment^a

	% Protection
<u>Engineering Controls</u>	
Closed m/l system plus chemical-resistant apron	95
Enclosed cab with positive pressure and a charcoal air-filtration unit	98
Enclosed cab	90
<u>Work clothing, Protective Clothing and Equipment for Pesticide Handlers</u>	
Work clothing (e.g. long-sleeved shirt, long pants)	90
Coveralls or overalls	90
Chemical-resistant full-body protective clothing	95
Chemical-resistant gloves	90
Full face respirator with cartridges ^b (Approved by NIOSH and/or MSHA)	98
Half face respirator with cartridges ^c (Approved by NIOSH and/or MSHA)	90

- ^a From Thongsinthusak *et al.* (1991). Actual protective values will be used when available, especially for pesticides with high vapor pressure.
- ^b Equivalent to a protection factor of 50.
- ^c Equivalent to a protection factor of 10.

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