Human Exposure Assessment for 1,3-dichloropropene

by

James R. Sanborn, Staff Toxicologist

Sally Powell, Senior Environmental Research Scientist

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California Environmental Protection Agency
Department of Pesticide Regulation
Worker Health and Safety Branch
1020 N Street, Sacramento California 95814

ABSTRACT

The soil fumigant 1,3-dichloropropene (1,3-D) is used to control soil parasitic nematodes and other soil pests in annual crops and some perennials before planting. Metabolism and pharmacokinetic data on 1,3-D indicate facile conjugation as a mercapturate, and renal elimination after inhalation. The primary mode of exposure is inhalation, with dermal absorption of the vapor considered unimportant. Inadvertent exposure of humans during application equipment failure or repair has resulted in skin and/or eye irritation. Biological monitoring of workers demonstrated an estimated Absorbed Daily Dosage of 1.9 ug/kg/day (1.13 and 0.73 ug/kg/day for application and loading, respectively) when adjusted for respiratory protection worn during the entire fumigation cycle. These adjusted numbers are reflective of practices to be implemented in California should 1,3-D be reinstated, including spill control, dry disconnects and vapor recovery measures. Non-occupational inhalation exposure for residents of a Telone reinstatement area was estimated by stochastic simulation. Estimated 95th percentile Lifetime Average Daily Dosages ranged from 0.167 ug/kg/day for residents living 500 m from treated fields for 30 years, to 0.373 ug/kg/day for residents living 100 m from fields for 70 years. Estimated 95th percentile 62-day Average Daily Dosages ranged from 0.674 ug/kg/day for infants living 500 m from treated fields, to 6.272 ug/kg/day for young children living 100 m from fields. This report was prepared as Appendix B to the Department's risk assessment document for 1,3-D. The necessity for this risk document stemmed from the identification of adverse effects in acute and chronic studies as well as characterization of 1,3-D as an oncogen in rat chronic feeding and mouse inhalation studies.

APPENDIX B

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
DEPARTMENT OF PESTICIDE REGULATION
WORKER HEALTH AND SAFETY BRANCH

HUMAN EXPOSURE ASSESSMENT

1,3-DICHLOROPROPENE

May 26,1989
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INTRODUCTION

The fumigant 1,3-dichloropropene (1,3-D) (CAS # 542-75-6, molecular formula $C_3H_4Cl_2$) is a liquid used as a soil treatment for the control of plant parasitic nematodes and other soil pests. The physical properties of 1,3-D are listed below:

Boiling point 108°C (Composite of *cis/trans* isomers: higher BP 112.0^{o}C, lower BP 104.3^{o}C)
Vapor pressure 27.3 mm at 25°C
Density 1.2 g/ml at 25°C
Water solubility 2180 ppm (*cis-*), 2320 ppm (*trans-*)
Octanol/water partition coefficient 104
Cis-/*trans-* ratio 1:1

EPA STATUS

A Registration Standard was issued in September 1986 for 1,3-D which includes exposure and risk assessments for workers handling 1,3-D. These assessments assume that inhalation is the primary route of exposure, and that dermal exposure may only contribute during episodes of equipment repair or failure. Respirators, chemically resistant clothing and gloves are required during mixing and loading.

USAGE

1,3-D is manufactured by Dow Chemical Co. as a formulation containing 94% active ingredient (1:1 *cis-*:*trans-* isomer ratio) and 6% inert ingredients. Commercial 1,3-D is sold under the name Telone II™ and contains 9.5 lbs a.i. per gallon. 1,3-D is registered for use on more than 120 crops and ornamentals. It is used for preplant soil treatments for vegetable crops, field crops, deciduous fruit trees, nut trees and vines. It is recommended that soils where annual crops are grown be treated each year before planting. Over 15 million pounds were reported sold in California in 1987 (California Department of Food and Agriculture, 1988). Application rates of 1,3-D depend on crop and soil type, and range from 43 to 970 lbs a.i./acre. The soil surface is sealed by covering or rolling after application to increase efficacy by reduction of vapor loss. Application equipment injects 1,3-D to a depth of at least 12 inches below the sealed soil surface.

LABEL PRECAUTIONS

The label for Telone II contains the signal word "WARNING" and the following precautionary statements:

PRECAUTIONARY STATEMENTS

HAZARDOUS TO HUMANS AND DOMESTIC ANIMALS, HAZARDOUS LIQUID AND VAPOR

- o MAY CAUSE ALLERGIC SKIN REACTION
- o MAY BE FATAL IF INHALED, ABSORBED THROUGH SKIN, OR SWALLOWED
- o CAUSES SEVERE EYE DAMAGE
- o CAUSES BURNS OF SKIN
- o MAY CAUSE LUNG, LIVER AND KIDNEY DAMAGE AND RESPIRATORY SYSTEM UPON PROLONGED CONTACT
- o Do not breathe vapor
- o Do not get in eyes, on skin, on clothing
- o Do not take internally
- o Use only with adequate ventilation
- o Wear eye and skin protection necessary to prevent contact when handling TELONE II
- o Wash thoroughly with soap and water after handling and before eating or smoking
- o If protective gear, such as boots or gloves, becomes contaminated, immediately wash with soap and water. Never wear protective gear having the odor of 1,3-dichloropropene. Aerate and wash all protective gear thoroughly after each use until odor is gone.
- o Render unusable and dispose of contaminated leather goods, including shoes.
- o Do not apply this product in such a manner as to directly or through drift expose workers or other personnel. The area being treated must be vacated by unprotected persons.

California regulations and permit conditions: Additional requirements

California regulations require respiratory protection when inhalation exposure potential is high (e.g., during loading and equipment repair). Eye and skin protection (gloves and chemical resistant clothing) are required when handling Telone II.

The California permit conditions will require additional protective equipment. Loaders will be required to wear full-face respirators. Applicators must either wear a half-face respirator or be inside a charcoal-filtered cab during application. Workers re-entering a treated area during the first 7 days post application will be required to wear a one-half face respirator.

WORKER ILLNESS

Table 1 shows that from 1982-1990 there were 55 illnesses that were related to exposure to 1,3-D. In terms of type of illness, they were almost equally divided between systemic (16), eye (14) and skin (18). With respect to the causality most of the illnesses were classified as definite (33), followed by probable (9) and possible.

Table 1. 1,3-dichloropropene illnesses in California (1982-1990)

Year	Type				Causality		
	Systemic	Eye	Skin	Eye/Skin	Definite	Probable	Possible
1982	4	2	1	0	1	2	4
1983	2	3	1	0	5	1	0
1984	1	3	2	0	4	1	1
1985	0	2	3	0	4	1	0
1986	1	0	2	1	1	2	1
1987	1	0	0	0	1	0	0
1988	1	2	7	0	6	2	2
1989	1	2	1	2	5	0	1
1990	5	0	1	0	6	0	0

METABOLISM/PHARMACOKINETICS

ANIMAL STUDIES

Inhalation

Rats exposed nose-only to 30, 90, 300 or 900 ppm of 1,3-dichloropropene (*cis*- 49.3%, *trans*-42.8%) for three hours absorbed 14, 29, 85, and 171 mg/kg, respectively, or 82, 65, 66, 62 percent, respectively, of the exposure dose (Stott and Kastl, 1986). Decreases in percent absorbed as the exposure concentration increases are apparently related to the decreased ventilation frequency at higher exposure levels. Tissue distribution of inhaled vapors indicated the lungs contained approximately 50 percent of the total inhaled vapors and the nasal passages contained an additional 10-16 percent. Depuration of 1,3-D in the blood was biphasic with the initial half-life estimated to be 3-6 minutes and the terminal half-life 30-40 minutes. Levels of protein sulfhydryl amino acids were reduced, but no reduction in pulmonary sulfhydryl amino acids was observed. Similar results for rats were reported for tissue distribution and glutathione depletion after a one-hour exposure (Fisher and Kilgore, 1988a).

The characterization of the primary urinary metabolite from rats after inhalation was accomplished by Fisher and Kilgore (1988b) who found a mercapturate after a one hour exposure to 1,3-D at 40, 107, 284, 398, or 789 ppm. The excretion of the conjugate was nearly linear with respect to 1,3-D exposure up to 400 ppm. Above 400 ppm, the excretion of the mercapturate declined relative to this initial linearity. This may have been due to decreased ventilation frequency in rats exposed three hours to doses greater than 90 ppm as reported by Stott and Kastl (1986). Alternatively, it may have been due to depletion of conjugable glutathione.

Oral dosing

Several investigators have examined the metabolic fate of 1,3-D in animals after an oral dose. Hutson *et al*., (1971) reported that 81% of 10-mg doses of *cis*-1,3-D, and 57% of 10-mg doses of *trans*-1,3-D, were eliminated in the urine. Dietz *et al., (*1984 a,b) reported 50-80 percent renal elimination and 14-17 percent elimination as CO_2 in rats or mice treated with 1,3-D. No evidence of saturation of metabolic pathways was observed up to 50 mg/kg in these later studies. Urinary elimination of ^{14}C-equivalents was estimated to have a half-life of approximately 5.5 hours.

The primary metabolite in urine of rodents dosed orally with 1,3-D is *N*-acetyl-*S-(*3-chloroprop-2-enyl) cysteine (DCPMER) and its sulfoxide. This indicates that 1,3-D is metabolized and conjugated via a glutathione pathway in rodents. The formation of this metabolite is consistent with the loss of non-protein sulfhydryl levels in the liver and stomach after *per os* doses with 1,3-D (Dietz *et al*., 1984, Climie *et al*., 1979).

HUMANS

Inhalation

In workers exposed to 1,3-D during loading and application, Osterloh *et al.* (1984, 1989), Brouwer *et al.* (1991) and van Welie *et al.* (1991) observed DCPMER as a urinary metabolite. The common urinary metabolite in rodents and humans indicates that these species metabolize 1,3-D by similar metabolic pathways.

A PB/PK study was conducted by the registrant in which six humans were exposed to 1,3-D in an inhalation chamber at 1 ppm for 6 hours (Waechter *et al.,* 1992). Estimates of respiratory uptake, made from analysis of exhaled breath during the exposure, averaged 78% for the two isomers. Urine was collected during and after exposure (84 hrs post exposure). Excretion of the *cis*- and *trans*-mercapturates was complete 36 hours post exposure. The combined conversion of inhaled 1,3-D to the two mercapturates was found to be 24% (Stott, 1992).

DERMAL ABSORPTION

The high vapor pressure of 1,3-D (27.3 mm) reduces its dermal absorption potential. There is a single report in the literature concerning dermal absorption of 1,3-D and other low-boiling organic chemicals (Cohen and Poppendorf, 1989). The experimental details are not complete as the paper reported the values from a thesis by the first author. The values reported for dermal absorption of 1,3-D in rats *in vivo* were 0.62 and 1.5% for doses of 1.9 and 19 ug/cm^2, respectively. This range of absorption values was found for exposed skin that was not occluded.

WORKER EXPOSURE

Inhalation

Worker inhalation exposure assessed by breathing zone measurements during loading, application or equipment repair are summarized in Table 2.

Table 2. Breathing zone air concentrations of workers handling 1,3-dichloropropene during loading and application

ppm	Reference	Date
0.37[a/]	Davies and Fraser	1988
0.04-0.40	Tobol and Axe	1982[b/]
0.38[a/]	Maddy *et al*.	1980
0.71[a/]	Maddy *et al*.	1982
0.17[a/]	Fong and Maykoski	1985
<1.0[a/]	Albrecht	1987
<0.2[a/]	Cook	1982[b/]

[a/] Time-weighted average
[b/] Cited by Davies and Fraser (1988)

These studies suggest that workers are exposed to time-weighted average levels that are below the recommended 1 ppm Permissible Exposure Limit set by the Occupational Safety and Health Administration.

Since concentrations were measured in the workers' breathing zones while they performed a variety of tasks (some loaded and some applied, others loaded or applied and some unspecified), the reported inhalation exposure results from a composite of work tasks. The individual studies did not always report exposures by task, nor did they report any more than TWA values or monitoring results, making it difficult to obtain an absorbed dose for each work task.

Table 3. Potential inhalation exposure for 1,3-dichloropropene estimated from reported breathing zone concentrations, assuming a respiratory rate of 29 L/min

Study	mg/8-hr day
Poppendorf *et al.,*(1983)	142.3
Maddy *et al.*, (1980)	24.0
Maddy *et al*.(1982)	44.8
Fong and Maykoski(1985)	10.8
Davies and Fraser, (1988)	23.3
Cook,(1983)	12.6
Albrecht,1987)	63.1
Geometric Mean	31.5

The air monitoring results of several studies have been converted to potential inhalation exposures in mg/8-hr day, by assuming a respiration rate of 29 L/min (Table 3). The geometric mean of these data is reported because the data are log-normally distributed (Shapiro and Wilk, 1965). It is conventional to treat exposure data by this statistical method as it allows the use of all the environmental or exposure data that may be widely variant (Owen and DeRouen, 1980). If the mean for potential inhalation exposure from breathing zone measurements is mitigated by a respirator (90 reduction in exposure), corrected for respiratory uptake (78 %, Waechter *et al.,* 1992)) and a 70-kg person is assumed, then the ADD (Absorbed Daily Dosage) is 35.1 ug/kg/day.

Hand Exposure

The data available on potential hand exposure to 1,3-D are conflicting. Maddy *et al*., (1980, 1982) reported hand a contamination level of 16.4 ug/hr for workers wearing gloves. The other data on hand exposure (Table 4) were taken from the work of Davies and Fraser (1988), on an application of 1,3-D in Canada. The range of the data for the eight individuals' hand residues was 0.1-570 mg/hr with a geometric mean of 9.7 mg/hr.

Table 4. Hand exposure to 1,3-dichloropropene during loading[a/]

Worker	mg/hr
1	14
2	0.8
3	26.5
4	193
5	570
6	0.7
7	33.3
8	0.1
Geometric Mean	9.7

[a/] Davies and Fraser (1988)

This exposure value for the hand of 9.7 mg/hr is almost 600-fold greater than that reported by Maddy, (1982). The reasons for this large difference may be in the experimental design. In the Davies and Fraser (1988) study, the protocol was a cotton glove-polyethylene glove (1 mm)-cotton glove arrangement where the inner cotton gloves were analyzed for 1,3-D. The inner glove provides an absorptive sink whereas the outer glove compared to the smooth protective glove normally worn, provides a sponge for liquid 1,3-D for eventual penetration through the thin polyethylene glove. This type of thin glove (polyethylene) is not normally utilized in application of this material as it would not withstand the physical abuse of daily operations during loading the fumigant into the tanks. It is likely that in the studies of Maddy *et al*. (1982) where hand residues were monitored under normal work conditions, that thicker gloves were worn. Further, Maddy suggests that hand washes may not be an effective means for the removal of residues because some evaporation may have occurred as well as some dermal absorption. Even so, the analysis of hand washes in the work reported by Maddy *et al*., reported microgram amounts of 1,3-D rather than the milligram amounts in the work of

Davies and Fraser. While the Maddy data is very likely an underestimate of dermal exposure, the dermal estimates of Davies and Fraser are overestimates due to the experimental design. Since the hand exposure values are for 1.2 hrs/day (estimated daily loading time), the dermal component becomes a minor contributor of the overall human exposure which is primarily via inhalation.

Annual and Lifetime Exposure Days

Estimates of worker exposure time are provided by the US EPA Data Call-In for handlers of 1,3-D in crops grown in California that have been treated with 1,3-D (Houtman, 1992). This survey provided information on the number days per year for each crop that 1,3-D was handled for applicators and loaders in California (Table 5). The maximum number of days per career was estimated to be 270. The number of days per career ranged from a low of 24 for potatoes to a high of 270 for brassica. It is possible that the same individuals applying for brassica could be applying in vegetables, which could mean that an individual's exposure days per year or career could be as high as the total for all crops. However, it is likely to be much less because the calendar window for application to each crop prevents any one person from working all of them.

Table 5. Annual and lifetime handling days for loaders (L), applicators (A) and repairs (R)

	Tomato L,A,R	Potato L,A,R	Cotton L,A,R	Vegetables L,A,R	Brassica L,A,R	Beets L,A,R	Tree/Vine L,A,R
				Annual			
Custom	16,23,34	4,4,4	40,36,26	18,35,24	36,36,36	10,10,10	22,9,8
Grower	1,1,1,	1,1,1	2,2,13	3.5,3.5,3.5	0,0,0	1,1,1	4,4,4,
				Lifetime			
Custom	104,150,221	24,24,24	260,234,169	108,210,144	270,270,270	65,65,65	198,81,72
Grower	4.5,4,5,4.5	2.5,2.5,2.5	9,9,58.5	8.75,8.75,8.75	0,0,0	4.5,4.5,4.5	12,12,12

Biological Monitoring

Osterloh *et al*. (1984, 1989 a and b) reported human exposure studies with 22 workers loading and applying, in which they conducted urinary monitoring for *N*-acetyl-*S*-(3-chloroprop-2-enyl)cysteine (DCPMER). Respiratory protection (half-face) was worn only during loading and not during application. An average of 3.4 mg of DCPMER was excreted in the 24-hour period after exposure. Correction for the molecular weight difference between 1,3-D (111) and DCPMER (237) gives an ADD of 1.6 mg/person/day or 22.7 ug/kg/day. Using the data of Davies and Fraser (1988), it is possible to calculate the percentage of the exposure received during application and loading. In Davies and Fraser it was determined that 26.1 percent of the exposure occurred during application, 73.9% during loading. Osterloh *et al*. assumed 90% protection from the half-face respirator worn during loading, hence the inhaled dose was 0.1 times the exposure. During application, 1.0 (0% respiratory protection) indicates the absence of respirators. The absorbed dose for each activity may be found by the following equation.

$$\underbrace{(73.9\ \%)(X)(0.1)}_{\text{Loading}} + \underbrace{(26.1\%)(X)(1.0)}_{\text{Application}} = 22.7\ \text{ug/kg/day} \qquad (1)$$

where X is exposure. Solving for X gives 67.8 ug/kg/day. Putting this value back into equation (1), and adding respiratory protection (half-face respirators) during application gives

$$\underbrace{(73.9\%)(67.8)(0.1)}_{\text{Loading}} + \underbrace{(26.1\ \%)(67.8)(0.1)}_{\text{Application}} = 6.8\ \text{ug/kg/day}$$

The value of 6.8 ug/kg/day is the expected ADD if half-face respirators are worn during *both* loading and application.

Houtman (1993) monitored five individuals loading or applying 1,3-D in Washington state. The same individual did not do both tasks. These applicators and loaders carried out one application per day, at a rate of 25 gal/acre, lasting about four hours. One application was done without mitigation measures, while the others used various mitigation measures specified by the US EPA including dry disconnects (with and without vapor recovery), spill control at the end of the rows, and a cab with charcoal-filtered air. Houtman collected urinary monitoring data only for the application conducted without mitigation measures. To estimate the absorbed daily dose from these unmitigated conditions, respiratory protection factors of 0.9 and 0.95 for half-face and full-face respirators were used for applicators and loaders, respectively. The human chamber PB/PK exposure study data were used in the absorbed dose calculation. These respiratory protection requirements for loaders and applicators were part of the Permit Conditions in California for the flux studies and the Monterey Commercial Use Project. These same respiratory protection conditions will be required if 1,3-D is reinstated in California.

The exposure data, shown in Table 6 as geometric means, have been normalized to an 6.8-hour day, which is consistent with the data of Davies and Fraser (1988) and allows comparison with the data of Osterloh *et al.* where one person performed both loading and application.

Houtman (1993) found that utilizing spill control during application reduced the ambient air concentrations by 79%. The urinary metabolite data were adjusted by this factor. The absorbed dose was adjusted for the wearing of a one-half face respirator from the unmitigated application in Washington. The final adjustment of the data from Washington was the factoring of the reduced rate in California (12 gal/acre) as compared to the 25 gal/acre that were used in the studies in Washington. The loader exposure data were not adjusted for the reduced rate in California as the exposure occurs primarily during the connecting and disconnection of the hose from the nurse tank and is unrelated to the amount placed in the tank on the tractor.

With respect to the estimation of AADD and LADD, the range of values for loading and applying were obtained from the crop specific data compiled in Table 5.
There are several reasons for the reduced exposure of a combined (one person doing both tasks) load and apply (1.9 ug/kg/day) in the Washington study (Houtman, 1993) as compared to the earlier combined estimate of Osterloh *et al.* (6.8 ug/kg/day). Firstly, for the loader, the Washington study used dry disconnects and vapor recovery devices. For the applicator, spill control was used at the end of the rows. Each of these mitigation strategies reduces ambient air concentration which resulted in lower estimated exposure value of more than three-fold. It is further likely that the soil moisture content will be higher in California than occurred during the applications in Washington. This will further reduce emissions.

Table 6. ADD, AADD and LADD values for loading and application of 1,3- dichloropropene.

Study	Task	ADD[1/] (ug/kg/d)	Days/ Year	SADD[4/] (ug/kg/d)	AADD[5/] (ug/kg/d)	Days/ Career	LADD[6/] (ug/kg/d)
Osterloh *et al.*	Load/Apply	6.80					
Houtman	Load	0.73[3/]	4	0.016	0.008	24	6.9×10^{-4}
			40	0.16	0.08	270	7.7×10^{-3}
	Apply	1.13[3/]	4	0.025	0.012	24	1.1×10^{-3}
			36	0.23	0.11	270	1.2×10^{-2}
	Total[2/]	1.86					

1 Absorbed Daily Dosage, two load and application cycles/day; body weights of study volunteers used in calculations
2 One person doing both loading and applying-for comparison to studies of Osterloh *et al.*
3 Normalized to 6.8 hrs based on registrant study (Davies and Fraser, 1988), for one person doing both tasks to be compared with Osterloh *et al.,*
4 Split application for brassica, 90-day window (see Table 5)
5 Annual Average Daily Dosage (365 days/year)
6 Lifetime Average Daily Dosage 70 years life (25,550 days)

Exposure Appraisal

The exposure estimates based on the Houtman (1993) study, in which exposures were measured separately for loading and application, should be used for the assessment of risk. These estimates are based on biological monitoring that assessed both *cis*- and *trans*-mercapturate metabolites in the urine and utilized the pharmacokinetic information developed from exposure of humans under controlled conditions. Hand exposure information developed by previous investigators was not used as this route of exposure would be reflected in the total exposure measured by the biological monitoring.

None of the occupational exposure studies in which biological monitoring was conducted employed exactly the mitigation measures that would be required in California. These requirements are for full-face respiratory protection during loading and half-face protection during application.

NON-OCCUPATIONAL EXPOSURE

Inhalation exposure was estimated for residents of an area where Telone is used in carrot growing. Both lifetime and subchronic (seasonal) exposures were estimated for residents of the area in general, and for residents with homes at specified distances from Telone-treated fields (100, 200 and 500 meters). The estimated lifetime exposure distributions are given in Tables 7 through 10, seasonal exposures in Tables 11 through 14.

The exposure assessment relied on simulated air concentrations from a study provided by the registrant (Calhoun *et al.*, 1994), in which the ISCST simulation model (Wagner, 1987) was used to predict concentrations of 1,3-D in air for a scenario of limited reintroduction of Telone II™ soil fumigant in carrots. In the use scenario modeled, Telone is applied to 25 80-acre fields (2000 acres total) per year in a 9-township (324-square-mile) area in Kern County. Under this scenario, there is no other use of Telone. All applications are at the rate of 12 gallons per acre, and no field is treated more than once in three years. Calhoun *et al.* simulated three years of daily air concentrations for one point at the center of each section in the reintroduction area to produce an annual average daily concentration for each point. The locations of treated fields were assigned randomly in their model, so that concentrations at the section centers vary in part due to being different distances and directions from applications. The modeled concentrations thus represent long-term ambient concentrations for the reintroduction area. Calhoun *et al.* presented separately the concentrations for the township of highest Telone use within the 9-township area. These concentrations were used in the exposure assessment.

Probability distributions of exposure were estimated using stochastic simulation ("Monte Carlo") methods, implemented with the program @RISK (Palisades Corporation, 1992). The distribution of lifetime average daily dose (LADD), as ug of 1,3-D inhaled per kg of body weight per day (ug/kg/day), was estimated separately for persons living 1) the first 30 years of, and 2) all of a 70-year lifetime in the reintroduction area. Seasonal exposure was estimated for July-August, the period of greatest Telone use, by adjusting the long-term air concentrations for proportional use and mass loss during that 62-day period. Additional simulated air concentrations provided by the Environmental Monitoring Branch (Johnson, 1994a) were incorporated to estimate both lifetime and 62-day exposures to residents whose dwellings are close to treated fields. Exposure distributions were estimated separately for residents living 100, 200 and 500 meters from the edges of treated fields. Each estimated exposure distribution is based on a simulation with 10,000 trials.

LADD (ug/kg/day) was calculated by the following equation.

$$\mathrm{LADD} = \sum_{i=1}^{10} \mathrm{RT}_i \left[\left(\mathrm{Conc}_i \text{ x } \mathrm{BR}_i \right) / \mathrm{BW}_i \right] / 70$$

where the summation is over 10 age intervals,

RT_i = number of years in age interval *i* that the person resides in the Telone use area,

Conc_i = average of air concentrations (ug/m^3) in 5 locations weighted by the proportion of time spent in each location in interval *i*,

BR_i = average breathing rate (m^3/day) at each of 4 activity levels weighted by proportion of time spent at each level in interval *i*,

BW_i = body weight (kg) in interval *i*, and

70 years is the assumed lifetime.

Seasonal exposure (62-day average ug/kg/day) was calculated separately for each age interval, as

$$\text{Average daily dose} = \frac{\text{Conc x BR}}{\text{BW}}$$

where concentration, breathing rate and body weight are as defined above for LADD, but with air concentrations modified to approximate seasonal averages as explained in the next section.

Concentration, breathing rate and body weight were stochastic variables in the exposure simulation model. The statistical distributions used to simulate them are described in the sections on specific input variables following Tables 7-14.

Table 7. Lifetime average daily dose (ug/kg/day) of 1,3-D inhaled by residents of an area where Telone is applied to a total of 25 80-acre fields each year.

	Residence Time			
	Birth to age 30		Birth to age 70	
	Male	Female	Male	Female
Mean	0.0800	0.0783	0.1510	0.1436
Std Deviation	0.0480	0.0487	0.0867	0.0902
Percentile				
5	0.027	0.026	0.053	0.047
10	0.032	0.031	0.063	0.056
25	0.044	0.042	0.087	0.078
50	0.066	0.063	0.129	0.116
75	0.103	0.101	0.193	0.186
90	0.150	0.148	0.277	0.270
95	0.179	0.179	0.326	0.330
97.5	--[a]	--	--	--
99	0.230	0.236	0.425	0.444

a not calculated

Table 8. Lifetime average daily dose (ug/kg/day) of 1,3-D inhaled by residents living 100 m from treated fields in an area where Telone is applied to a total of 25 80-acre fields each year.

	Residence Time			
	Birth to age 30		Birth to age 70	
	Male	Female	Male	Female
Mean	0.1022	0.1001	0.1892	0.1829
Std Deviation	0.0514	0.0515	0.0926	0.0959
Percentile				
5	0.042	0.04	0.078	0.071
10	0.048	0.047	0.091	0.084
25	0.063	0.061	0.12	0.111
50	0.09	0.087	0.168	0.159
75	0.129	0.128	0.238	0.233
90	0.176	0.174	0.319	0.319
95	0.204	0.201	0.373	0.371
97.5	0.228	0.227	0.416	0.423
99	0.262	0.257	0.481	0.481

Table 9. Lifetime average daily dose (ug/kg/day) of 1,3-D inhaled by residents living 200 m from treated fields in an area where Telone is applied to a total of 25 80-acre fields each year.

	Residence Time			
	Birth to age 30		Birth to age 70	
	Male	Female	Male	Female
Mean	0.0996	0.0973	0.1846	0.178
Std Deviation	0.0501	0.0499	0.0901	0.0932
Percentile				
5	0.039	0.038	0.073	0.067
10	0.046	0.044	0.087	0.08
25	0.061	0.06	0.116	0.108
50	0.088	0.086	0.165	0.156
75	0.127	0.124	0.234	0.227
90	0.171	0.168	0.311	0.307
95	0.199	0.196	0.36	0.363
97.5	0.222	0.22	0.408	0.414
99	0.253	0.248	0.458	0.465

Table 10. Lifetime average daily dose (ug/kg/day) of 1,3-D inhaled by residents living 500 m from treated fields in an area where Telone is applied to a total of 25 80-acre fields each year.

	Residence Time			
	Birth to age 30		Birth to age 70	
	Male	Female	Male	Female
Mean	0.084	0.0818	0.1577	0.1498
Std Deviation	0.0423	0.0419	0.0772	0.0781
Percentile				
5	0.034	0.033	0.065	0.059
10	0.04	0.039	0.076	0.069
25	0.053	0.051	0.101	0.093
50	0.074	0.071	0.14	0.13
75	0.106	0.103	0.198	0.189
90	0.144	0.141	0.265	0.259
95	0.169	0.167	0.31	0.305
97.5	0.191	0.189	0.352	0.352
99	0.216	0.212	0.4	0.4

Table 11. Average daily dose (ug/kg/day) of 1,3-D inhaled by residents during the 62-day period of highest Telone use in an area where Telone is applied to a total of 25 80-acre fields each year.

Age Group

	< 1		1 < 2		2 < 3		3 < 6		6 < 9	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Mean	0.2499	0.2707	1.5513	1.6841	1.3685	1.4366	1.1103	1.1467	1.0548	1.0651
Std Deviation	0.2270	0.2431	1.0419	1.1219	0.9039	0.9243	0.7460	0.7561	0.6797	0.6863
Percentile										
5	0.045	0.050	0.470	0.520	0.422	0.464	0.333	0.361	0.330	0.326
10	0.058	0.065	0.558	0.616	0.501	0.549	0.399	0.426	0.397	0.395
25	0.098	0.108	0.770	0.841	0.691	0.750	0.553	0.589	0.558	0.560
50	0.173	0.192	1.207	1.308	1.070	1.134	0.869	0.904	0.849	0.863
75	0.321	0.343	2.052	2.244	1.815	1.897	1.466	1.507	1.367	1.396
90	0.539	0.590	3.126	3.385	2.738	2.804	2.242	2.249	2.050	2.038
95	0.714	0.789	3.750	4.047	3.260	3.375	2.659	2.731	2.464	2.474
97.5	0.903	0.966	4.233	4.530	3.667	3.821	3.010	3.137	2.783	2.880
99	1.125	1.183	4.711	5.124	4.108	4.260	3.468	3.522	3.230	3.296

	9 < 12		12 < 15		15 < 18		18< 25		25 < 70	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Mean	0.7953	0.7730	0.6536	0.5394	0.5300	0.4984	0.5297	0.4964	0.4809	0.4414
Std Deviation	0.5168	0.4897	0.4050	0.3320	0.3172	0.2980	0.2904	0.2913	0.2688	0.2840
Percentile										
5	0.239	0.237	0.208	0.172	0.176	0.164	0.188	0.164	0.167	0.132
10	0.291	0.292	0.254	0.209	0.214	0.196	0.228	0.200	0.201	0.164
25	0.417	0.412	0.360	0.295	0.298	0.278	0.314	0.284	0.281	0.236
50	0.645	0.635	0.545	0.453	0.447	0.419	0.459	0.422	0.416	0.362
75	1.029	1.007	0.835	0.694	0.676	0.645	0.676	0.637	0.618	0.567
90	1.529	1.455	1.209	0.998	0.977	0.917	0.930	0.904	0.848	0.830
95	1.870	1.767	1.457	1.207	1.171	1.103	1.103	1.085	1.018	1.022
97.5	2.118	2.080	1.713	1.413	1.338	1.279	1.267	1.252	1.166	1.190
99	2.496	2.341	2.020	1.645	1.568	1.450	1.468	1.433	1.342	1.382

Table 12. Average daily dose (ug/kg/day) of 1,3-D inhaled during the 62-day period of highest Telone use by residents living 100 m from fields in an area where Telone is applied to a total of 25 80-acre fields each year.

Age Group

	< 1		1 < 2		2 < 3		3 < 6		6 < 9	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Mean	0.4940	0.5352	3.0723	3.3330	2.6876	2.7770	2.1802	2.2126	1.9918	1.9861
Std Deviation	0.3548	0.3830	1.4181	1.5406	1.2335	1.2549	1.0277	1.0370	0.9528	0.9564
Percentile										
5	0.118	0.128	1.368	1.490	1.206	1.263	0.942	0.968	0.852	0.833
10	0.152	0.166	1.545	1.672	1.347	1.418	1.069	1.098	0.969	0.965
25	0.238	0.258	1.924	2.096	1.697	1.757	1.366	1.393	1.255	1.254
50	0.395	0.425	2.710	2.949	2.360	2.470	1.918	1.960	1.760	1.766
75	0.641	0.699	4.008	4.347	3.502	3.620	2.833	2.868	2.545	2.529
90	0.976	1.076	5.137	5.567	4.481	4.594	3.657	3.725	3.371	3.371
95	1.217	1.331	5.792	6.272	5.021	5.177	4.158	4.258	3.831	3.879
97.5	1.450	1.563	6.306	6.950	5.536	5.720	4.615	4.647	4.261	4.271
99	1.680	1.784	6.915	7.610	6.021	6.204	5.033	5.157	4.801	4.847

	9 < 12		12 < 15		15 < 18		18< 25		25 < 70	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Mean	1.4857	1.4065	1.1533	0.9575	0.9336	0.8872	0.8833	0.8610	0.8063	0.8020
Std Deviation	0.7344	0.6874	0.5796	0.4659	0.4444	0.4134	0.3970	0.4030	0.3694	0.4061
Percentile										
5	0.603	0.573	0.464	0.396	0.393	0.379	0.383	0.359	0.350	0.305
10	0.701	0.667	0.539	0.459	0.454	0.438	0.447	0.422	0.405	0.366
25	0.923	0.890	0.723	0.610	0.599	0.571	0.584	0.558	0.526	0.499
50	1.314	1.244	1.020	0.849	0.833	0.792	0.802	0.770	0.733	0.704
75	1.899	1.795	1.456	1.209	1.184	1.126	1.111	1.091	1.007	1.034
90	2.530	2.389	1.927	1.605	1.549	1.481	1.436	1.433	1.316	1.382
95	2.925	2.770	2.287	1.863	1.809	1.695	1.662	1.661	1.524	1.604
97.5	3.280	3.076	2.623	2.102	2.000	1.867	1.841	1.818	1.725	1.790
99	3.678	3.463	3.033	2.434	2.278	2.101	2.083	2.029	1.922	2.018

Table 13. Average daily dose (ug/kg/day) of 1,3-D inhaled during the 62-day period of highest Telone use by residents living 200 m from fields in an area where Telone is applied to a total of 25 80-acre fields each year.

Age Group

	< 1		1 < 2		2 < 3		3 < 6		6 < 9	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Mean	0.4605	0.5018	2.8772	3.1305	2.5168	2.6084	2.0439	2.0856	1.8713	1.8739
Std Deviation	0.3227	0.3596	1.3044	1.4290	1.1309	1.1633	0.9438	0.9779	0.8750	0.8917
Percentile										
5	0.112	0.117	1.229	1.308	1.089	1.124	0.851	0.854	0.758	0.745
10	0.139	0.155	1.382	1.492	1.222	1.278	0.978	0.986	0.895	0.871
25	0.219	0.243	1.778	1.935	1.568	1.633	1.265	1.293	1.169	1.170
50	0.374	0.401	2.647	2.865	2.324	2.404	1.865	1.887	1.700	1.694
75	0.607	0.664	3.775	4.152	3.289	3.433	2.687	2.734	2.426	2.428
90	0.906	0.998	4.704	5.195	4.114	4.278	3.387	3.499	3.103	3.164
95	1.112	1.238	5.266	5.730	4.585	4.726	3.771	3.915	3.536	3.593
97.5	1.300	1.441	5.770	6.269	5.016	5.128	4.206	4.249	3.908	3.920
99	1.534	1.688	6.289	6.837	5.542	5.607	4.605	4.696	4.281	4.346

	9 < 12		12 < 15		15 < 18		18< 25		25 < 70	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Mean	1.3973	1.3308	1.0879	0.9069	0.8808	0.8389	0.8368	0.8156	0.7646	0.7564
Std Deviation	0.6736	0.6511	0.5331	0.4368	0.4053	0.3864	0.3650	0.3789	0.3405	0.3774
Percentile										
5	0.539	0.511	0.423	0.356	0.362	0.348	0.358	0.328	0.322	0.284
10	0.648	0.604	0.501	0.423	0.424	0.405	0.419	0.390	0.376	0.336
25	0.872	0.824	0.679	0.567	0.570	0.530	0.554	0.523	0.503	0.462
50	1.254	1.199	0.982	0.819	0.799	0.766	0.779	0.745	0.706	0.675
75	1.816	1.723	1.388	1.170	1.128	1.081	1.064	1.044	0.961	0.984
90	2.351	2.273	1.816	1.521	1.439	1.382	1.328	1.350	1.231	1.286
95	2.687	2.563	2.107	1.726	1.643	1.579	1.522	1.527	1.409	1.483
97.5	2.965	2.847	2.365	1.940	1.850	1.741	1.692	1.704	1.581	1.659
99	3.358	3.142	2.680	2.170	2.043	1.922	1.877	1.904	1.767	1.851

Table 14. Average daily dose (ug/kg/day) of 1,3-D inhaled during the 62-day period of highest Telone use by residents living 500 m from fields in an area where Telone is applied to a total of 25 80-acre fields each year.

Age Group

	< 1		1 < 2		2 < 3		3 < 6		6 < 9	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Mean	0.2906	0.3157	1.8121	1.9672	1.5953	1.6652	1.2951	1.3295	1.2146	1.2220
Std Deviation	0.1948	0.2105	0.7170	0.7709	0.6263	0.6341	0.5264	0.5343	0.4984	0.5174
Percentile										
5	0.078	0.085	0.934	1.024	0.826	0.878	0.655	0.659	0.588	0.584
10	0.099	0.107	1.041	1.141	0.920	0.977	0.724	0.750	0.671	0.666
25	0.147	0.161	1.257	1.387	1.111	1.185	0.892	0.940	0.840	0.842
50	0.242	0.264	1.653	1.777	1.457	1.523	1.180	1.209	1.114	1.116
75	0.378	0.413	2.232	2.419	1.974	2.044	1.596	1.633	1.494	1.494
90	0.550	0.592	2.797	3.022	2.460	2.547	2.028	2.059	1.897	1.936
95	0.674	0.724	3.194	3.462	2.803	2.891	2.301	2.344	2.167	2.204
97.5	0.809	0.878	3.536	3.831	3.097	3.174	2.574	2.652	2.438	2.478
99	0.957	1.046	3.922	4.256	3.424	3.539	2.853	2.981	2.705	2.881

	9 < 12		12 < 15		15 < 18		18< 25		25 < 70	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Mean	0.9136	0.8829	0.7399	0.6103	0.5984	0.5640	0.5913	0.5588	0.5364	0.5024
Std Deviation	0.3929	0.3854	0.3262	0.2660	0.2473	0.2308	0.2375	0.2331	0.2169	0.2240
Percentile										
5	0.418	0.399	0.330	0.285	0.280	0.274	0.280	0.264	0.254	0.223
10	0.481	0.463	0.381	0.324	0.321	0.310	0.327	0.305	0.292	0.258
25	0.621	0.603	0.501	0.418	0.418	0.392	0.415	0.385	0.373	0.336
50	0.841	0.805	0.677	0.556	0.557	0.517	0.553	0.516	0.501	0.455
75	1.127	1.084	0.917	0.749	0.732	0.689	0.724	0.689	0.658	0.624
90	1.458	1.401	1.188	0.961	0.927	0.877	0.908	0.872	0.833	0.813
95	1.674	1.633	1.373	1.129	1.069	1.009	1.044	0.999	0.947	0.922
97.5	1.843	1.818	1.532	1.256	1.208	1.112	1.175	1.101	1.055	1.031
99	2.078	2.087	1.729	1.481	1.323	1.276	1.306	1.277	1.190	1.210

INPUT VARIABLES FOR EXPOSURE SIMULATION

Air concentrations

Table 15 gives the probability distributions of air concentrations (in ug/m^3) used as input in the exposure simulations. The first column gives percentiles of the distribution, interpolated from a four-parameter logistic curve fit to the original Calhoun *et al.* frequency distribution. The interpolated concentrations were adjusted by factors developed by the Environmental Monitoring Branch of DPR (Johnson, 1994b), shown in the second column. Environmental Monitoring did additional modeling with ISCST to develop an adjustment to approximate the effect of using a 36-point-per-section spatial grid to model air concentrations, instead of the relatively coarse 1-point-per-section grid used by Calhoun *et al.* The effect of the adjustment is to increase the variability of the air concentrations, while the mean level is unchanged. The adjusted concentrations appear in the third column. These adjusted values, reflecting annual average daily concentrations for points on a 36-point-per-section grid, were used for the estimation of lifetime average exposure.

Table 15. Air concentration (ug/m^3) probability distributions used in exposure simulation.

Percentile	Concentrations interpolated from 4-parameter logistic curve[a]	Adjustment factors to approximate 36-point grid[b]	Adjusted concentrations used to estimate lifetime exposure	Adjusted concentrations used to estimate 62-day exposure
0.0001	0.103842	0.69359	0.072024	0.278587
0.01	0.106063	0.84461	0.089582	0.346503
0.1	0.128835	0.93182	0.120051	0.464356
0.2	0.160687	0.96331	0.154791	0.598731
0.3	0.201575	0.98483	0.198517	0.767865
0.4	0.254546	1.00283	0.255267	0.987372
0.5	0.323879	1.01963	0.330237	1.277356
0.6	0.415684	1.03671	0.430944	1.666892
0.7	0.538854	1.05566	0.568846	2.200298
0.8	0.706593	1.07924	0.762583	2.949673
0.9	0.938983	1.11571	1.047632	4.052242
0.95	1.088601	1.15040	1.252327	4.844000
0.99	1.228987	1.23092	1.512784	5.851450
0.999	1.263482	1.35000	1.705701	6.597652
0.9999	1.266995	1.49000	1.887822	7.302097

a Curve fit to high-end air concentration frequency distribution in Calhoun *et al.* (1994)
b Johnson (1994b)

Seasonal exposure was estimated for July-August, the period of historically highest Telone use. To estimate average daily concentrations for this 62-day period, the adjusted annual concentrations were modified as follows. In the Calhoun *et al.* simulation, all positive air concentrations occurred in two 74-day periods (60 days of Telone use plus 14 additional days for the material to dissipate), one in spring and the other in summer. In their simulation, 70.7% of the total Telone was applied during the summer use period, with 40% mass loss to air. In the spring period, 29.3% of the Telone was applied with a mass loss rate of 25%. To approximate the average daily concentrations during the summer period, the fraction of the annual concentration contributed by the summer period was assumed to be (70.7 x 40) / [(70.7 x 40) + (29.3 x 25)] = 0.794. This fraction was condensed into 74 days by multiplying by 365/74. Since actual Telone applications will probably not be restricted to the four months assumed by Calhoun *et al.,* historical use patterns were consulted. Pesticide use reporting data showed that in 1988 and 1989, 58.5% and 49.9%, respectively, of 1,3-D applied to carrots in Kern County was applied during July and August. The simulation summer-period concentrations were further modified to represent concentrations for the 62 days of July-August by multiplying by (58.5 / 70.7) x (74/62). The net effect was to multiply the annual concentrations by 3.868. The concentrations thus modified, shown in the fourth column of Table 15, were used for the estimation of seasonal exposure.

For both lifetime and seasonal exposure assessments, the average air concentration experienced by each person was simulated by randomly selecting five values from the relevant air distribution. These values represented five locations where the individual spent his or her time. A weighted average of the five concentrations, weighted by the proportion of time spent at each location, was used as the air concentration experienced by the individual. The same five locations were used throughout a person's life, but the division of time between them changed as a function of age. The division of time between locations was a random variable in the simulation, and is discussed in the section on individual mobility.

To estimate exposure to persons living close to fields, additional modeling with ISCST was done by the Environmental Monitoring Branch to provide annual average daily air concentrations at 100-meter increments from edges of treated fields (Johnson, 1994a). The probability distributions of concentrations at 100, 200 and 500 meters, which were used in this exposure assessment, are given in Table 16. In calculating the average concentration experienced by a person, the first "location" selected, at which the greatest portion of time is spent, was considered the home location. The concentration for the home location was simulated by selecting one value from, e.g., the 100-meter distribution and one from the general distribution, then calculating a weighted average with the two values weighted one-third and two-thirds, respectively, to reflect the fact that a field is treated only once in three years. The two values were chosen to have a rank order correlation coefficient of 0.80, based on an observed correlation of 0.86 between ambient concentrations in the same township from year to year (personal communication, Bruce Johnson, Environmental Monitoring Branch, DPR, June 22, 1994). For seasonal exposures, the home concentration was simply a value from the relevant distance distribution. This home location concentration was then used as described in the preceding paragraph in the calculation of the average concentration over five locations.

Table 16. Annual average air concentrations (ug/m^3) at specified distances from treated fields[a].

Percentile	100 meters	200 meters	500 meters
0.00333	0.35393	0.30113	0.24996
0.01	0.37037	0.31439	0.26472
0.05	0.46011	0.40619	0.29312
0.1	0.50768	0.44753	0.31998
0.15	0.55763	0.48264	0.35456
0.2	0.58246	0.51404	0.36323
0.25	0.60290	0.55147	0.37940
0.3	0.64604	0.58207	0.38904
0.35	0.70250	0.62520	0.40306
0.4	0.77585	0.74610	0.41207
0.45	0.87638	0.85215	0.45127
0.5	0.90497	0.90723	0.49474
0.55	0.97657	0.96199	0.55052
0.6	1.05653	1.02253	0.57466
0.65	1.17366	1.17403	0.62218
0.7	1.31421	1.25398	0.67783
0.75	1.43991	1.34267	0.75510
0.8	1.54023	1.42689	0.79173
0.85	1.63177	1.51078	0.83575
0.9	1.75806	1.59046	0.87488
0.95	1.95317	1.78902	0.99410
0.99	2.20345	1.98031	1.27958
0.99667	2.26113	2.04338	1.35822

a Johnson (1994a)

Individual mobility within the Telone use area

Individuals were assumed to divide their total time between five randomly selected locations within the Telone high-use area. The average air concentration to which an individual is exposed was calculated, as described above, as the mean of the five location concentrations weighted by the proportion of time spent in each location. The mean division of time between locations was derived for each age interval from Table 4.5 in the Arab's *Survey of Children's Activity Patterns* (Wiley, 1991a) and Table 3.3 in *Activity Patterns of California Residents* (Wiley, 1991b). Wiley's "time at home" was used as the time spent in the first selected location, his "time in transit" was divided equally between two locations, and the remaining time in the day divided between two others. The division of time between these last two locations was 70/30% for infants, stepping down by age interval to a 50/50% division for adults. Individual time divisions were allowed to vary from the mean by randomly generating them from a multinomial distribution with *n* chosen to give fairly small variability in the youngest intervals and greater variability in the adolescent and adult intervals. The distributions for time division are shown in Table 17.

Table 17. Probability distributions of time spent in five locations

Age interval	Multinomial *n* parameter		Average minutes per day spent in location				
			1	2	3	4	5
0 to 1	100	Male	1157	27	27	160	69
		Female	1151	38	38	150	63
1 to 2	100	Male	1157	27	27	160	69
		Female	1151	38	38	150	63
2 to 3	90	Male	1134	31	31	170	74
		Female	1099	44	44	151	102
3 to 6	90	Male	1134	31	31	170	74
		Female	1099	44	44	151	102
6 to 9	80	Male	1044	59	30	170	137
		Female	1021	27	26	256	110
9 to 12	80	Male	1020	31	31	250	108
		Female	968	47	46	265	114
12 to 15	70	Male	893	61	60	256	170
		Female	917	49	49	255	170
15 to 18	70	Male	893	61	60	256	170
		Female	917	49	49	255	170
18 to 25	60	Male	782	75	74	255	254
		Female	862	60	60	229	229
25 to 70	60	Male	798	60	59	262	261
		Female	960	51	51	189	189

Breathing rates

An individual's average breathing rate in each age interval was calculated as a weighted average of his rates at each of four activity levels: resting, light, moderate and heavy. The rate at each level was weighted by the proportion of time the individual was assumed to spend at that level. Breathing rate at each activity level was a random variable. The proportion of time at each level was a constant fixed for each age interval.

For infants (0-1 year), a triangular distribution of breathing rates was derived from the mean and range reported in the *Exposure Factors Handbook*, Table 3A-2 (USEPA, 1990). The mode of the triangular distribution was set equal to the lower limit of the range in order to match the EPA mean. For the other age intervals, uniform distributions were derived from data in the ARB's *Measurement of Breathing Rate and Volume* (Adams, 1993). In each case, the range was chosen to include all the reported rates relevant to an activity level for a specific sex and age group. These ranges are given in Table 18. Data were unavailable for children aged 1-3, so the breathing rates for 3-6-year-olds were used. The breathing rates of an individual at different activity levels, within and across ages, were assumed to have the rank order correlations shown in Table 19. (The value of 0.8 on the diagonal represents the correlation between breathing rates of the same individual at the same activity level, at different ages.) It was not possible to incorporate correlations between body weight and breathing rates because the software used did not handle them correctly. Correlation coefficients of body surface area and breathing rate within age intervals and activity levels, reported in Adams (1993), ranged from 0.06 to 0.84, with a mean of 0.40. The correlation of body weight and breathing rate may be similar. The effect of omitting this correlation from the simulation was probably to increase the estimated exposures to an unknown degree, because if the greater exposures associated with high breathing rates tended to be paired with high body weights, the exposure would be mitigated somewhat.

The proportion of time assumed to be spent at each activity level is shown in Table 20.

Body weight

Body weight distributions were taken directly from Tables 5A-1 through 5A-4 in the *Exposure Factors Handbook* (USEPA, 1990). The histograms reported in these tables were used without smoothing. Upper and lower bounds were supplied to produce a mean weight equal to the mean given in the EPA tables. An individual's weights in different age intervals were assumed to have the rank order correlations shown in Table 21.

Residence time and lifetime

In estimating lifetime exposures, lifetime length was fixed at 70 years. Exposure was estimated separately for fixed times of residence in the Telone use area of 30 and 70 years. Since the exposure assessment is viewed as applying to any areas where Telone may be reintroduced in the proposed way, and not just to the specific township in Kern County for which Calhoun *et al.* modeled air concentrations, it was not reasonable to define a distribution of residence time in the area. Instead, the estimated exposures are those expected to result from living the first 30 or 70 years of a 70-year lifetime in any area with Telone use like that described here.

Table 18. Breathing rates (L/min) as ranges of uniform distributions.

Age interval	Activity level	Male	Female
0 to 1	All	Triangular (0.25, 0.25, 2.09)	
1 to 2	Resting	5-7	
	Light	7-11	
	Moderate	8-15	
	Heavy	14-22	
2 to 3	Resting	5-7	
	Light	7-11	
	Moderate	8-15	
	Heavy	14-22	
3 to 6	Resting	5-7	
	Light	7-11	
	Moderate	8-15	
	Heavy	14-22	
6 to 9	Resting	5-9	
	Light	10-17	
	Moderate	11-23	
	Heavy	20-45	
9 to 12	Resting	5-9	
	Light	10-17	
	Moderate	11-23	
	Heavy	20-45	
12 to 15	Resting	6-12	5-10
	Light	7-17	7-15
	Moderate	17-35	15-27
	Heavy	25-72	24-59
15 to 18	Resting	6-12	5-10
	Light	7-17	7-15
	Moderate	17-35	15-27
	Heavy	25-72	24-59
18 to 25	Resting	7-11	5-10
	Light	8-18	6-15
	Moderate	18-42	15-28
	Heavy	48-80	39-62
25 to 70	Resting	7-11	5-10
	Light	8-18	6-15
	Moderate	18-42	15-28
	Heavy	48-80	39-62

Table 19. Rank order correlation coefficients between individual's breathing rates at different activity levels, within and across age intervals.

	Resting	Light	Moderate	Heavy
Resting	0.8	0.5	0.5	0.4
Light		0.8	0.5	0.4
Moderate			0.8	0.5
Heavy				0.8

Table 20. Proportion of time at each activity level (constant in exposure simulation).

Age interval		Activity level			
		Resting	Light	Moderate	Heavy
0 to 1	Male	1	0	0	0
	Female	1	0	0	0
1 to 2	Male	0.8	0.15	0.04	0.01
	Female	0.8	0.15	0.04	0.01
2 to 3	Male	0.75	0.2	0.04	0.01
	Female	0.75	0.2	0.04	0.01
3 to 6	Male	0.7	0.2	0.08	0.02
	Female	0.7	0.2	0.08	0.02
6 to 9	Male	0.7	0.17	0.10	0.03
	Female	0.7	0.2	0.08	0.02
9 to 12	Male	0.6	0.32	0.05	0.03
	Female	0.6	0.33	0.05	0.02
12 to 15	Male	0.6	0.32	0.05	0.03
	Female	0.6	0.33	0.05	0.02
15 to 18	Male	0.5	0.4	0.06	0.04
	Female	0.5	0.42	0.05	0.03
18 to 25	Male	0.4	0.50	0.06	0.04
	Female	0.4	0.52	0.05	0.03
25 to 70	Male	0.35	0.57	0.05	0.03
	Female	0.35	0.60	0.04	0.01

Table 21. Rank order correlation coefficients between the weights of an individual at different ages.

	0 to 1	1 to 2	2 to 3	3 to 6	6 to 9	9 to 12	12 to 15	15 to 18	18 to 25	25 to 70
0 to 1	1.00	0.92	0.82	0.72	0.61	0.61	0.61	0.61	0.61	0.61
1 to 2		1.00	0.92	0.82	0.72	0.61	0.61	0.61	0.61	0.61
2 to 3			1.00	0.92	0.82	0.72	0.61	0.61	0.61	0.61
3 to 6				1.00	0.92	0.82	0.72	0.61	0.61	0.61
6 to 9					1.00	0.92	0.82	0.72	0.61	0.61
9 to 12						1.00	0.92	0.82	0.72	0.61
12 to 15							1.00	0.82	0.82	0.72
15 to 18								1.00	0.82	0.82
18 to 25									1.00	0.82
25 to 70										1.00

Exposure appraisal

The estimated exposure distributions may be regarded as providing a reasonable idea of the highest exposures that should be expected under the use scenario. The distributions should not be interpreted as reflecting the exposures of a population of individuals, but as a set of values that are likely to bracket the exposure of an individual in this situation.

It should be noted that the large differences between estimated seasonal exposures of children less than one, and children from one to three, are largely produced by the input breathing rate distributions. The breathing rate data for infants under one came from a different source than all the other breathing rate data. In addition, no data were available for children from one to three, so the rates for three- to six-year-old children were used. In combination with the small body size of these children, this may have overestimated their exposures.

An important limitation of this exposure assessment is that it used 1,3-D concentrations in outdoor air to estimate 24-hour/day exposure, even though most people spend the greatest part of the day indoors. Since the registrant provided no data on indoor concentrations, and since no appropriate surrogate data were available to estimate them, it was judged that there was no alternative.

It is important to remember that these estimates of non-occupational exposure apply only to the use scenario of Calhoun *et al.*, which specified Telone applications to only 2000 acres per year in an area which has 8500 acres of carrots alone. Any change in the use scenario would require a new exposure assessment.

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