DDVP: Metabolic Fate, Dermal Transport and Human Exposure Data

by

Harvard R. Fong, Associate Industrial Hygienist
Tareq A. Formoli, Associate Environmental Research Scientist

HS-1540 August 1, 1991
Revised June 14, 1993

California Environmental Protection Agency
Department of Pesticide Regulation
Worker Health and Safety Branch
1220 N Street
Sacramento, California 95814

ABSTRACT

DDVP (dichlorvos) is a volatile organophosphate insecticide. Its uses in field agriculture are very limited. Its major uses are structural (commercial and home) and livestock pest control. It is rapidly and fully metabolized in mammals. Dermal absorption of DDVP was 13 percent in laboratory rats. Human exposure studies, largely on non-agricultural subjects, yielded estimated absorbed daily dosages ranging from 0.3 ug/kg/day (pet owners) to 135 ug/kg/day (child resident after home-use fogger).

This exposure assessment was written to define indoor exposure potential to DDVP which has shown adverse effects such as cholinergic signs and hepatotoxicity in laboratory animals.

APPENDIX B

Department of Pesticide Regulation
Worker Health and Safety Branch

Human Exposure Assessment

DDVP

August 1, 1991
Revised June 14, 1993

GENERAL CHEMISTRY

DDVP (2,2-dichlorovinyl dimethyl phosphate / VAPONA^{R} / dichlorvos) is a volatile insecticide of moderate toxicity. It has a vapor pressure of 1.2×10^{-2} Torr (20^{o}C) and a boiling point of 35^{o}C at 0.05 Torr. Its chemical formula is $C_4H_7Cl_2O_4P$ and the molecular weight is 221 g/mole. It is soluble to 1 percent in water and very soluble in alcohols and organic solvents.

FORMULATIONS

In June 1993, there were 59 DDVP-containing pesticides products registered in California. There were 4 pet collar products for control of fleas and ticks. The rest were foggers, pressurized sprays, and liquids that were labeled for control of nuisance insects, pests in or on structures (homes, apartments, warehouses, office buildings, etc.), and pests associated with livestock production and storage of agricultural commodities. Home-use materials (foggers, pet collars, pressurized sprays and liquids) are primarily marketed to the general public to be applied in residences by the occupants.

The home-use aerosols usually have less than one percent DDVP in their formulation and in many cases the DDVP is only one of several materials in the product. The collars have ~10 percent DDVP for dogs and ~5 percent for cats. Home-use foggers are 0.5 percent DDVP.

REPORTED USAGE

The major uses of DDVP as reported by the 1990 Pesticide Use Report are shown in Table 1.

TABLE 1: Reported Uses of DDVP During 1990 (DPR, 1992).

USE	LB APPLIED	PERCENT OF TOTAL LB. APPLIED
Struc. Pest Cont.	2,252	46%
Cattle, Beef and Dairy	826	17%
Poultry	715	15%
Rights-of-way	276	6%
Landscape and Ornamentals	256	5%
Vertebrate Pest Control	174	3%
Other Uses	398	8%
TOTAL	4,897	100%

Formoli, WH&S, 1992

* - DPR, 1984-1990

Formoli, WH&S, 1993

The reported sale of DDVP in California, as shown in Figure I, has been in a sharp decline for last several years (DPR, 1984-1990). The reported sale for 1984 was 117,213 lbs DDVP and it was reduced to only 17,301 lbs for 1990. The discrepancy between pounds used and pounds sold in 1990 are in the home-use formulations which did not require use reporting.

Use of DDVP in agriculture has been in decline for a number of years. Livestock use has shown the material to not be adequately effective in controlling horn and face flies and has resulted in reduction of use. Poultry producers, as reported by the UC Agricultural Extension, have great concerns over egg and meat residues and potential intoxication of the poultry from the "tight- ventilation" conditions of the poultry house. Outside the production facility some formulations are still apparently used.

Structural pest control use has dwindled to a very small user base. Because of DDVP's volatility, it has good "penetrating power" and is used for crack-crevice or spot-type treatments.

DERMAL ABSORPTION

A dermal absorption study of DDVP technical in male rats was submitted by the registrant (Jeffcoat, 1990). Rats were divided into three dose groups. The fur on the back of each rat was clipped. ^{14}C-labeled DDVP was mixed with unlabeled DDVP and applied to the clipped back of rats at three dose levels (30, 3, and 0.3 ug/cm^2). The dosing solution was prepared with water. Each dose group was subdivided into three sacrifice times of 10, 24, and 120 hours. Exhaled $^{14}CO_2$, urine, and feces were collected at 10 hours, 24 hours and each subsequent 24-hour period until sacrifice.

The overall total radioactivity recovery of the administered dose ranged from 96.0 to 99.3 percent. Percent dermal absorption at each observation period and dose level is shown in Table 2. Dermal absorption of DDVP ranged from 10 to 13 percent of the applied dose in rats observed for 120 hours. A dermal absorption of 13 percent will be used in this document to estimate absorbed daily dosage.

TABLE 2: Percent DDVP Dermal Absorption in Rats.

Applied Dose (ug/cm^2)	Observation Period (hours) 10	24	120
30.0	13.3	11.4	12.9
3.0	10.7	11.0	12.7
0.3	7.3	10.8	9.8

Formoli, WH&S, 1992

METABOLIC DISPOSITION

DDVP is rapidly metabolized by mammals (Hudson, 1971). There is very little parent material found in tissues or biological media after exposure to DDVP. The metabolic products include dimethyl phosphate (DMP), dichloro-acetic acid, dichloro-ethanol glucuronide and carbon dioxide (Hudson, 1972). After oral or intraperitoneal administration of ^{14}C (vinyl)-DDVP, most of the radiolabel, 27 to 32 percent, was found in the urine, 16 percent in the expired CO_2 and 3 percent in the feces (24 hours post-application) (Shell, 1970).

An early multiphasic study of different carriers and radiolabels (Casida, 1962) used DDVP labeled at either the alpha-dichlorovinyl carbon (^{14}C) or the phosphorous (^{32}P). Rats were orally dosed with the test material in either water, corn oil, or propylene glycol at rates of 10 or 4 mg/kg. The data is reported in parts-per-million and is not convertible to ug or percentage. The results indicate that the ^{32}P label is retained in the bone, probably as incorporated phosphate. The ^{14}C label appears, even after 7 days, in the liver. But the radioactive residue was not DDVP and was most likely ^{14}C that was removed from DDVP, metabolized into the carbon-pool and utilized by the body for other functions.

DMP is an excellent indicator of total dermally absorbed doses of DDVP (McDonald, 1991). Six spare rats (4 dosed 2 controls) from the dermal absorption study (Jeffcoat, 1990) were dosed in the same manner. The urine of these rats was analyzed for DMP by British Columbia Research Corporation in Canada. The analyses were performed under a separate project from the dermal absorption study. No sample storage stability or spike recoveries were determined for DMP because of inadequate sample volumes. The amount of DMP found in urine was corrected for DDVP molecular weight and was reported as percentage of the applied dose. Total urinary DMP was equivalent to 37 to 45 percent, and in one rat to 82 percent, of DDVP applied dose.

WORKER ILLNESSES

From 1982 to 1990, there were 78 cases of human illness/injury reported by WH&S in its Pesticide Illness Surveillance Program that were associated with exposure to DDVP. These include 60 systemic illnesses, 12 eye injuries and 6 skin injuries. Many of these events also included a second or third pesticide material associated with the illness.

WORKER EXPOSURE

There are no studies available that could be considered standard agricultural worker exposure studies. This stems from the properties of the material and its primary mode of application. DDVP is usually applied in such a way as to maximize its fumigating properties. The 1990 ACGIH Threshold Limit Value (TLV^R) for DDVP is 0.9 mg/m^3 (0.9 ug/L, 0.1 ppm). The following summaries are from available DPR Registration Library files

and WH&S data files for DDVP exposure. It is very difficult to approximate the degree of dermal contact and subsequent transfer of DDVP from surfaces to skin. Additionally, there is no information available to estimate dermal exposure in the diverse scenarios indicated.

In one study a warehouse of ~95,000 ft^3 was fumigated with 236 grams of 20 percent DDVP. The maximum theoretical concentration would be 17.7 ug/L. Actual air concentration was 6.3 ug/L at 2 hours post application. Air concentration dropped rapidly over the monitored time period (21 hours). Workers re-entering the fumigated warehouse 12 hours after fumigation could be exposed to 0.21 ug/L. The calculated 8-hour Time Weighted Average (TWA) would be 0.124 ug/L. In a different warehouse using the same exposure parameters, surface residue was shown to be 1.43 mg/m^2 two hours after application and 0.19 mg/m^2 at 12 hours post-application (Knight, 1985).

A study reported in the public domain (Gold, 1985) investigated professional home-applicator exposure. This was not a registrant submitted document. Both dermal and inhalation exposure were measured, as were acetylcholinesterase (AChE) activity and urinary metabolites. The residents of the homes were also monitored. The applicators were equipped with interior and exterior clothing dosimeters. Washes measured hand exposure and air pumps connected to ethylene glycol-loaded impingers measured airborne DDVP levels. The applications took place in 20 residences, averaging 25.5 minutes per residence to apply 19.6 grams of DDVP (0.19 g/m^2) each. Applicators wore coveralls and rubber gloves.

Applicator dermal exposure was 2.35 mg/hr. The greatest exposure was to the face (20 percent of total), followed by the chest (17 percent) then the lower legs (16 percent). A 20 percent clothing penetration factor, empirically derived by the authors, is reflected in the 2.35 mg/hr dermal exposure. Hands accounted for less than 1 percent of the exposure, validating the use of rubber gloves as protective equipment. Airborne levels were 0.021 ug/L. Using 29 liters per minute (LPM) as the breathing rate over the 25.5 minutes, potential airborne exposure was 15 ug/application. The rate of inhalation exposure was 36.5 ug/hr. Total worker exposure was 2.39 mg/hr.

Analysis of urine samples from both applicators and residents failed to detect either DDVP or one of the metabolites, DCAA. Assay sensitivity was 1 ppb. Both applicators did show reduction in pseudo-acetylcholinesterase activity, up to 50 percent inhibition for one worker from baseline. Red blood cell (RBC) AChE results were inconclusive with one worker showing increased RBC AChE.

There are no DDVP exposure data for livestock applicators. The exposure data for cyromazine applicators were used as surrogate to estimate livestock applicator exposure to DDVP. Workers applied cyromazine (0.1% solution) to chicken manure using hand-held, backpack, or portable sprayers (Merricks, 1988). The applicators wore long-sleeved shirts, long pants, rubber gloves, socks, and shoes. Dermal exposure was monitored by attaching alpha-cellulose patches to the various parts of the body. Hand exposure was determined by wearing cotton gloves underneath the rubber gloves. A total of nine replications of mixing and applying were conducted at three locations. Dermal exposure was estimated at 1.44, 69.69, and 0.15 mg/kg active ingredient handled for applicators using hand-held, backpack, and portable sprayers, respectively.

DDVP is applied to livestock using hand application equipment. The maximum application rate is two ounces of a one percent solution (0.035 kg a.i./gal) per adult animal. An applicator could treat a maximum of 100 animals in an eight-hour workday. This is equivalent to 1.56 gallons of the spray solution or 0.05 kg of DDVP applied by an applicator during a workday. Using the worst case of the surrogate data (backpack), DDVP dermal exposure to livestock applicators is estimated at 3.83 mg/workday.

The rather high vapor pressure of DDVP discredits the use of inhalation exposure data from cyromazine or any other low vapor pressure chemicals. A study of mushroom house workers' exposure to DDVP found that the highest DDVP level in the air (0.55 ug/L) was during the application (Maddy, 1982). Inhalation exposure of livestock applicators in Table 3 was calculated assuming that they would be exposed to the same DDVP level as observed in the air during a mushroom house application.

RESIDENT EXPOSURES

Environmental monitoring of the homes treated by PCO's indicated that DDVP was present in the air for up to 24 hours post application (Gold, 1985). At two-hours post-application, air levels monitored by stationary air pumps were 0.55 ug/L. At 24 hours post-application air levels were 0.21 ug/L. Fallout dosimeters suggested an average deposition of 0.32 ug/cm^2/hour.

A second article not submitted by the registrant (Cavagna, 1969) investigated the AChE inhibition in patients admitted to a hospital. Of special concern were children, both babies (ages 7 to 21 months, mean 13 months) and children (ages 2 to 7, mean 4 years). Both RBC and pseudo-AChE were monitored every three days. Air levels of DDVP given off by the resin strips hanging in the children's rooms were also monitored. The older group of children, exposed an average of 22 days, showed no reduction in either RBC or pseudo-AChE, even when exposed for 16 hours a day to levels up to 0.21 ug/L. The younger group, exposed an average of 17 days (9 to 33 days), showed some reduction (9 to 45 percent, mean of 25 percent) in pseudo-AChE, none in their RBC AChE, when exposed for 24 hours/day to levels ranging between 0.10 ug/L and 0.21 ug/L. No one developed any cholinergic signs. There was no change in either parameter when the air levels were less than or equal to 0.10 ug/L.

Airborne levels for DDVP from the resin strips showed seasonal variation. In the winter, air levels peaked at 0.28 ug/L within the first 15 days of use and dropped to lower rates with increasing time. In the summer, with increased ventilation (open windows), the highest level reached was 0.18 ug/L, on day 4 to 6 post-introduction. Levels dropped below 0.100 ug/L in less than 10 days and had decreased to <0.020 ug/L in 20 to 30 days.

There are three DPR/Worker Health and Safety HS Reports dealing with DDVP exposure from home fogger use (Maddy, 1981, Maddy, 1984, and Goh, 1987). The earliest study (Maddy, 1981) was done using 0.5 percent DDVP foggers. Only air monitoring was conducted. Three rooms monitored showed a mean concentration of 0.41 $\pm$0.26 mg/m^3 at the time of allowed reentry (2.5 hours from the start of fogging). Only one room was followed for 24 hours or more. Its air residue level was 13.0 ug/m^3 at 24 hours, 10.0 ug/m^3 at 48 hours and below the limit of detection (unspecified) at 72 hours.

The second home-fogger study (Maddy, 1984) also addressed airborne DDVP levels. After use of a 0.5 percent DDVP fogger, air samples were taken at selected time intervals after the two hour treatment phase. Between 1 and 2 hours, the DDVP concentration averaged 0.4 $\pm$0.5 ug/L [n=10]; between 4 and 6 hours it was 0.100 $\pm$0.100 ug/L [n=11]; between 6 and 8 hours it was 0.040 $\pm$0.050 ug/L [n=8]; and at 24 hours the concentration had remained at 0.040 $\pm$0.030 ug/L [n=10]. Surface residue monitoring showed average residue levels of 1.2 $\pm$2.2 ug/cm^2 [n=10] at 2 hours post and 0.44 $\pm$0.62 ug/cm^2 [n=8] at 6 hours post, declining to 0.3 $\pm$0.4 ug/cm^2 [n=8] at 24 hours.

The third study (Goh, 1987) used the same percentage of a.i. in the fogger but only sampled surface residues. Both a theoretical and an actual measurement of DDVP deposits during fogging (first 15 minutes of application) were given. Three sites were sampled, each site having its own fogger. The mean theoretical maximum during fogging was 5.7 $\pm$1.0 ug/cm^2 and the mean actual maximum was 6.1 $\pm$0.6 ug/cm^2, indicating that a preponderance of the fogger's active ingredient initially impinge on the floor.

From the preceding studies, Average Annual Daily Dosages (AADD) and Lifetime Average Daily Dosages (LADD) were estimated. The following table displays the assumptions used in the AADD/LADD calculations. AADD was derived from Absorbed Daily Dosage multiplied by the Days Exposed per year. LADD was derived by multiplying AADD by Career Lifetime and dividing by Lifetime (except in case of Residents and Children, see footnotes).

TABLE 3: Annual Average and Lifetime Average Daily Dosage (AADD & LADD) for persons using or incidentally exposed to DDVP. Weight of adult male worker for dosage calculation is 70 kg. Dermal absorption is 13 percent (see dermal absorption section) and inhalation uptake is 50 percent (Raabe, 1988). Career lifetime for workers is 40 years. Lifetime is 70 years.

Exposure Type	TWA Air Levels [ug/L]	Air Exposure Time	Potential Dose Dermal/Inhal.[a] mg/day	Absorbed Daily Dosage ug/kg/day	Days Exposed	AADD[b]	LADD[c]
Warehouse							
12hr-post	0.12	8 hr.	ND / 1.67	12	17[d]	0.6	0.3
Struct. PCO	0.02	2 hr.	4.7 / 0.07	9	30	0.8	0.4
Livestock applicator	0.55	8 hr.	3.8 / 7.66	62	27	4.6	2.6
Resident[e]	0.10	16 hr.	NS / 0.71	5	6	0.1	0.06[f]
Resident[g]	0.20	16 hr.	NS / 1.42	10	6	0.2	0.11[f]
Child[h]	0.04	24 hr.	0.4 [i] / 0.24	16	6	0.3	0.10[j]
Child[k]	0.14	24 hr.	NS / 0.85	40	60[l]	6.6	3.1[j]
Child[m]	0.10	24 hr.	NS / 0.60	29	60[l]	4.8	2.2[j]
Pet Owner[n]	0.02	1 hr.	NS / 0.04	0.3	60[l]	0.05	0.03

a. inhalation dose = (air level)(exposure time)(29 LPM breathing rate, EPA, 1987).
b. ug/kg/day/year.
c. ug/kg/day/lifetime (Assuming children's body surface and weight increases are proportional to increases in the exposure).
d. application every 3 weeks.
e. exposed to home-use fogger air residue, breathing rate 7.4 LPM [resting (EPA, 1987)].
f. 40 years exposure.
g. exposed to SPCO application residue, breathing rate 7.4 LPM [resting].
h. child weighs 10.5 kg, body surface area of 3925 cm^2, breathing rate 4.2 LPM (Snyder, 1974), exposed to fogger residue at six hours post-ventilation and LADD calculated for 16 years.
i. DDVP transfer factor [McDonald, 1991]: (4 percent/hr)(6 hr contact/day) (0.4 ug/cm^2, Maddy, 1984).
j. 16 years as a child and 24 years as an adult in a 70-year lifetime.
k. from resin strip air-levels which caused inhibition in pseudo-AChE (Cavagna, 1969)
l. 10 days of high exposure/strip replaced every 2 months
m. from resin air-levels which did not cause inhibition in pseudo-AChE (Maddy, 1984)
n. collar is 1/10th weight of resin strip, thus 1/10th residue exposure from resin strip.

ND - no data
NS - not significant, material primarily airborne vapor or not available for dermal contact.

Fong, WH&S, 1993

A more recent DDVP indoor fogger exposure study was conducted in three phases in a hotel in British Columbia, Canada (McDonald, 1991). The first phase monitored residue fallout on the carpet, airborne residues, and carpet residue transfer to wipe fabrics at various intervals during 24 hours following treatment of rooms with a 0.5% DDVP fogger. The second phase monitored residue transfer from the carpet to the clothing (used as dosimeters) of four human volunteers performing Jazzercise^R routines and stretches at various times after the fogger treatment. The Jazzercise^R routines were used to conduct reproducible motions with extensive floor contact. Urine and blood samples were also collected in this phase for dimethyl phosphate (DMP) and cholinesterase (ChE) analysis, respectively. The third phase monitored urinary DMP and blood ChE activity of volunteers wearing shorts only and performing the same routines and stretches in DDVP treated rooms. The volunteers performed the routines for 20 minutes each time, for a total of 160 minutes in phase II and 80 minutes in phase III.

In phase II, DDVP airborne residues were 395, 234, and 50 ug/m^3 at three, nine, and 27 hours post-treatment, respectively. Clothing dosimeters contained 2010, 1506, and 1269 ug/person/20 minutes at three, six, and nine hours post-treatment, respectively. Gloves contained 99 ug/person/20 minutes at three hours and 67 ug/person/20 minutes at nine hours post-treatment. Urinary DMP averaged 390 ug/person/hour of exposure in phase II and 432 ug/person/hour of exposure in phase III, suggesting that the tight-fitting clothing worn in phase II did not provide significant exposure protection. Blood acetyl-ChE activities of collected samples were within the normal range. The results for pseudo-ChE activities were inconclusive because of some missing or lost samples. Estimated absorbed daily dosages (ADD) for adult and child from dermal, inhalation, and non-dietary ingestion exposure to DDVP (Table 4) is based on average airborne residues and residues found in clothing dosimeters. ADDs based on urinary DMP are also shown in Table 4.

TABLE 4: DDVP Estimated Absorbed Daily Dosages from Clothing Dosimetry vs. Biological Monitoring Following DDVP Indoor Fogger Use for Resident Children and Adults.

	dermal	Inhalation	Ingestion	ADD	AADD**	LADD
				(ug/kg/day)		
Clothing Dosimetry (C.D.):						
Adult	57.2	31.5	1.1	89.8	1.48	0.84
Child	84.6	33.3	16.6	134.5	2.21	1.01
Biological Monitoring (B.M.):						
Adult	73.0*		1.1	74.1	1.22	0.70
Child	107.9*		16.6	124.5	2.05	0.88

* - Dermal and inhalation for six hours of activity based on urinary DMP corrected for the ratio of DDVP/DMP molecular weights (1.754) plus inhalation for 18 hours of light activity and rest.

**- Six days in a year.

Based on: Six hours of activity and 18 hours of light activity and rest, dermal absorption of 13% (Jeffcoat, 1990), Inhalation uptake of 50% (Raabe, 1988), urinary DMP corrected for DDVP molecular weight and ratio of children body surface area over body weight to that of an adult.

	Adult	Child	Reference
Clothing (C.D./B.M.)	none/shorts	none/diaper	-
Body weight (kg)	70	10.5	Snyder, 1974
Body surface (cm^2)	17700	3925	Snyder, 1974
Inhalation rate (m^3/hr)	1.74 | 0.44	0.25 | 0.09	EPA, 1987
Hand residue ingestion (%)	5	50	Ross, 1992
Lifetime exposure (years)	40/70	16+24/70	-

Formoli, WH&S, 1992

The estimates of exposure based on clothing dosimetry and biological monitoring for home residents in Table 4 are very close. Biological monitoring is a more reliable indicator of exposure compared to passive dosimetry.

REFERENCES

Casida, J.E., L. McBride, and R.P. Niedermeier. 1962. Metabolism of 2,2- dichlorovinyl dimethyl phosphate in relation to residues in milk and mammalian tissues. DPR Registration. Doc. No. 215-063 <40344>.

Cavagna, G., G. Locati and E.C. Vigliani. 1969. Clinical effects of exposure to DDVP (Vapona) insecticide in hospital wards. Arch. Environ. Health 19:112-123.

Department of Pesticide Regulations (DPR). 1984-1990. Pesticide sold in Californnia, 1984 to 1990 annual report. Sacramento, California.

Department of Pesticide Regulations (DPR). 1992. Pesticide use report, annual 1990. Sacramento, California.

Environmental Protection Agency (EPA). 1987. Pesticide Exposure Assessment Guidelines, Subdivision U.

Goh, K.S., S. Edmiston, K.T. Maddy, and S. Margetich. 1987. Dissipation of DDVP and propoxur following the use of a home fogger: Implication for safe reentry. Bull. Environ. Contam. Toxicol. 39:762-768.

Gold, R.E. and T. Holcslaw. 1985. Dermal and respiratory exposure of applicators and residents to dichlorvos-treated residences. ACS Symposium Series #273.

Hutson, D.H., E.C. Hoadley and B.A. Pickering. 1971. The metabolic fate of [vinyl-1-^{14}C] dichlorvos in the rat after oral and inhalation exposure, . Xenobiotica 1:593.

Hutson, D.H. and E.C. Hoadley. 1972. The metabolism of [^{14}C-methyl] dichlorvos in the rat and mouse. Xenobiotica 2:107.

Jeffcoat, A.R. 1990. Dermal absorption of dichlorvos in rats. Research Triangle Institute, Research Triangle Park, N.C. DPR Registration Doc. No. 235-101.

Knight, L.P. 1985. Virginia Chemical: Lethalaire A-41 Insecticide air concentration/worker exposure study. DPR Registration. Doc. No. 235-058.

Maddy, K.T., S. Edmiston and A.S. Fredrickson. 1981. Monitoring residues of DDVP in room air and on horizontal surfaces following use of a room fogger. DPR HS-897.

Maddy, K.T., S. Edmiston and E. Ochi. 1984. Dissipation of DDVP and propoxur following the release of an indoor fogger - A preliminary study. DPR HS-1259.

Maddy, K.T., F. Schneider, J. Lowe, E. Ochi, S. Fredrickson, and S. Margotich. 1982. Vapona (DDVP) exposure potential to workers in mushroom houses in Ventura county, California in 1981. DPR HS-861.

McDonald, E.C. 1991. Indoor fogger dermal and inhalation exposure study with DDVP. British Columbia Research Corporation, British Columbia, Canada, DPR Registration Doc. No. 235-113.

Merricks, L.D. 1988. Exposure of workers to cyromazine during the mixing, loading and application of of Larvadex® 2 SL in poultry houses. DPR Registration Doc. No. 414-084.

Raabe, O.G. 1988. Inhalation uptake of xenobiotic vapors by people. University of California, Davis. Performed as contract to California Air Resources Board No. A5-155-33, March .

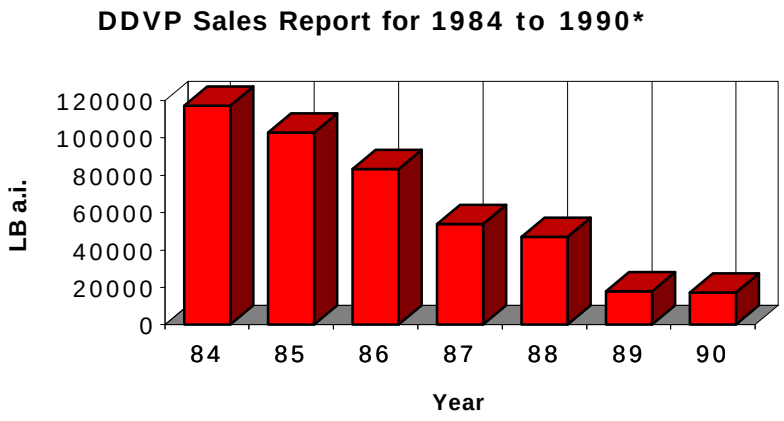
Ross, J.H. 1989. Pers. Comm. on chlorpyrifos dermal transfer after indoor pesticide fogger use, unpublished data.

Ross, J.H., H.R. Fong, , T. Thongsinthusak, and R.I. Krieger. 1992. Experimental method to estimate indoor pesticide exposure to children. In Similarities and Differences Between Children and Adults: Implications for Risk Assessment. PP 226-241. ed., P.S. Guzelian, ILSI Press, Washington, D.C.

Shell International Chemical Company, Limited. 1970. Safety evaluation of Vapona strips, . DPR Registration. Doc. No. 235-011 <47155>.

Snyder, N.S., M.J. Cook, E.S. Nasset, L.R. Karhausen, G.P. Howells, I.H. Tipton. 1974. Report of the task group on reference man, . International Commission on Radiological Protection No. 23, Permagon Press, N.Y.

FIGURE I:
==========


DDVP Sales Report for 1984 to 1990*
LB a.i.
120000
100000
80000
60000
40000
20000
0
84
85
86
87
88
89
90
Year