COMPILATION OF CLOTHING PENETRATION VALUES: HARVESTERS

by

Robert K. Brodberg, Staff Toxicologist
and
James R. Sanborn, Staff Toxicologist

HS-1652

August 28, 1996

California Environmental Protection Agency
Department of Pesticide Regulation
Worker Health and Safety Branch
1220 N Street, Sacramento, California 94271-0001

Abstract

This report summarizes available information on the penetration of pesticides through clothing worn by harvesters. The data for this report were taken from three sources: published peer-reviewed articles, registrant-submitted data and information generated by the Worker Health and Safety Branch. The weighted arithmetic mean for clothing penetration (11 studies with five pesticides) was found to be 24.2%. Based on this evaluation and incorporating some of the observed variability, a default value of 25% penetration can be utilized during the development of exposure assessments for workers involved in harvest activities. This clothing penetration default for harvesters is greater than that for pesticide handlers wearing the same type of clothing, i.e., long sleeve shirt, and long pants

INTRODUCTION

During the development of pesticide exposure assessments for harvesters there is often a paucity of data from which to estimate dermal dose (the dose reaching the skin). Dermal dose can be estimated from direct measurements of pesticide residue on the skin, supplementary data on pesticide transmittance through the media (work clothes, dosimeter, *etc.*) on which they are initially deposited, or by applying assumptions about clothing penetration to exposure data collected using only external dosimeters. Clothing penetration values are necessary to estimate the pesticide dose that reaches the skin in cases where worker exposure studies collect residue data only from external dosimeters. The Federal Guidelines for worker exposure during reentry (Subdivision K, U.S. EPA, 1984) do not provide any direction with respect to clothing penetration for various work activities. They give neither an empirically derived value for clothing penetration (or its inverse, protection), nor is a default value of 100% suggested. Thus, some specific guidance would be useful. Thongsinthusak, *et al.*, (1990) reviewed empirical studies of clothing penetration for mixer/loader/applicators and found that an assumption of 100% clothing penetration for these workers would be a gross overestimate. They found penetration of 1-10% through protective clothing worn by workers performing these tasks. Harvesters may wear different protective clothing than mixer/loader/applicators and perform more upper and lower body movements that could redistribute residues and draw them through the clothing (called ergonomic pumping). Clothing penetration under these conditions may be different than for the less active pesticide handlers. Multiple studies have been combined in this review to derive a general estimate of clothing penetration for harvesters.

LITERATURE REVIEW OF PENETRATION VALUES

Investigators have applied several dosimetry methods using either patches of cloth or gauze, or whole clothing items to collect pesticide residues. Cardboard-backed patches attached to worker's clothing collect residues from a small area that can be extrapolated to larger body regions. Patches may be constructed or placed to measure deposition of pesticide residue on the surface of work clothing, deposition on the skin, or both.

Clothing penetration values can be derived from studies that correctly use single or double-layered patches, or whole clothing as dosimeters. Single layered patches are placed in an offset pattern outside and inside of work clothing to measure penetration. Actual clothing material at the surface of the patch and gauze layers under it are used to collect penetrating residue with double-layered patches. In both cases the ratio of internal to external patch residues is utilized to estimate the clothing penetration. Whole clothing dosimetry uses two layers of clothing (e.g., outer work shirt and inner undershirt) to collect deposited and transmitted residues. Since the clothing covers entire body regions no extrapolations are necessary. This method measures direct penetration at all points across a body region and is potentially a more accurate collection system when body movements create ergonomic pumping that can influence penetration (Fenske, 1988).

The data in Table 1 reflect published literature, Worker Health and Safety Branch studies and registrant information on the clothing penetration. Pesticide penetration in these studies was measured using typical dosimetry methods but the media for all studies was not the same (i.e., some used shirts and some used patches). Clothing penetration values in this table were calculated using the following equation:

$$\frac{\text{pesticide inside clothing}}{\text{pesticide outside} + \text{inside}} \times 100 = \text{\% clothing penetration}$$

The most representative estimate of the central tendency for these data is the weighted (weighted to the number of replicates in each study) arithmetic mean given the differences in sample size between studies. The weighted arithmetic mean of all studies is 24.2%.

TABLE 1: SUMMARY OF PESTICIDE PENETRATION FROM VARIOUS CROPS THROUGH HARVESTER'S CLOTHING

Crop	Chemical	N	% Penetration	Method	Reference
Peaches	Azinphosmethyl	50	33	shirt	Spencer *et al.*, 1990
Peaches	Azinphosmethyl	12	21	shirt	Spencer *et al*,. 1990
Peaches	Azinphosmethyl	48	19	patch	Popendorf *et al.*, 1979
Peaches	Phosalone	48	21	patch	Popendorf *et al.*, 1979
Peaches	Captan	10	10	patch	Fong 1989a
Strawberries	Captan	10	34	patch	Fong 1989b
Grapes	Captan	10	13	patch	Fong 1989c
Tomatoes	Captan	10	17	patch	Fong 1989d
Oranges	Parathion	27	31	patch	Spear *et al.*, 1977
Tomatoes	Chlorothalonil	11	30	shirt	Rech *et al.*, 1989

Brodberg & Sanborn, WH&S, 1996

Influence of Active Ingredient On Clothing Penetration.

Clothing penetration values for five pesticides derived for harvesters are given in Table 1. The range of penetration for all chemicals was 10-34%. This is greater penetration than the range observed with multiple chemicals and studies for mixer/loader/applicators. All of these pesticides have similar low volatility (10^{-5} to 10^{-7} mm of Hg). This may reduce potential differences in transmittance due to a chemical's ability to penetrate clothing as a vapor. Although the data are limited, it does not appear that a single chemical in this group shows a high or low bias for penetration.

Influence of Clothing On Clothing Penetration.

Mixer/loader/applicators often wear multiple layers of work clothes, special protective clothing, or clothing made of chemical resistant material (Fenske, 1988; and Stamper *et al.*, 1989). Harvesters do not typically wear such specialized clothing and no values enabling clothing comparison are available from the data set examined. (See discussion in Summary and Conclusions for a comparison of differences in harvester and mixer/loader/applicator clothing penetration.)

Influence of Crop On Clothing Penetration.

Based on the data in Table 1 there is no clear pattern in percent penetration for high exposure crops (grapes, oranges) *vs.* lower exposure crops (strawberries, stone fruit, tomatoes) for these five pesticides. In fact, the range of penetration (regardless of pesticide) within peaches alone

(10-33%) is almost as great as the entire range for all crops. The significance and interpretation of differences among crops is uncertain due to the lack of replicates varying the crop and pesticide in a controlled manner. For example, the penetration of captan through peach harvester's clothing (10%) is lower than the penetration of azinphosmethyl (mean = 25.6%) or phosalone (21%) in these harvesters. This low clothing penetration value for captan may be the result of studies which were done at the maximum rate and applications with the shortest reentry level. It may also be related to the active ingredient, but the relationship is complex because other harvesters working with captan show higher penetration in other crops (*e.g.*, strawberries 34%). On the other hand the 10% penetration may just represent an estimate of the lower limit of the range of penetration for this chemical. This possibility is supported by the peach harvester data for azinphosmethyl where a range of 19-33% penetration is observed.

<u>Influence of Body Region On Clothing Penetration.</u>

The data presented in Table 2 are taken from studies in peaches where Popendorf *et al.*, (1979) examined the penetration of phosalone and azinphosmethyl through different regions of harvester's clothing.

TABLE 2: PENETRATION OF AZINPHOSMETHYL AND PHOSALONE RESIDUES IN PEACH HARVESTERS AS A FUNCTION OF BODY REGION

	Penetration (%)	
Body Region	Phosalone	Azinphosmethyl
Hands	9	8
Forearms	48	42
Upper Arms	37	30
Shoulders	12	10
Chest	19	16
Back	16	21
Thighs	7	9
Calves	18	-

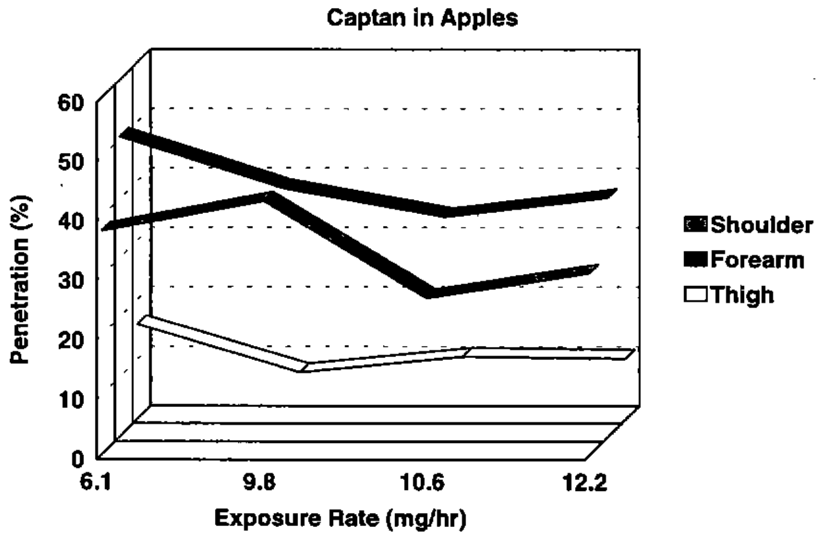
Brodberg & Sanborn, WH&S, 1992

These data show differences in the pattern of penetration for different body regions that are similar for both chemicals. This consistency suggests that real differences do exist and that they are related to either the clothing covering these body regions, the activities of these regions, or both. Interestingly, the hands, which are clearly very ergonomically active during the harvest of peaches, had one of the lowest penetration values (8 or 9%). This may have been due to differences in fabric used in gloves and those in shirts and pants. The gloves were nylon and other clothing was made of cotton or polyester blends. Hand washes were used to estimate the residues on the hands. The thighs also show a similar low penetration value (7 or 9 %). This is probably due to lower contact and movement in this region and, in addition, may be influenced by amount of contact with the crop that is harvested (e.g., peaches). The upper arms and forearms exhibit the highest penetration (>30%). These are regions of combined high contact exposure and ergonomic activity .

Influence of Exposure (μg/cm²/hr) On Percent Penetration

The influence of the level of exposure on the percent penetration for captan in apple harvesters is presented in the following figure, (adapted from data in Knarr, 1982).

Influence of Exposure Rate on Clothing Penetration



These data from the exposure of workers in apples treated with captan provide a qualitative indication that lower exposures for the ergonomically most active regions, shoulders and forearms, tend to have the greatest clothing penetration. For the thighs, the change in clothing penetration as a function of exposure rate appears to be less pronounced. Since the exposure rate differs by only a factor of two, the observation that there are qualitative differences in clothing penetration is somewhat remarkable, given the normal variation of exposure data.

Additional field data empirically demonstrating this relationship between percent penetration and exposure (expressed as a flux) might make it possible to model and estimate clothing penetration of pesticides based on exposure values. Different models may be necessary for mixer/loader/applicators and harvesters (less activity range and of motion for mixer/loaders as compared to applicators) or for pesticides with very different physical properties.

SUMMARY AND CONCLUSIONS

This report assesses the data on clothing penetration for five different pesticides in several studies during harvest activities. Since the pesticides used in these studies have relatively low vapor pressures (10^{-5}-10^{-7} mm), there is no confounding issue of vapor penetration through the clothing material. It would not be justified to use the penetration value 24.2% derived from these compounds for other pesticides with vapor pressures $>10^{-5}$ mm.

The weighted arithmetic mean value (24.2%) for clothing penetration derived in this report can be used as a default for assessment of harvester exposure. This would prove useful in commonly encountered data gap situations. Given the observed variability in these studies and the limited data available, **a value of 25% penetration should be adopted as the default.** The default could be used when the compound of interest had only external patch data or shirt data and no patches placed under the work clothing to capture penetrated clothing residues. It could also be used when a surrogate chemical must be used for estimating exposure and no penetration values were measured. The use of this value as a default should be limited to chemicals with vapor pressures $\leq 10^{-5}$ mm.

This is the same sort of default value previously derived for mixer/loader/applicators (Thongsinthusak, *et al.*, 1990). In that case a number of default penetration values were set for various types of specialized protective clothing. The value for mixer/loaders (10%) is less than that derived here for harvesters (25%). This apparent qualitative two-fold difference is likely related to differences in the clothing worn by these different workers and to differences in type and amount of body movements. Harvesters wear lighter clothing to reduce the possibility of health effects related to heat stress and exertion over a 6-8 hour work day. Mixer/loader/applicators do not exert themselves as much and work for shorter periods. Consequently, they tolerate heavier, potentially more protective, clothing (Fenske, 1988 and Stamper *et al.*, 1989).

For future determination of clothing penetration, the optimal dosimetry situation is full cover under-garments (long-sleeved shirt and long-johns) underneath the work clothing. Following exposure both the outer and under-garments should be analyzed for residues. The use of under-garment dosimeters covering the whole body should only be considered if heat stress/stroke is not a possibility. This utilization of under-garment dosimeters under the worker's clothing to capture the "skin" residue allows normal ergonomic freedom. One advantage of this method is that the integrity of patch dosimeters can be compromised during ergonomically active situations whereas shirts or long-johns remain intact during all activities associated with harvesting.

Passive penetration may not be the only route by which pesticides reach the skin. The flexing of arms, legs and hands may stretch fabric and create air movements that draw pesticides to the skin (Fenske, 1988). This would be especially prevalent during harvesting activities which involve constant flexing movements. While it may be speculated that the double patch method (double patch dosimeter consists of two layers of cloth on a inflexible cardboard matrix) may underestimate clothing penetration values since the small stiff patches are not subject to this same effect, the data of this report do not support this presumption.

REFERENCES

Fenske, R.A. (1988) Comparative assessment of protective clothing performance by measurement of dermal exposure during pesticide applications. Appl. Ind. Hyg. 3: 20:213.

Fong, H., (1989a) Review of "Worker exposure to residues of Captan 50-WP during peach harvest". DPR Registration Doc. No. 103:227.

Fong, H., (1989b) Review of "Worker exposure to residues of Captan 50-WP during strawberry harvest". DPR Registration Doc. No. 103:228.

Fong, H., (1989c) Review of "Worker exposure to residues of Captan 50-WP during grape harvest". DPR Registration Doc. No. 103:232.

Fong, H., (1989d) Review of "Worker exposure to residues of Captan 50-WP during tomato harvest". DPR Registration Doc. No. 103:229.

Knarr, R.D. (1982) Harvester exposure to captan during apple-picking: preliminary evaluation of Pennsylvania State University data. DPR Registration Doc. No. 103-084, ID No. 10437E.

Popendorf, W.J., Spear, R.C., Leffingwell, J.T. and Kahn, E. (1979) Harvester exposure to Zolone® (phosalone) residues in peach orchards. J. Occup. Med 21:189-194.

Rech, C., Bissell, S., and Margetich, S. (1989) Worker exposure to chlorothalonil residues during the harvest of fresh market pole tomatoes. Department of Food and Agriculture, Worker Health and Safety Branch, HS-1456.

Spear, R, C.,, Popendorf, W.J., Leffingwell, J.T., Milby, T.H., Davies, J.E. and Spencer, W.F. (1977) Fieldworker's response to weathered residues of parathion. J. Occup. Med. 19:406-410.

Spencer, J.R., Sanborn, J.R., Hernandez, B.Z., and Margetich, S. (1990) Long and short intervals of dermal exposure of peach harvesters to Azinphos-methyl residues. Department of Food and Agriculture, Worker Health and Safety Branch, HS-1578.

Stamper, J.H., Nigg, H.N., Mahon, W.D., Nielson, A.P. and Royer, M.D. (1989) Pesticide exposure to handgunners. Arch. Environ. Contam. Toxicol. 18:515-529.

Thongsinthusak, T., Brodberg, R.K., Ross, J.H., Gibbons, D., Krieger, R.I. (1990) Reduction of pesticide exposure by using protective clothing and enclosed cabs. Department of Food and Agriculture, Worker Health and Safety Branch, HS-1616.

U.S. Environmental Protection Agency. (1984) Pesticide assessment guidelines Subdivision K, exposure: reentry protection.