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EVALUATION OF THE HEALTH HAZARDS INVOLVED IN HOUSE-SPRAYING WITH DDT*

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SYNOPSIS

The dermal and respiratory exposure of workers during house-spraying operations has been measured to find out the main factors affecting the exposure, and to develop effective, acceptable protective measures and clothing. Dermal exposure was found to be much greater than respiratory exposure. The major factors affecting exposure with a single concentration of formulation appeared to be spray-pump pressure, height of area being sprayed, and absorbency of surface. Temperature, type of formulation, and nozzle size had little or no effect on exposure. A plastic cape, a hard hat with a plastic visor, and rubberized gauntlet gloves gave a fully clothed man almost complete protection from dermal and respiratory exposure. A tropical helmet equipped with a plastic-netting veil is proposed for field testing. This equipment gave good protection of the shoulders, back, and chest and excellent protection of the face and neck.

Spraying the interior and parts of the exterior of dwellings and other buildings for the control of various insect vectors of disease is a common practice in many parts of the world, especially in tropical and subtropical areas. The insecticide most widely used for this purpose for some time has been DDT. However, since certain insects have become resistant to this material, other insecticides are finding a place in vector-control programmes. Some of these newer materials, such as dieldrin and diazinon, are significantly more toxic than DDT. This increased toxicity is only partially compensated for by a decreased concentration of active ingredient in the formulation. Where these more toxic insecticides are used, the hazard to the operators of spray equipment is undoubtedly increased. Cases of poisoning in public health workers using dieldrin have been reported from Venezuela, Ecuador, and Nigeria (Hayes, 1957), and also from India (Patel & Rao, 1958; Rahman, Singh & Datta, 1958).

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Although the exposure factors involved in the outdoor application of various toxic spray materials both for agricultural and for public health purposes have been studied extensively (Batchelor & Walker, 1954; Batchelor, Walker & Elliott, 1956; Culver, Caplan & Batchelor, 1956; Hayes et al., 1957), little research has been directed towards evaluating the hazards involved in the spraying of houses. The desirability of making such studies has been pointed out by Barnes (1957).[1]

The present paper presents the results of studies to determine the dermal and respiratory exposure of workers during indoor and outdoor spray operations, to find out the main factors affecting the exposure, and to develop effective, acceptable protective measures and clothing. Although this work was carried out using DDT only, the results should be applicable, at least qualitatively, to other insecticides which are used in a similar manner.

Materials and Methods

The indoor exposure tests were done in a small, single-room dwelling, typical of the housing provided for itinerant orchard workers in the Wenatchee Valley Area of Washington. In regard to size, this house would probably be representative of the type of dwelling sprayed for vector control throughout the world. The room measured 8 feet by 12 feet (2.4 m $\times$ 3.7 m) with walls 6 feet (1.8 m) high. The ceiling, which was the underside of the pitched roof, was 6 feet high at the wall and sloped up to 9 feet (2.7 m) at the apex. All surfaces were smooth and painted. In the room during the experiment were a small cooking-stove, an ice-box, a sink, and a waist-high cupboard along one wall.

The sprayer used was a cylindrical, compressed-air, hand-operated type, of capacity 3.5 US gallons (about 13 litres), equipped with a 20-inch (50-cm) wand. Two different nozzles were used in various tests. Both produced fan-type spray patterns, one size 50-0.15 and the other 80-0.20. (The first number refers to the angle subtended by the fan pattern and the second number to the rate of discharge, in gallons per minute, at 40 pounds per square inch (p.s.i.) pressure (2.8 atm.).) A pressure gauge was attached to the spray tank. Except where noted, all tests were conducted at an average pressure of 40 p.s.i. All the spraying involved in this study was performed by one of the authors (H.R.W.) in order to minimize variations in the technique of spraying. The same procedure was followed during each spraying cycle; the wand was held approximately 15-18 inches (38-45 cm) from the surface being sprayed, and the spraying was accurately timed by means of a stop-watch. In all the spraying, including that of the ceiling, the operator stood as far as possible out of the spray drift. The walls and ceiling

[1] An excellent study has recently been carried out by Fletcher, Press & Bagster Wilson (see article on page 15 of this number of the *Bulletin*).

were sprayed at a rate necessary to obtain a deposit of 200 mg of DDT per square foot (about 2 g per m^2) when using the 50-0.15 nozzle at a pressure of 40 p.s.i. The same time schedule was used with the 80-0.20 nozzle. With this larger nozzle, a somewhat greater deposit was obtained. Each spraying cycle consisted in spraying the interior of the dwelling twice, giving a total exposure time of 6 minutes. Two-thirds of the spraying time was required for the walls and one-third for the ceiling. The pump pressure for a spraying cycle is given as the average p.s.i. The pressure was regulated by pumping the sprayer a predetermined number of p.s.i. above the pressure desired, so that during the cycle the pressure would drop the same number of p.s.i. below, and the desired test pressure would thus be averaged.

Two different formulations of 5% DDT in water were sprayed: an emulsion made from a 25% emulsifiable concentrate and a suspension prepared from a 75% water-dispersible powder.

The potential dermal exposure was estimated by attaching absorbent pads to various parts of the operator's body or clothing, and allowing them to be exposed during a spraying cycle. The technique was essentially that described by Batchelor & Walker (1954) and by Batchelor, Walker & Elliott (1956). The pads were placed on the tops of the right and left shoulders, the back, the upper chest near the jugular notch, the back of the forearms and neck, the front of the thighs, and over the nose and mouth when the respirator was not being used. For measuring potential respiratory exposure, a single-unit respirator containing a filter-pad was worn. A plastic funnel was inverted over the filter-pad holder and taped securely. The funnel tip was cut off and the hole plugged. On the under surface two openings, each 12 mm in diameter, were cut. The respirator was modified in this way in order to prevent impingement of spray drift on to the respirator pad, and to simulate more closely the position of the nasal orifices.

In the laboratory, a 2-inch (5-cm) square section cut from the centre of each dermal exposure pad or the entire respirator pad was extracted in a Soxhlet apparatus. The DDT content of the extract was determined by a modification of the Schechter-Haller procedure (Communicable Disease Center, 1953). Results were converted to milligrams of DDT deposit per square foot per hour of exposure. During the course of this study, 1404 dermal and 113 respirator pads were analysed.

Air samples were collected using the procedure described by Batchelor & Walker (1954). The DDT content was determined by the method cited above.

DDA in urine was determined by the method described by Cueto, Barnes & Mattson (1956).

The protective clothing studied is illustrated in Fig. 1-4. The only newly introduced item is the veil, which is made from 20×20 mesh plastic netting of a dark green colour. A finer mesh interferes too much with vision and a coarser mesh offers less protection. A light-coloured mesh is not satisfactory because it reflects light and thus interferes with vision. A number of patterns were tried. Making the side pieces wider in an effort to cover the shoulders merely caused the veil to rub the shoulders, and thus led to discomfort and occasionally to a shifting of the hat on the head. A full-size pattern for a satisfactory veil can be made easily by reference to the l-inch grid shown in Fig. 4. The back piece of the veil should be sewn to the sides using an overlap seam (see diagram in Fig. 4). The veil should then be fitted over the hat with which it is to be used. It will be found that the netting stretches and permits a snug fit on the hat. The next step is to take up the front seams with pins to determine the proper width of seam. The width should be such that the front of the veil will hang parallel to the front of the face or even slope in slightly at the bottom. After this fitting has been done for one hat and the proper amount of overlap of the front seams determined, it should be possible to make veils for identical hats without additional fitting. After the seams have been sewn, they should be reinforced with pre-shrunk bias tape. Bias tape should also be stitched around the lower edge of the veil, but not around the top margin. Masking-tape is the best material for fastening the veil to the hat. It is easy to remove or replace. Stiffeners made of steel wire (about 3/32 inch (2.4 mm) in diameter) may be used to hold the front piece of the veil straight, but they are not essential. It is desirable to stiffen the front lower edge of the veil with one or two strips of masking-tape.

A small, one-roomed house, similar to that described for the indoor tests, was used in the outdoor studies. The surfaces sprayed included the upper part of the walls and the under side of the eaves. The same sprayer was used both outdoors and indoors.

Results

Exposure under usual conditions

To provide an estimate of exposure of workers under the conditions most often prevalent in indoor spraying operations, measurements were carried out during the use of a 5% DDT suspension, made from a 75% water-dispersible powder, with an 80-0.20 nozzle at an average pressure of 40 p.s.i. The exposure values determined under these conditions for various body areas are shown in Table 1. The area of highest exposure was found to be the right arm and hand. In right-handed persons this is the hand which holds the spray wand and is, therefore, nearest the spray. This exposure is about three times that for the right shoulder, which received the next highest dose. In all preliminary tests the exposure on the lower legs was found to be negligible ; therefore, measurements of exposure in this area were not continued throughout the experiment. From these data it appears that the main exposure from indoor surface spraying is on the upper trunk

TABLE 1. EXPOSURE TO DDT DURING INDOOR AND OUTDOOR SPRAYING OPERATIONS *

Variable studied		Number of replicates	Average exposure (mg/square foot/hour)										
			Right shoulder	Left shoulder	Back	Chest	Right arm	Left arm	Right thigh	Left thigh	Face	Back of neck	Total
Exposure under usual conditions		4	410	145	86	250	1497	35	36	8	41	15	2523
Pressure	20 p.s.i. (1.4 atm.)	4	29	35	7	25	118	18	12	< 5	—	< 6	< 255
	30 " (2.1 ")	4	92	70	11	33	438	14	11	< 10	—	< 4	< 719
	40 " (2.8 ")	4	289	126	51	112	993	32	18	< 4	—	14	< 1639
	50 " (3.5 ")	4	576	168	58	305	1524	69	33	4	—	22	2759
Height of surface	Walls	8	16	20	8	7	28	9	6	3	4	4	105
	Ceiling	8	1106	242	148	230	2632	161	94	27	133	36	4807
Type of surface	Smooth	4	592	132	118	200	1475	65	58	12	54	34	2749
	Heavy residue	2	137	49	30	88	462	11	20	30	14	11	852
	Roughed-up fibreboard	4	24	19	9	18	132	12	4	7	< 2	4	< 231
Temperature	34-38°F (1-3°C)	4	39	10	10	30	201	7	5	1	9	3	< 315
	58-90°F (14-32°C)	4	108	36	28	36	491	33	10	4	14	6	766
Formulation	Water-dispersible powder	4	410	145	86	250	1497	35	36	8	41	15	2523
	Emulsion	4	289	126	51	112	993	32	18	< 4	—	14	< 1639
Nozzle size	50-0.15	4	592	132	118	209	1475	65	58	12	54	34	2749
	80-0.20	4	289	126	51	112	993	32	18	< 4	—	14	< 1639
Protective clothing	None	13	410	110	62	158	1094	37	44	10	46	18	1989
	Cape, type 1	4	< 2	< 2	< 3	< 3	< 2	< 2	7	6	—	—	< 27
	Cape, type 2	4	4	< 2	56	< 2	921	44	20	< 4	—	—	< 1053
	Hat, plastic visor	4	91	46	24	18	—	—	—	—	< 2	< 2	< 183
	Hard hat only	12	276	111	47	113	—	—	—	—	80	< 4	< 631
	Hat, 20 × 20 visor	8	276	90	47	57	—	—	—	—	18	< 6	< 494
	Hat, 28 × 28 visor	8	352	124	57	83	—	—	—	—	18	< 4	< 638
	Helmet, veil	12	26	32	8	22	—	—	—	—	< 7	< 2	< 97
Exposure during outdoor spraying		4	84	71	31	60	170	28	22	16	15	4	501

* Unless otherwise noted, indoor spraying was carried out at a temperature of 36-65°F (2-18°C) and at an average pump pressure of 40 p.s.i.

TABLE 2. DERMAL EXPOSURE TO DDT PER HOUR OF INDOOR SPRAYING *

Unclothed body part	Location of pads	Body area (square feet**)	Pad recovery (mg/square foot/ hour) †	Total calculated exposure (mg/ body part/hour)
Face	Face	0.70	41	29
Right side of head	Face	0.18	41	7
Left side of head	Face	0.18	41	7
Back of neck	Back of neck	0.12	15	2
Front of neck and "V" of chest	"V" of chest	0.16	250	40
Right forearm and right hand	Right forearm	1.09	1497	1632
Left forearm and left hand	Left forearm	1.09	35	38
Total		3.52		1755

* Calculated on the basis of an operator wearing a short-sleeved, open-necked shirt and no gloves. The spraying was carried out with a 5 % DDT suspension at an average pump pressure of 40 p.s.i.

** 1 square foot ≃ 0.1 m^2

† 1 mg per square foot ≃ 10 mg per m^2

and upper extremities. (It is important to note, however, that the feet and lower legs of some members of spray teams become grossly contaminated. The cause of this observed variation is not known.)

Assuming that the operator wears a shirt with short sleeves and an open collar, that he wears no hat or gloves, and that his clothing gives complete protection to the area covered, it can be calculated from the above data that his dermal exposure would be about 1755 mg of DDT per hour of spraying. These calculations are summarized in Table 2.

The average respiratory exposure, based on absorption of DDT by respirator pads, was found to be about 7.1 mg per hour of spraying. This very low value in comparison with dermal exposure is similar to the results reported for outdoor spraying of parathion (Batchelor & Walker, 1954) and of dinitro-orthocresol (Batchelor, Walker & Elliott, 1956) for agricultural purposes.

Air samples taken in the breathing zone of the operator under these basic conditions of indoor surface spraying were found to contain 7.1 mg of DDT per m^3. This level exceeds the 1 mg per m^3 value which has been set by the American Conference of Governmental Industrial Hygienists (1957) as the maximum level to which workers should be exposed for an 8-hour working-day.

The figure for respiratory DDT exposure calculated from respirator-pad values has been compared with the respiratory-exposure figure calculated from air-concentration values. Assuming a tidal air volume of 480 litres per hour, it may be calculated that the inhalation of DDT is 3.4 mg per hour. This figure is of approximately the same order of magnitude as the 7.1 mg per hour value based on the respirator pads.

Using the values given above, it can be calculated that the total potential exposure for a spray operator under these conditions would be about 105 mg/kg for a day's work, assuming that the worker was actually spraying for 4 hours out of his 8-hour working-day. This figure may be compared to the acute dermal LD_{50} value of 2510 mg/kg for dissolved DDT in white rats. Rats are usually able to withstand repeated daily dermal dissolved doses of 100 mg/kg, but are usually killed by 200 mg/kg under these conditions (Hayes, 1959). Hayes, Durham & Cueto (1956) have reported a study in which men were fed DDT at the daily rate of 35 mg per man (0.5 mg/kg) for periods of up to two years. During this entire study, no volunteer complained of any symptom or showed, by the tests used, any sign of illness that did not have an easily recognized cause, clearly unrelated to exposure to DDT.

Effect of various factors on exposure

A number of factors, some of which could be modified under practical field conditions and others of which would be fixed, were studied to determine their effect on exposure. These factors include the following:

(*a*) *Spray-pump pressure.* Since it is common practice in the field to pump sprayers up to 50 or 55 p.s.i. and then spray until the pressure falls to about 20 p.s.i., comparative studies were made of exposure at pressures of 20, 30, 40 and 50 p.s.i. (1.4, 2.1, 2.8, and 3.5 atm.). The results of this work are shown in Table 1. It will be noted that for each 10 p.s.i. (0.7 atm.) increase in pressure the dermal exposure increased by a factor of between 2 and 3. At 50 p.s.i. the exposure was about 11 times as great as that at 20 p.s.i. Respiratory exposure was about 1 mg per hour of spraying at 20 and 30 p.s.i., 3 mg at 40 p.s.i., and 6 mg at 50 p.s.i. A longer time is required to deliver a given volume of spray at a low pressure than at a high pressure. However, the time taken to spray at 20 p.s.i. is less than twice that taken at 50 p.s.i. Thus, there is a significant decrease in the exposure of the operator at low spraying pressures, even if the comparison is based on a standard rate of deposit per unit area.

Since higher pressures give increased dermal and respiratory exposures, the lowest pressure that gives a suitable spray pattern and surface coverage would seem to be the most desirable from the standpoint of the health hazard to spray operators. At 20 p.s.i. the spray pattern was slightly uneven. At 30 p.s.i., however, the pattern appeared to be even and the rate of discharge was great enough to allow surface coverage with 200 mg of DDT per square foot at a reasonable speed.

(*b*) *Height of area sprayed.* It was apparent from visual observation of indoor spraying that exposure of the operator was greatest while he sprayed surfaces above his head. A comparison of exposure during wall-spraying with exposure during ceiling-spraying is made in Table 1. The measurement confirmed the visual observation that spraying the ceiling resulted in much greater exposure than spraying the walls. In the dwelling under study, in which the ceiling surface was only about one-third as great as the wall surface, over 97% of the total exposure during a spraying cycle occurred while the ceiling was being sprayed.

In contrast to the exposure values determined under the usual conditions for complete spraying cycles, the exposure on the right-arm area was only slightly greater than that on the shoulder area when only the walls were sprayed. Also, during wall-spraying, the exposure on the left shoulder, instead of being considerably less, was slightly greater than that on the right shoulder, and exposure on the neck and face was very low. The ratio of the exposure values for the various body areas was approximately the same for ceiling-spraying as for spraying the complete room.

If a spraying operation should involve overhead spraying only, it is possible for the operator to receive several times as much exposure per unit time as he would when spraying both walls and ceiling.

(*c*) *Type of surface.* A study of the effect of the type of surface on exposure was of interest because various surfaces, ranging from smooth, painted wood to rough or absorbent surfaces of mud and thatch, are encountered in the field.

One variation in surface was produced by spraying the room several times without cleaning the walls or ceiling, so that a heavy residual deposit was built up. The effect of this change in surface was to decrease the exposure of the operator to about one-third its value in the case of the smooth, painted surface.

Other tests were carried out in which the ceiling was covered with absorbent fibreboard which had been roughened by scratching with a sharp implement until many bits of fibreboard protruded ¼ to ½ inch from the surface. This type of surface produced a still larger decrease in exposure. The exposure resulting from spraying the entire room with fibreboard on the ceiling was less than 10% of the exposure resulting from spraying the room's painted surfaces.

(*d*) *Temperature.* Comparative studies made at two different temperature ranges indicate that exposure is increased when spraying is carried out at higher temperatures. The exposure was approximately twice as great at the high temperature-range studied—58-90° F (14-32° C)—as at the low range—34-38°F (1-3°C). The detailed results are not shown in Table 1, since not enough replications were involved to make the results significant, but small increases in exposure were found with each temperature increment. All the tests involving variation in temperature were carried out using the DDT emulsion prepared from the emulsifiable concentrate. It may be that the increased exposure at the higher temperature is associated with an increased volatilization of the xylene vehicle and a consequent reduction in the size and mass but not in the velocity of the spray particles.

(*e*) *Formulation.* A slightly greater dermal and respiratory exposure was found when using a suspension prepared from water-dispersible powder than when using an emulsion prepared from emulsifiable concentrate.

The concentration of DDT in the air was also found to be somewhat higher when the water-dispersible powder formulation was used. On the other hand, the operator commented repeatedly on the discomfort caused by spraying indoors with the emulsion. Spraying with this formulation burned his eyes and caused him to become nauseated. These effects were more pronounced at higher temperatures and may be attributed to the solvent. There was no discomfort associated with spraying the suspension prepared from the water-dispersible powder.

(*f*) *Spray-nozzle size.* There appeared to be no appreciable difference in dermal exposure when comparing the 50-0.15 nozzle with the 80-0.20 nozzle. From visual observation it appeared that, particularly at higher pump pressures, the 80-0.20 nozzle broke the spray into smaller droplets that seemed to " hang " in the air for a longer period of time. It was expected, therefore, that the suspended particles would cause a greater general exposure with the 80-0.20 nozzle. The quantitative study failed to corroborate the visual observation in the case of dermal exposure, but respiratory exposure, which is favoured by small particles, did appear to be higher with the 80-0.20 nozzle (4.5 mg/hour) than with the 50-0.15 nozzle (2.3 mg/hour).

Efficiency of various types of protective clothing in preventing exposure

Some of the various types of protective clothing studied are illustrated in Fig. 1-4. Capes, types 1 and 2, and the hard hat with plastic visor (see Fig. 1 and 2) have previously been proposed for use and have had field trial.

It appeared that ordinary cotton clothing gave almost complete protection to the body area covered. All values for exposure under cotton clothing in four replicated tests were below the experimental limit of the analytical method. It should be noted, however, that the spraying time involved in these tests (24 minutes) was not sufficiently long to wet the cotton garments with the spray. Undoubtedly, the protective effect of these garments is limited by the capacity of the fabric to absorb the spray. However, wetting does not usually occur if spraying is done carefully because the small amount of liquid evaporates as rapidly as it is deposited. These

FIG. 1. TYPE-1 CAPE AND HARD HAT WITH PLASTIC VISOR, SIDE VIEW

Note the almost complete coverage afforded the arms by this cape. Gloves would ordinarily be used with this equipment.

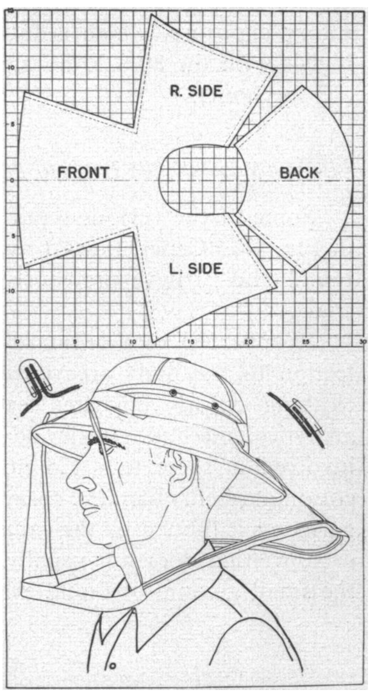
FIG. 2. TYPE-2 CAPE, HARD HAT WITH PLASTIC VISOR, AND RUBBERIZED GAUNTLET GLOVES, SIDE VIEW

Note exposure of arms with this cape and also exposed neck-shoulder area due to displacement of cape by shoulder strap of sprayer.

FIG. 3. TROPICAL HELMET WITH PLASTIC-NETTING VEIL AND RUBBERIZED GAUNTLET GLOVES, FRONT VIEW

Note coverage afforded to neck, shoulder, upper back, and upper chest areas as well as to face by this veil.

FIG. 4. PATTERN AND DRAWING OF PLASTIC-NETTING VEIL (SHOWING TAPE ATTACHMENT TO TROPICAL HELMET)



The diagrams indicate details of the front and back seams and the bias tape used to reinforce them.

results are similar to those reported by Hayes (1959), who found that wearing a cotton shirt reduced skin contamination from 1200 mg/m^2 to 5 mg/m^2.

As can be seen from Table 1, the type-1 cape gave almost complete (about 98%) protection from the neck down, whereas the type-2 cape gave only about 50% protection. The primary difference between these two capes with regard to protective effect lay in the greater shielding afforded the arms by type 1.

The hard hat with plastic visor gave almost complete protection to the face and neck and this combination, as well as the hard hat alone, also gave some protection to the shoulders, back, and chest. Almost complete protection of significantly exposed body areas may be achieved by wearing the type-1 cape and the hard hat with plastic visor.

It is difficult to enlist the co-operation of spray-men in the wearing of protective clothing which is heavy or which adds to their discomfort in tropical areas by preventing free circulation of air. Capes, type 1 and type 2, and the hard hat with plastic visor suffer from both these disadvantages. In addition, it is difficult, owing to the fastening of the cape at the wrists, to get the sprayer over the shoulder with the type-1 cape. With the shoulder pads now used in the type-2 cape, the sprayer strap tends to pull the cape in one direction or the other, with the result that a larger than necessary area of the neck, shoulders, and chest is exposed to possible dermal contamination. A further disadvantage of the plastic visor is that it quickly becomes coated with residue and vision is seriously interfered with, particularly in subdued light. After a short period of spraying the plastic visor becomes so coated that it is impossible to see through it at all. This deposit is not easily removed with water, but can be removed by means of an organic solvent.

In an attempt to develop more acceptable protective clothing, a visor cut from 20 × 20 mesh plastic netting was used with the hard hat. This modification was lighter and cooler than the hard hat equipped with plastic visor, but gave little better protection than the hard hat alone, except around the mouth and nose. Results with a visor cut from 28 × 28 mesh plastic netting were similar.

Another modification tested was the use of a tropical helmet equipped with a plastic-netting veil (Fig. 3 and 4). The tropical helmet with such a veil should be acceptable to the spray-men, since it is a combination that offers little interference to circulation of air and is considerably lighter in weight (255 g) than the hard hat with plastic visor (670 g). Spray droplets or dried residue deposits which collect on the veil interfere little with vision. The veil requires cleaning less often and is more easily cleaned than the plastic visor.

It can be seen from Table 1 that the tropical helmet with veil gave excellent protection of the shoulders, back, and chest and almost complete

TABLE 3. PROTECTION AFFORDED BY TROPICAL HELMET AND VEIL TO VARIOUS BODY AREAS DURING INDOOR SPRAYING OF DDT

Body area	Protective effect (%) *		
	using 80-0.20 nozzle and water-dispersible powder	using 50-0.15 nozzle and emulsifiable concentrate	mean
Right shoulder	76	84	80
Left shoulder	27	71	49
Back	68	87	77
Chest	64	86	75
Face	46	87	67
Back of neck	53	89	71
Respiratory	—	31	31

$$* \text{ Protective effect (\%)} = \frac{\text{(unprotected value — protected value)}}{\text{unprotected value}} \times 100$$

protection of the face and neck. The percentage protection afforded to various body areas by this equipment is shown in detail in Table 3.

Other measurements of exposure

As noted above, all the indoor spraying reported in this paper was carried out by the same person. During a period of 6 months, this man sprayed the test building inside 309 times, using a total volume of 123 US gallons (465 litres) of 5% DDT spray representing 46 pounds (about 20 kg) of actual DDT. He spent about 15.5 hours actually spraying. Twice during this period tests of his urine for DDA content were carried out, at times when it was felt that his exposure was likely to have been maximal. On both occasions his urinary DDA content was below the limit of sensitivity of the experimental method. Previous work has indicated that absorption of oral dosages of DDT as low as 3.5 mg per day will result in the excretion of measurable quantities of DDA in the urine. (Obviously, the implications of this study of excretion are limited to DDT. It is known that some other compounds are absorbed by the skin in significant and even toxic quantities under field conditions.)

Exposure during outdoor spraying

For comparative purposes, measurements were made of dermal and respiratory exposure to DDT during simulated outdoor surface spraying activities for control of insect vectors of disease. The results of this work are shown in Table 1. The total dermal exposure during outdoor spraying, calculated in the way shown in Table 2, was 243 mg/hour and, therefore, considerably less than that during indoor spraying (1755 mg/hour). The respiratory exposure was very much less outdoors (0.11 mg/hour) than indoors (7.1 mg/hour). The order of comparative exposure for various body areas during outdoor spraying was similar to that found indoors.

One might expect a somewhat greater variation in exposure between different outdoor spraying cycles, since, out of doors, one has much less control over wind and temperature. However, in the present study, the inter-cycle variations were similar outdoors and indoors. This similarity is probably explained by the fact that there was little variation in wind or temperature during the days on which the outdoor tests were conducted.

Discussion

The studies reported in this paper indicate that, of the clothing tested, the type-1 cape and hard hat with plastic visor together afford the best protection during indoor spraying. The spray-man should wear rubberized gauntlet gloves to protect his hands during mixing and filling as well as during actual spraying operations. This combination of protective equipment (type-1 cape, hard hat with plastic visor, and rubberized gauntlet gloves) should give almost complete protection from both dermal and respiratory exposure to a spray-man wearing a long-sleeved shirt, long trousers, and shoes.

The important features of the spray-man's hat include a wide brim and a waterproof surface. Hats of local manufacture may be entirely satisfactory and much cheaper than the ones shown in the figures.

In view of the possible non-acceptance by field personnel of the protective clothing listed above, consideration should be given to field trials of the combination of tropical helmet and veil described. When worn with other appropriate clothing, the wide-brimmed, waterproof hat and veil should give quite satisfactory protection against both dermal and respiratory contamination. Calculations similar to those summarized in Table 2 indicate that these protective devices (long-sleeved shirt, long trousers, shoes, rubberized gauntlet gloves, and tropical helmet and veil) would decrease potential exposure almost to zero (less than 2% of unprotected value). It should be noted that this protection is better than that shown in Table 3, which includes the effect of the tropical helmet and veil only. In addition, the spray-man can further reduce his exposure by using the lowest spray-pump pressure consistent with an acceptable spray pattern and adequate surface coverage. It is probably not necessary to mention more obvious safety practices such as standing as far as possible out of the spray drift, especially when spraying overhead surfaces. The importance of washing hands and face before eating or smoking, of a daily bath with soap and water, and of the daily washing of contaminated clothing also should be strongly emphasized.

RÉSUMÉ

Les dangers d'intoxication encourus par les opérateurs chargés de pulvériser des insecticides en plein air pour lutter contre les ennemis des cultures ou les vecteurs de maladies ont été bien étudiés. Ceux qui menacent lés techniciens opérant à l'intérieur des habitations ont été moins exactement évalués.

Les auteurs ont mesuré la quantité de DDT à laquelle est exposé un opérateur dans un local de $2,5 \times 4 \times 2$ m environ, soit par contact, soit par inhalation. Ils décrivent la protection vestimentaire à recommander à un opérateur portant une chemise à manches longues, un pantalon long et des chaussures: cape, chapeau imperméable à larges bords rigides, avec masque en plastic, gants à manchettes caoutchoutés. Le casque tropical avec voile peut remplacer le chapeau à bords rigides et le masque. L'opérateur peut encore diminuer les risques, en limitant la pression du pulvérisateur au minimum compatible avec l'efficacité requise. Une hygiène personnelle est en outre à recommander: lavage des mains et du visage avant de manger ou de fumer, bain quotidien avec savonnage, lessivage quotidien des vêtements souillés.

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