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Protecting the Tractor Operator in the Application of Pesticidal Chemicals

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The hazards associated with the handling and application of toxic chemicals employed in insect control require that strict precautionary measures must be followed. It necessitates the use of appropriate safety equipment. The types of protective devices needed are dictated by the tox-icity of the given insecticide, its formulation, the method of application, and whether the treatment will be made in an open or enclosed area.

Toxic amounts of pesticide may gain entrance to the body through these pathways: accidental or intentional intake by mouth (oral); by absorption through the skin (dermal) and the eyes; and by inhalation. The latter two routes are the ones most likely involved in applying insecticides on a commercial scale in the field. Absorption of the chemicals through the skin is usually the major means of contamination, and it becomes increasingly critical at higher temperatures and when the skin is wet with perspiration. Poisoning from inhalation is most likely to be serious when treatments are made in confined areas. Nevertheless, it can also occur under field conditions where the operator is frequently exposed to spray and dust drifts containing vapors of the more volatile compounds, Figure 1. Fine spray droplets may also be highly hazardous in these situations if highly concentrated spray mixtures are applied.

Protection against contamination by inhalation is achieved by covering the mouth and nose with a respirator equipped with a chemical-absorbing cartridge or cartridges. The respirator can remove both vapor and fine spray droplets. Dermal contamination is avoided by wearing the proper protective clothing, either a neoprene or a rubber-coated jacket, pants, hat, and gloves. The eyes can be protected with snug-fitting goggles.

Although the above-mentioned protective gear can provide adequate protection for the handler and user of highly toxic insecticides, there are some drawbacks. This gear becomes uncomfortable after extended use under high temperatures. For this reason, some operators may refuse the employment of such protection. To perform efficiently, too, the respirator and goggles must fit tightly and as comfortably as possible.

THE PROBLEM

Basically there has been little or no improvement made in protective equipment employed after about 1949 for the users of moderate to highly toxic insecticides. They were brought into use initially with the introduction of the organophosphate insecticides. A probable explanation for the status quo position we find ourselves in is that direct means of protection (gear worn by an operator) are simple and inexpensive compared with protective equipment not worn by the operator.

The introduction and wide use of tractor cabs afforded a new approach to the problem. First, the cab automatically would be expected to give at least some reduction in dermal exposure. But, unfortunately, the air entering the cab would easily contain insecticide vapor and fine spray at toxic levels. Any protective benefit from the cab alone would depend too on how tight the cab was maintained.

Recently, progress has been made to eliminate the need for wearing a respirator and protective clothing when applying tractor-applied insecticidal sprays and dusts. The objective was to develop a practical mechanical means of

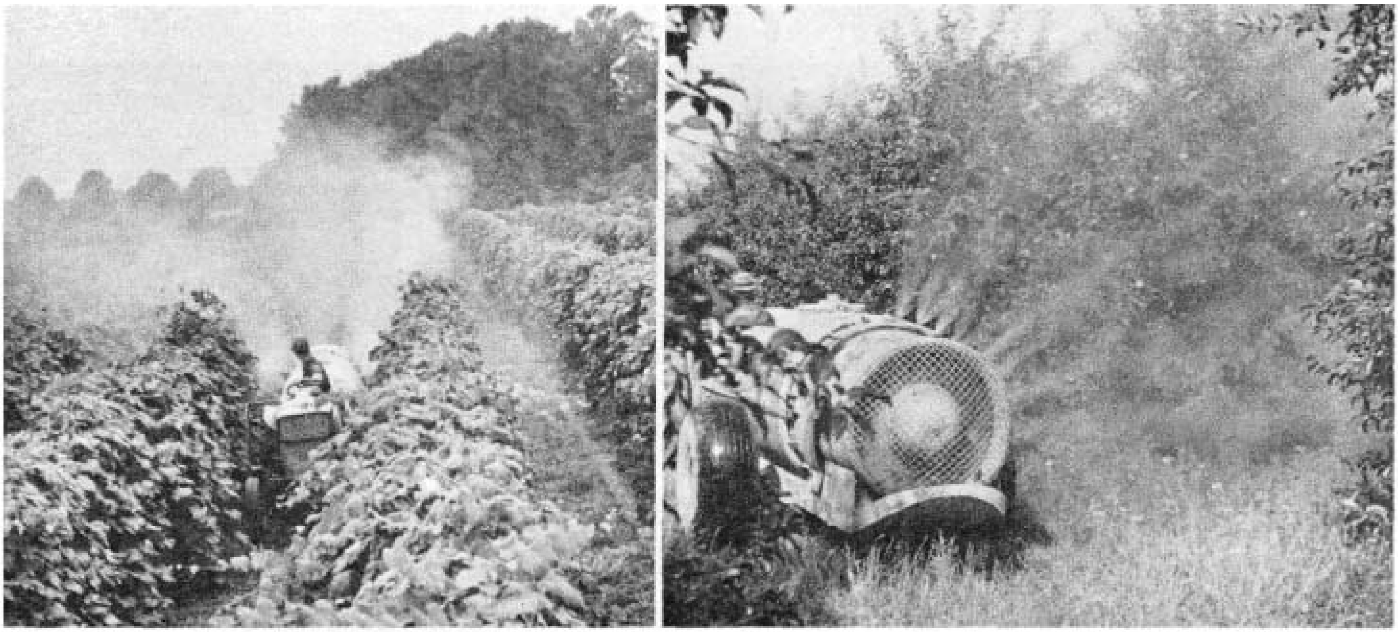

Figure 1.—Showing potential exposure of tractor operators treating vineyards (left) and orchards (right).

providing the tractor operator with a continuous supply of filtered air. An air filter-pressurization unit was designed and built for mounting on the roof of a tractor cab (Figs. 2,3, and 5). The purpose of this paper is to describe briefly the air-filtering unit developed and to report results of tests made to determine the efficiency of the unit in removing insecticides from the air entering the cab.

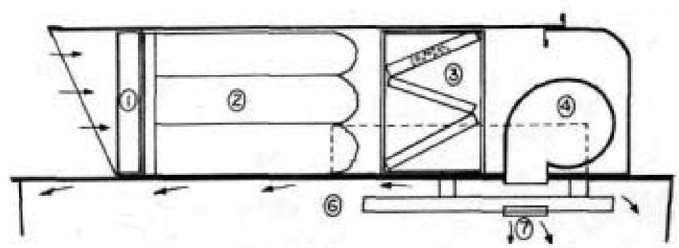

Figure 2.—Longitudinal sketch showing various parts of the air filter-pressurization unit. (1) prefilter, (2) high efficiency bag filters, (3) activated charcoal, (4) fan, (6) air deflector plate, (7) air distribution nozzle.

AIR FILTER-PRESSURIZATION UNIT

The air filter-pressurization unit consists of a rectangular-shaped metal casing, a series of three filters, and a fan (Fig. 2). One end of the casing—the air inlet—is open and protected only by a 1 x 1 -inch mesh screen which faces forward when the unit is mounted on the tractor cab. The top or cover of the casing is a sheet metal panel with rubber stripping about the edges to prevent leakage when it is bolted or latched in place.

As the air is drawn through the casing, it passes through three filters. The first, or pre-filter, is fitted over the air inlet and consists of a heavy mat of fiber glass. It is intended to remove coarse dust and spray particles. The second filter is a fiber, bag-type filter which removes very fine spray and dust particles. The third is a chemical-absorbing filter consisting of 40 pounds of activated charcoal having an activity range of 60 to 65. The primary function of this last filter is to absorb pesticide vapors.

Outside air is drawn into the unit through the filters by a fan mounted on the bottom of the casing. The filtered air is forced downward into the fan discharge ducts which extend into the tractor cab through aligned openings in the bottom of the casing and the roof of the cab, Figure 3. As air

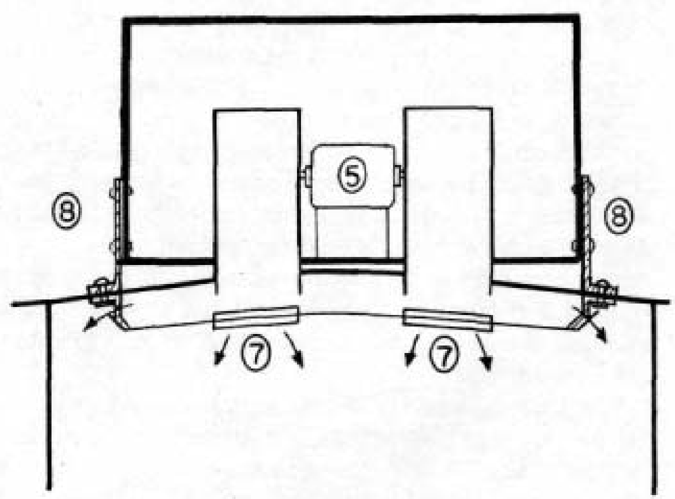

Figure 3.—Showing rear aspect of the air filter-pressurization unit. (5) fan motor, (7) air distribution nozzles, (8) brackets anchoring filter to cab roof.

enters the cab it collides with the sheet metal air-distribution plate which is held in place with brackets. This plate and the roof of the cab define a plenum chamber from which the air under pressure is distributed in the cab. A steady flow of air is maintained over the operator, without producing a draft, by means of two diffusing nozzles mounted in the air-distribution plate.

EFFICIENCY OF UNIT

Methods and Materials

An important phase of the development of the tractor cab air filter-pressurization unit was to determine its efficiency in filtering out the insecticides. For evaluation studies, the ideal procedure would be to expose the unit to conditions existing during the actual operation of applying insecticides to crops. However, this course was not followed in the present studies and for these reasons: the apparatus needed to collect air samples inside and outside the cab is fragile and bulky and the space is limited in a rather small-sized cab usually used in treating vineyards and orchards. Therefore, the testing was of necessity carried out by a method to provide cab and filter exposure comparable to conditions encountered in normal field operations. To assure the desired exposure, the air and spray outlets on the applicator were adjusted to discharge upwards and into the wind. The arrangement provided an intermittent forward flow of spray clouds over the tractor cab and air-

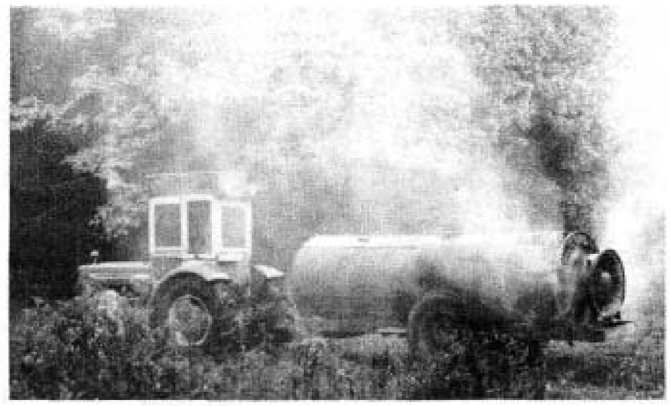

Figure 4.—One of the spray applicators used to determine the efficiency of the air filter-pressurization unit. Note: The exposure of the tractor cab and air filter unit to drifting clouds of spray.

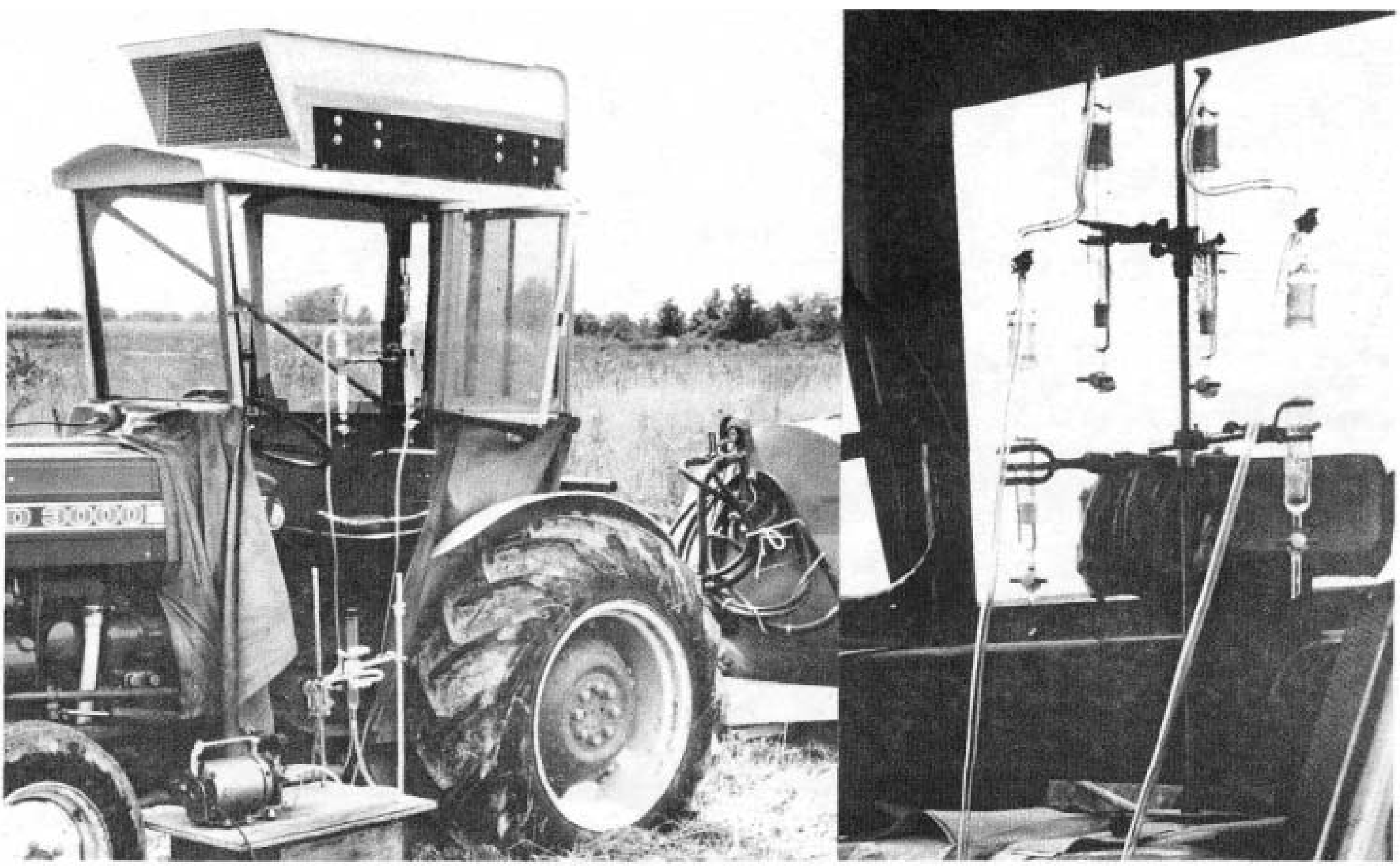

Figure 5.—Air filter-pressurization unit mounted on roof of a narrow tractor cab. Showing position of air samples inside cab. In foreground the rotary air-vacuum pump for drawing air through samples (left). Air samplers inside cab connected in series (right).

filtering unit, Figure 4. For the tests, spraying was done with the applicator and tractor being maintained in a fixed position. This eliminated any advantage that might be gained by having the equipment moving during the spraying operation. Also, the clouds of drifting spray particles were not subjected to the buffeting effect of vines or trees.

Air sampling for the investigations reported here was done by the liquid absorption or extraction method using as the trapping liquid 40 ml acetone in the impinger. The impinger "sampler" was a standard glass column with a single side arm and a stop cock at one end to facilitate removal of trapping liquid. The column was fitted with a fine-mesh fritted (sintered) glass gas dispersion tube. A rotary air-vacuum pump was used to draw air through the air sampler and the air flow was regulated with a controllable flow meter. The air flow was at the rate of 14.2 liters per hour in the tests with Meta-Systox-R® (oxydemeton-methyl) and Systox® (0,0-Diethyl 0-[2-(ethylthio)ethyl] phosphorothioate mixture with 0,0-Diethyl S-[2-(ethylthio)ethyl] phosphorothioate) and at 21.3 liter per hour in the parathion (0,0-Diethyl 0-p-nitrophenolphosphorothioate) test. In the 1973 tests with Meta-Systox-R®, all air sampling was done with single impingers (Fig. 5), whereas in the 1974 tests with Systox® and parathion, the air was passed through two impingers connected in series.

The air inlet of samplers in the cab was placed at a zone location comparable to that occupied by the head of a tractor operator of average height. Air samplers outside of the cab were supported so the inlets were in the path of outside air flow to the filtering unit and at a distance of about 18 inches ahead of the intake.

Analyses on samples containing Meta-Systox-R® were made according to the total phosphorous method (1). The analytical method used for determining parathion was electron capture gas chromatography (2). Systox® was analyzed by flame photometric gas chromatography utilizing a 6-foot by ¼-inch column of 3 per cent 0V1 on 60-80 mesh gas chrom Q.

The organophosphate insecticides selected for determining the efficiency of the air filter-pressurization were Meta-Systox-R®, rated as moderately hazardous; and Systox® and parathion, both of which are rated as highly hazardous. The basis for these toxicity ratings are the dermal LD_{50} and the inhalation LC_{50} dosages. For the investigation, only emulsible concentrate formulations of the insecticides were tested. In Table 1, information is provided on (1) the rate of actual insecticide used per 100 gallons, (2) the number of gallons of spray mix sprayed in one hour, (3) the amount of actual insecticide sprayed in one hour, and (4) the maximum and minimum temperatures during the sampling period. The make and type of applicators used are recorded in the footnotes to Table 1.

Results and Discussion

The results of analyses on samples collected for the purpose of determining the efficiency of the air filter-pressurization unit are recorded in Table 1. According to the data on Meta-Systox-R®, the quantity of insecticide in filtered air was very small, 0.11 microgram per liter, for an average of 11 samples, 5 collected in one test and 6 in another. Information on the amounts of insecticides in individual samples is reported in another publication (3). In the outside air entering the filter there was 28 micrograms of Meta-Systox-R® per liter, 255 times the amount in filtered air. Thus the efficiency of the filtering unit was above 99 per cent.

The highly toxic insecticide Systox® was used in two tests at very high concentrations. From the result (Table 1), it is seen that all the insecticide was removed from the air reaching the inside of the cab. Systox® was present at a concentration of 0.24 microgram per liter, an average of two tests, in unfiltered air.

In the only test with parathion, the concentration of the insecticide in the spray was greatly in excess of that usually recommended. Again the filtering unit proved to be highly efficient. Inside the cab the filtered air was found free of the insecticide whereas the air prior to entering the filter contained 1.31 micrograms of parathion per liter. We were unable to find any reference giving the inhalation toxicity LC_{50} for parathion to laboratory animals. Therefore, the industrial exposure tolerance (threshold limit value) for the insecticide seemed appropriate for comparing the data at hand (4). The value is the standard for parathion in a workroom environment and represents approximate substance in air as opposed to vapor. Such a comparison revealed that the amount of parathion in the air entering the filtering unit was 13 times the threshold limit value which is 0.1 mg per m^3.

Since unfiltered air samples were taken in the path of air flow to the filtering unit and relatively near the unit's intake, the amounts of insecticide found are representative of quantities entering the filter. In all probability, the greatest concentrations of pesticide would be present in air samples collected at more exposed positions such as along the sides and rear of both the cab and filtering unit.

The quantities of insecticide recorded for samples collected before and after the air was filtered are also of interest when examined in relation to the inhalation LC_{50} values reported for rats (Table 2).

Initially, it is assumed that a tractor operator inspires 20 liters of air per minute. This volume of air inspired in one minute by man was arrived at by averaging these figures: 16 liters of air inhaled by man when sitting and 24 liters per minute when walking (5). According to the data for Meta-Systox-R®, an operator inside the cab (filtered air) would inhale about 132 micrograms of insecticide per hour. This amount is well below the inhalation LC_{50} value for rats using the technical formulation (6). Without a cab and air filter the operator would be exposed in one hour to an amount of insecticide which is 22.4 times the LC_{50} inhalation value for rats. By applying the above criterion to the amount of Systox® found in unfiltered air, an operator would inhale about 288 micrograms of the insecticide in one hour, a quantity 1.6 times the LC_{50} value of 175 micrograms (7).

Table 1.—Details of tests to evaluate the air filter-pressurization unit and results showing the efficiency of the unit.

Test No.	Amount of actual insecticide, lbs. per 100 gals.	Amount of actual insecticide, lbs. Sprayed per hour	Volume sprayed in 1 hour (gals.)	Temperature F (range)	Microgram of insecticide[a] per liter of air (av.) Inside cab[b]	Microgram of insecticide[a] per liter of air (av.) Outside cab[c]
			1973-Meta-Systox-R®, e.c.; 2 lbs.[d]/gallon			
1[e]	0.50	1.50	300	75-80	0.11	
2[f]	0.80	1.40	175	73-75	0.11	28.0
			1974-Systox®, e.c.; 6 lbs.[d]/gallon			
1[g]	2.80	2.80	100	67-70	0.0	0.18
2[g]	2.80	3.40	120	58-60	0.0	0.30
			1974-Parathion, e.c.; 8 lbs.[d]/gallon			
1[g]	3.75	2.25	60	73-76	0.0	1.31

[a] 14.2 liter air scrubbed per hour with Meta-Systox-R® and Systox®; 22.3 liters per hour, parathion
[b] Filtered air
[c] Air before filtering
[d] Actual insecticide
[e] Hardie; air-spray applicator
[f] Windmill; air-sprayer
[g] Span Spray; air-spray applicator

Table 2.—Efficiency of air filter-pressurization unit in relation to LC_{50} value of Meta-Systox-R® and Systox®.

	Meta-Systox-R® Inside cab[a] air	Meta-Systox-R® Outside cab[b] air	Systox® Inside cab[a] air	Systox® Outside cab[b] air
Micrograms of actual insecticide per liter air (from tests)	0.11	28.0	0.0	0.24
Micrograms of actual insecticide by inspiring 1200 liters of air per hour	132	33600.0	0.0	288.0
No. times greater than LC_{50}		22.4		1.6

[a] Filtered air
[b] Unfiltered air

The hazard of dermal contamination is believed reduced to a minimum by the shielding provided by the cab. Such protection is likely to be of short duration in some cabs unless there is regular inspection, correction, and maintenance.

Relatively little is known about the life of the carbon filter in the air filter-pressurization unit. According to our most complete record, after 300 hours of spraying, the carbon activity was 50, as compared to an initial activity of 60 to 65.

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