Relationship of Ventilation and Dosage to the Effectiveness of DDVP as a Residual Fumigant


In 1958 and 1959 preliminary work indicated that small amounts of DDVP (0,0-dimethyl-2,2-dichlorovinyl phosphate) would produce sufficient vapour in plywood huts to give high mortalities of *Anopheles quadrimaculatus* for periods up to 10 weeks. However, the formulations of DDVP in these tests were unsatisfactory for field use because of their bulk and limited capacity for providing extensive residual action. In 1960, Miles et al. developed a new solid DDVP formulation which was found to be stable over a long period of time and which was capable of releasing DDVP vapour at a relatively uniform rate over a period of several months. The present paper describes biological tests conducted in 1960 with dispensers made of this formulation to determine their effectiveness at different levels of ventilation.

**Procedure**

For test purposes, 13 plywood huts of the same size (approximately 1000 cubic feet, or 30 m³) and design were constructed in a shaded area on the grounds of the Communicable Disease Center, Savannah, Ga. (Fig. 1). Each hut was 11 feet × 12 feet (3.35 m × 3.65 m) with 6-foot (1.8-m) high walls. A gable-type roof extended 4 feet (1.2 m) above the wall level. Openings in each hut included one door (3 feet × 6 feet; 0.9 m × 1.8 m) on the west side, one window (2 feet × 2 feet; 60 cm × 60 cm) in the center of both the north and east walls, and a 3-inch (8 cm) eave space between the roof and the top of the front and rear walls. All openings could be closed as desired. None of the huts had flooring other than the ground. A similar type of hut was also con-
constructed with walls of adobe and with roof and gable-ends of broom sedge.

The source of DDVP vapour was cylindrical dispensers 1 ½ inches in diameter and 5 inches in height (38 mm × 127 mm), each containing 40 g of technical DDVP formulated with 120 g of inert material. After preparation, the dispensers were hung for 10 days in a ventilated chamber which had one air exchange every three minutes. The dispensers were then installed in the test huts, where they remained for the duration of the tests. Each dispenser was hung about 12 inches (30 cm) from the peak of the roof near the centre of the hut (Fig. 2). When more than one dispenser was used, they were spaced at 6-inch (15-cm) intervals. In certain tests the dispensers were enclosed in perforated metal cases to determine whether such an enclosure would reduce the amount of vapour produced.

Three levels of ventilation were selected, and with each the number of dispensers installed varied, as shown below:

- D: door open, 1, 2, or 3 dispensers.
- DE: door and eaves open, 2, 4, or 6 dispensers.
- DEW: door, eaves, and windows open, 3, 6, or 9 dispensers.

Dieldrin-resistant *A. quadrinaculatus* were used as test specimens. Fourteen cages of mosquitoes of mixed sexes (50-100 specimens per cage) were hung on the walls of each hut at the 1-foot (30-cm) and 6-foot (1.8-m) levels in each corner and at the 1-foot, 6-foot and 9-foot (2.7-m) levels in the centre of the end walls (Fig. 2). The cages were placed in the huts at 8.00 p.m. and removed at 8.00 a.m. the following day. After the dead specimens were removed from the cage, the live adults were held for an additional 24 hours before the final female mortality was calculated. Beginning on 7 June, tests were made at weekly intervals and continued until the average mortality for the 14 cages dropped to or below 50%.

Temperature and relative humidity readings were obtained for each level of ventilation in plywood huts, the hygrothermographs being located adjacent to the dispensers so as to obtain readings on the conditions to which the dispensers were subjected.

### Results

The biological data are summarized in the table. For each ventilation level, no tests were made in the huts with the greater number of dispensers until the mortalities in the hut with the minimum number of dispensers declined.

The tests clearly showed the influence of ventilation on the biological activity of the residual fumigant. With one dispenser in huts with D ventilation, effective mortalities (70% or more) were obtained for 11 and 12 weeks. With DE ventilation, four dispensers were required to give similar mortalities; when the ventilation was increased to DEW, six dispensers were required. In a D-ventilated hut two dispensers gave effective kills for 15 weeks, whereas six dispensers were required to give the same protective period with DE ventilation. With DE ventilation two dispensers gave 8 and 9 weeks of satisfactory mortalities, but six were required to give similar mortalities with DEW ventilation.

The results obtained with different numbers of dispensers and with the same level of ventilation are of considerable significance. With D ventilation, one dispenser gave effective kills for 11 and 12 weeks. When the number of dispensers was doubled, this

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*During the period that the insects were exposed the door of the hut was closed.*
PERCENTAGE MORTALITY OF DIELDRIN-RESISTANT FEMALE ANOPHELES QUADIRNACULATUS EXPOSED FOR 12 HOURS TO DDVP VAPOURS AT 14 SITES IN PLYWOOD HUTS WITH THREE LEVELS OF VENTILATION

<table>
<thead>
<tr>
<th>Ventilation</th>
<th>No. of dispensers</th>
<th>Average female mortality (%) at indicated age of dispenser (weeks):</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>1</td>
<td>100 100 100 94 100 100 99 99 86 77 3</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>-- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>-- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --</td>
</tr>
<tr>
<td>DE</td>
<td>2</td>
<td>100 98 100 96 100 99 94 31 -- -- -- -- -- -- -- -- -- -- --</td>
</tr>
<tr>
<td>DE</td>
<td>4</td>
<td>-- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --</td>
</tr>
<tr>
<td>DE</td>
<td>5</td>
<td>-- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --</td>
</tr>
<tr>
<td>DEW</td>
<td>3</td>
<td>100 98 100 68 37 -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --</td>
</tr>
<tr>
<td>DEW</td>
<td>6</td>
<td>-- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --</td>
</tr>
<tr>
<td>DEW</td>
<td>0</td>
<td>-- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --</td>
</tr>
<tr>
<td>DE</td>
<td>None</td>
<td>1 1 0 2 0 0 5 3 1 2 2 1 6 5 3 3 9</td>
</tr>
</tbody>
</table>

a D = door open.
DE = door and eaves open.
DEW = door, eaves and windows open.

period was extended to 15 weeks. With three dispensers, the effective period increased one week. However, the last tests with the three dispensers were presumably influenced by the average temperature during the test period. On weeks 16 and 17 these temperatures were 73°F and 65°F (22.6°C and 18.3°C), respectively. On week 18, when the average temperature during the test period was 72°F (22.2°C), a mortality of 74% was obtained. This percentage kill compares favourably with the 77% kill recorded for one dispenser at 12 weeks. With DE ventilation, two dispensers produced effective mortalities for 9 weeks, four for 12 weeks, and six for 15 weeks. At DEW ventilation, increasing the number of dispensers from three to six nearly doubled the effective period (5 weeks to 9 weeks). However, nine dispensers increased the effective period to only 11 or possibly 12 weeks. These trends would indicate, particularly where ventilation is at a minimum, that it might be best to use a few dispensers and replace them more often, since this would decrease the initial concentration of DDVP in the air and also probably reduce the cost for a season’s protection.

In the tests, the decline in mortality was usually very abrupt, dropping as much as 50% within a period of one week. The mortality range among the different cage sites in the same hut was narrow, thus indicating a uniform distribution of the vapour. Greatest variability occurred at the 1-foot level, the 6-foot and 9-foot levels being similar. In 90 tests at all levels of ventilation and dosage in which the average mortality for all 14 cage sites was at or above 70%, the percentage of times any site at each height fell below 70% was 5, 3, and 3 at the 1-, 6- and 9-foot heights, respectively.

Enclosure of the dispensers in a metal case reduced the effective period by 1 week with the D (one dispenser) and DE ventilation (two dispensers). With three dispensers at DEW ventilation, the results were identical. This possible slight reduction in the effective period appears insignificant if this type of enclosure is found to be desirable as a safety precaution.

A total of 31 three-hour air samples were taken at sites 15 inches (38 cm) and 6 feet above the floor in the huts during the period in which the biological tests were in progress. Except for one sample with 0.124 mg of DDVP per litre of air, all other samples were in the range of from 0.002 to 0.045 mg of DDVP per litre of air. In 18 of the tests the DDVP concentration fell within the range of 0.008 to 0.045 mg per litre of air and in 14 of these 100% mortality of mosquitoes was obtained. In the remaining four tests, only one (0.008 mg/l) was completely out of line, giving only 36% mortality of mosquitoes. At concentrations below 0.008 mg/l, mosquito mortalities were erratic, ranging from 4% to 100%. These data substantiate previous laboratory tests, which...
indicated that dosages of 0.01 μg/l or greater for four hours would give satisfactory mosquito mortality. Since in these hut tests vapour concentrations below 0.010 μg per litre of air caused a sharp drop in mortality, a continuance of kills at or above 95% was a definite indication that the vapour concentration was at or above that level.

The period 1 June through 17 July was selected for comparison of temperatures and relative humidity in huts with the three levels of ventilation. The ranges in the daily minimum temperature were 59-78°F (15.1-25.5°C), 60-78°F (15.5-25.5°C) and 61-79°F (16.1-26.1°C), respectively, for huts with D, DE and DEW ventilation. The daily maximum temperature ranges under the same conditions were 82-116°F (27.8-46.7°C), 80-101°F (26.7-38.3°C), and 80-102°F (26.7-38.9°C), respectively. Thus, it can be seen that the greatest difference between temperatures in huts with different amounts of ventilation occurred with the maximum temperature, particularly in the huts with D ventilation. Even though the huts were shaded most of the day, parts of the buildings were directly in the sun at different times and this caused a rapid increase in temperature within the hut. This period of high temperature was usually short, and as a result the mean temperature for the 24-hour period in the hut with the least ventilation was only two or three degrees Fahrenheit higher than that for the huts with the greater ventilation.

The readings on relative humidity were too erratic to permit any correlation between humidity and the performance of the dispenser. Only slight differences were apparent in the range of relative humidities in the huts with three levels of ventilation. Relative humidity values varied mainly with the day and night fluctuations in temperature. On 40 of the 46 nights, the relative humidity in the DEW hut reached 100%, but in the D and DE huts the maximum levels were 95% and 97%, respectively.

In the mud-thatch hut with DEW ventilation three dispensers gave extremely poor kills at 3 and 4 weeks in contrast to satisfactory mortalities in the plywood huts which had the same dosage and type of ventilation. It was surmised that the loosely constructed thatch roof and gable-end increased the ventilation to the point that the vapour emitted from the dispenser attached to the peak of the roof was lost through the thatch roof rather than dispersed in the hut. The validity of this premise was established when coverage of the thatch with a paper liner resulted in an average mortality rising to a level of 85% at week 5. In a subsequent test in the mud-thatch hut (without a paper liner) four dispensers were installed in each corner 3 feet (90 cm) above the floor. Effective mortalities persisted for 3 weeks, the results being comparable to the use of three dispensers in a DEW plywood hut. Thus the data indicate that the thatch portion of the structure rather than the mud walls was the primary reason for the poor results in weeks 3 and 4.

Discussion

The previous data establish that it is possible to maintain biologically effective vapour concentrations of DDVP in naturally ventilated buildings for periods of 12-16 weeks. The number of dispensers required depends upon the degree of ventilation. The additional weeks of effectiveness achieved with a greater number of dispensers under the same conditions reflects the total vapour produced, since there is little difference in the rate of decline of vapour production among the individual dispensers. The effectiveness achieved was possible within a wide range of temperatures (70-79°F; 21.1-26.1°C) and at high relative humidities (58%–90%).

The application of this technique in the field will be enhanced with the development of dispensers which consistently produce vapour for periods greater than 3-4 months. Nonetheless, as with any type of fumigation, the limiting factor is the amount of air exchange. Under conditions where open hut construction permits an excessively rapid loss of vapour, the chances of maintaining an effective concentration are slight.

As the next step in the evaluation of the residual fumigant technique for use in malaria eradication projects, a pilot study will be conducted in occupied huts in a village in West Africa. This investigation will involve both toxicological and biological evaluations as well as an epidemiological appraisal of the effect the treatment exerts on malaria transmission.

Acknowledgment

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