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This is a very useful review of what has been happening in the past few years in the chemical control of pests. All health workers who have to deal with problems involving such matters can get an overview here.

RECENT DEVELOPMENTS IN PESTICIDES

Herbert F. Schoof, Ph.D.

THE CHEMICAL CONTROL of insects entered a new era in 1945-1950 when the chlorinated hydrocarbon insecticides such as DDT, dieldrin, chlordane, and others first appeared. Unfortunately, the hope of eradicating public health pests soon dissipated when several species developed resistance to certain of these chemicals within a relatively short period. Since then, the situation has worsened with each succeeding year as the number of resistant species increased from two in 1946 to 46 in 1958;[1] the areas occupied by resistant populations expanded; and the number of compounds to which a given species was resistant increased. The acuteness of the problem is best exemplified by the detection of dieldrin-resistant populations of three species of malaria vectors in Central America and Mexico[2,3] in 1958. The critical aspect of this development was the resistance of Anopheles albimanus to both dieldrin and DDT in certain areas of El Salvador and Nicaragua. These data point up the fact that man's insect enemies are adapting to successful coexistence with pesticides almost as rapidly as new technics and toxicants are produced.

During the past five years, the organophosphorous compounds have received major attention by investigators because of the widespread resistance of insects to the chlorinated hydrocarbon insecticides. Early work with the former group of pesticides concerned compounds such as EPN and parathion which are extremely toxic to man as well as to the insect. Fortunately, the chemical industry now has produced new organophosphorous pesticides such as malathion and ronnel which have relatively low toxicity to humans as compared to EPN or parathion. The general range of toxicity of organophosphorous compounds based on studies with female rats[4] is given in Table 1.

In the field of house fly control, new developments occurred along the lines of poison baits and impregnated cords. The cord method has provided season-long house fly control in many areas with only a single installation at the rate of 30 linear feet of cord per 100 square feet of floor area.[5] Fly baits incorporate 0.5 to 2.0 per cent toxicant in a carrier together with a sweetening agent. Such baits are popular with farm operators because they have a spectacular immediate effect on fly population. However, the reduction in fly densities is temporary and repeated bait applications (three to four per week) must be made to insure continuous control. Bait stations can be used to minimize maintenance operations. A chicken-watering device filled with a liquid bait containing DDVP has been shown to give effec-

tive house fly reduction for five weeks without replenishment of the toxicant.[6]

In mosquito control, the occurrence of dieldrin-DDT resistance in certain anopheline populations stimulated investigation of the phosphorous insecticides for a possible substitute residual chemical, even though these toxicants usually are characterized by a short residual life. One of the findings is that malathion, an erratic toxicant in its residual action against house flies, is extremely effective for extended periods against adult anophelines.[7-9] In initial tests using animal-baited huts at Savannah, Ga., malathion suspensions at dosages of 100 and 200 mg/sq ft on wood gave highly effective kills of Anopheles quadrimaculatus for periods of five months.[7] Subsequent studies have shown that marked residual action against mosquitoes is not unusual for that compound, a dosage of 200 mg/sq ft providing 100 per cent kills as long as 28 months after the original treatment.

Since the surfaces and conditions normally encountered in subtropical areas vary considerably from those found in this country, it is necessary to evaluate promising insecticides in such areas before deciding upon their potential use in malaria eradication campaigns. Therefore, in 1959, studies were established in El Salvador in cooperation with the Pan American Sanitary Bureau, International Cooperation Administration, and the El Salvador Ministry of Health. Many of the dwellings are entirely built of thatch while others may have a thatch roof with adobe or bajareque* walls. In some cases, a single dwelling may have wall surfaces of several materials (e.g., paper, metal, cane, and thatch).

The results obtained in El Salvador indicate that dosages below 1 g/sq m (100 mg/sq ft) are inadequate for long-term effectiveness[10] as measured by a bioassay technic. At 100 and 200 mg/sq ft malathion gave effective kills of Anopheles albimanus for periods of 8-12 weeks. Another organophosphorous compound (Baytex) also required a dosage of 100 mg/sq ft to provide like mortalities for periods of 8-12 weeks. Of interest are the data obtained with DDT residues applied at 100 and 200 mg/sq ft against a DDT-resistant strain of A. albimanus. Both of these dosages gave similar low but consistent mortalities for extended periods.

In the United States, most treatments against adult mosquitoes are done with fog or mist applications. In recent years, there has been an increasing interest in the use of dusts for this same purpose. Comparative studies of the three methods against salt marsh mosquitoes (caged), held at various distances from a commercial space treatment machine, have shown that the dust applications gave less satisfactory kills than either the fog or mist applications on the same nights, even though the dosage applied as a dust was greater than that for either of the other (Table 2).[11] In other tests with fog and dust applications on different nights, great variability in effectiveness has been observed, some dust applications giving kills superior to fog applications at similar dosage levels. From these studies, it has become obvious that marked differences in relative effectiveness can be obtained with any one of the three methods, depending on

Table 1—LD-50 Oral and Dermal Dosages for Female Rats Expressed as mg/kg*

Toxicant	Oral	Dermal
Parathion	3.6	6.8
Diazinon	76.0	455.0
DDVP	56.0	75.0
Malathion	1,000.0	>4,444.0
Ronnel	2,630.0	—

* Excerpted from reference.[4]

* Mud on a framework of saplings.

Table 2—Malathion as a Fog, Dust, and Mist Application Against Caged Aedes taeniorhynchus

Treatment*	Dosage Lb/A.†	Per cent Mortality at Distance (Foot) 135	270	540	810
Fog	0.1	98	53	39	0
Mist	0.2	95	55	32	27
Dust	0.3	63	81	3	2

* Three replicates each on same night.
† Based on 300 foot swath.

wind and temperature condition prevailing at the time of treatment. Mist applications are highly effective but usually for limited distances, since there is a rather quick fallout of the larger size particles. From the over-all data fog and dust treatments are approximately the same in their effectiveness, but fog applications generally provided slightly higher kills. Operationally and psychologically, the latter technic is the method of choice.

The newest development for the control of adult mosquitoes is the residual fumigant technic.[12] Discovered accidentally in 1958, when a sealed bag of fly bait containing DDVP and malathion produced high kills of nearby mosquitoes in a test room, experiments have revealed that a residual type of vapor action can persist for extended periods (Table 3). A single container (A) with 11.4 grams of DDVP gave excellent results for six weeks against caged female Anopheles quadrimaculatus in a field hut (8′ x 8′ x 7′) with two open windows, whereas a dosage three times that great was highly effective for 10 weeks. In contrast the same amount of DDVP on a different carrier and without malathion was far less effective. In one test series designed to evaluate the effects of ventilation, a dosage of 14 grams of DDVP in a building (11′ x 12′ x 8′) gave eight weeks of complete mortality of A. quadrimaculatus; with eave ventilation twice that dosage was far less effective. However, in a building with both eave and window ventilation, an increase in dosage to 42 grams of DDVP provided mortalities similar to that achieved with 28 grams of DDVP and less ventilation.

The significance of this development is that a relatively small amount of insecticide can be used to free a room or hut of mosquitoes on a continuous basis without requiring the time, manpower, or equipment normally expended in applying a residual application. When the technic is refined to the point of being suitable for field usage, it may well supplant the residual spray operations (now the basis of malaria eradication campaigns) in many countries where the types of housing are conducive to effective use of a fumigant method.

Another development of significance is the use of vapors for aircraft disinsection. Studies in early 1959 showed that the dispersal of DDVP vapor into the ventilation system of an intercontinental aircraft for 30 minutes would yield mortalities of from 95 to 100 per cent of caged house flies distributed in various parts of the passenger cabin.[13] The dosages ranged from 0.1 to 0.3 microgram of toxicant per liter of air, i.e., only 0.5 to 1.0 milliliter of DDVP was required for aircraft of the DC-6 type.

Table 3—Per cent Kill of Caged Anopheles quadrimaculatus Exposed Residual Fumigants Overnight in Huts (8′ x 8′ x 7′)

Formulation*	Weeks 4	6	8	9	10	12
A†	91	100	55	5	–	–
3A	100	100	100	100	85	59
B‡	100	35	–	–	–	–
3B	100	100	24	–	–	–

* 11.4 g DDVP per container A or B.
† 0.5 per cent DDVP+1.0 per cent malathion, commercial bait.
‡ 10 per cent DDVP on inert carrier.

In addition to methods utilizing pesticides, other technics such as male sterilization, and the use of parasitic fungi and bacteria, and silica aerogels are now receiving the attention of entomologists. The male sterilization technic was used successfully by the U. S. Department of Agriculture in eradicating screwworms from an island off the coast of Venezuela.[14] With this method male screwworm flies sterilized by irradiation of the pupae with Cobalt-60 are released to compete with normal males in the wild population. As the female screwworm fly mates only once, a predominance of sterilized over-fertile males eventually eliminates the breeding stock. Recent information from the U. S. Department of Agriculture indicates that a cooperative program by state and federal agricultural agencies in the southeastern United States and Florida, using this technic in 1959, has resulted in no screwworm flies being recovered in those areas since February, 1959.

Silica aerogels are sorptive dusts which remove the waxy protective layer of the insect integument resulting in the desiccation of the insects.[15] Successful roach control has been reported with such agents.

In concluding my comments, it would be amiss to omit mention of one technic found to be highly effective in the control of a resistant blow fly Chrysomyia putoria in the Belgian Congo. In Leopoldville, this species breeds extensively in the bored hole latrines commonly found in certain areas of the city. In 1952, health authorities began routine insecticidal treatments on a 12-day schedule to the 25,000 privies in the city. Since the species breeds only in human excrement, it obviously was faced with extinction unless resistance to the toxicant used was developed. The latter occurred, the insect coping successfully with the different insecticides applied during the period 1953-1957.[16] Confronted with this dilemma, the Health Department devised a type of rural "commode" which could be installed in each latrine and sealed around the edges with earthern fill. By teaching the natives to flush this apparatus daily, a water barrier was maintained in the device which blocked the entrance of adult flies into the latrine and at the same time prevented the emergence of newly developed flies. In addition to an effective reduction of blow fly densities, $80,000 was saved in one year in insecticide costs alone. This experience again stresses the fact that preventive control measures usually are the best and most economical means of overcoming our insect problems.

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