

sion was favorable and winds were less than 4 mph.

Practical tests on the Big Delta Army Base indicated that considerable immediate relief from mosquitoes could be obtained

with the Tifa and Dyna-Fog machines but even when adult mosquito populations were relatively low, as they were in 1950, treatments were needed almost daily to keep populations at a sub-annoyance level.

THE USE OF INSECTICIDES FOR MOSQUITO CONTROL IN CALIFORNIA

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Mosquito control in California now encompasses over 20,000 square miles, with Districts located throughout the length and breadth of the State. All control programs are primarily larviciding operations augmented by adulticiding through aerosol and spray applications. The Districts may be divided into those primarily concerned with salt marsh and coastal problems and those concerned with problems arising from an irrigation type agricultural economy. But this in no way seems to reflect the great diversity of breeding problems to which larvicidal applications must be adapted. These range from brackish and highly saline salt marsh along the coastal bays to clear river run-off in the interior, and from constantly flooded rice paddies in the Sacramento Valley to pasture, alfalfa and cotton lands, requiring repeated flooding and drying in the San Joaquin Valley. There are also the myriads of artificial containers collecting water from lawn sprinkling, etc. in the urban areas.

Aedes mosquitoes breeding in intermittent waters are a problem both in the salt marshes of the coastal areas and in the irrigated agricultural valleys. *Culex* mosquitoes are a problem throughout the state in any permanent or semipermanent waters. The *Anopheles* are a problem primarily in the north San Joaquin and Sacramento Valleys, breeding in extensive rice paddies and in the ditches carrying the water to and from these fields.

Before World War II diesel oil was the primary material used for a larvicidal

spray. Some pyrethrum in various formulations was used for adulticiding when necessary.

When DDT became available in the spring of 1946 the mosquito control picture in California entered a period of rapid change. Economy of use made mosquito control possible in areas of low assessed value. Low phytotoxicity made it possible to spray among crops without danger of injury and the fact that emulsible concentrates easily mixed with any available water could be carried and applied at low gallonage per acre made it possible for highly mobile equipment to be developed which could operate, independent of any set supply source, for a full day's work, resulting in a considerable saving of labor time.

The first DDT used in any quantity in California was a 25 per cent emulsible concentrate purchased from War Surplus stock. This material formed an excellent, highly stable emulsion which proved to be very satisfactory for use as a larvicide both by ground and aircraft spray application. Wettable and dry base dusts and oil solutions were also tried by plane and ground application. Of these materials DDT emulsible concentrate was judged, from the viewpoint of effectiveness, economy and ease of handling, to be the best all around material for use in ground spray applications. For aerial spray work emulsions seem to be more satisfactory in some areas and oil solutions in others.

When supplies of this War Surplus

DDT emulsible concentrate ran out considerable difficulty was encountered in obtaining satisfactory larval kills with proprietary formulations then on the market. Investigation showed that this was due in part to the use of soap emulsifiers which reacted with alkalies so prevalent in much of California's soils but primarily due to the lack of stability of the emulsions formed. Special formulations, giving a very high degree of emulsion stability and compounded with stable emulsifiers, were found to be a requisite to good control.

During the 1947 mosquito season several of the Districts began experimenting with others of the chlorinated hydrocarbons in an effort to find more efficient and economical synthetic insecticides. This work has been carried on more or less continuously since that time. At present a special grant requested by the California MCA from Subvention Funds, administered by the California State Health Department, Bureau of Vector Control, provides for a program of screening and field testing any available new insecticides and the undertaking of any other basic investigations that seem to be indicated by field usage problems. This program is being carried on by a full time entomologist under the direction of the Kern Mosquito Abatement District.

In 1949 an apparent resistance to DDT appeared in a number of Districts in California. It is interesting to note that this condition seemed to occur only in the San Joaquin Valley south of Sacramento. This area is one having very high summer temperatures at which DDT loses its efficiency to some degree, its killing power being inversely proportional to temperature changes. It is hoped that accurate data as to this resistance will be obtained this year.

Dosage Rates

Before discussing the various insecticides which have been or are now in use it would be well to explain the wide variations in dosages used by various Districts.

Salt marshes require much heavier doses of the chlorinated hydrocarbons than fresh water to obtain adequate kills. So also do waters containing high quantities of organic pollution such as some sewage effluent and wastes from food processing plants such as canneries and wineries. In these cases, where there is no danger of contact with warm blooded animals, sufficient material may be used to obtain a kill more economically than using diesel oil.

Insecticides Used

DDT emulsions have had the widest use of any of the larvicides used in California. They are used primarily as larvicides although occasionally may be used for adult kill as a spray and in aerosol units.

Dosages used for larviciding spray operation range from 0.17 lb. per acre in agricultural areas to 2.1 lbs. per acre for salt marshes. At the present time dosages in fresh water breeding are from 0.25 to 0.5 lb. per acre and in salt marshes from 0.96 to 2.1 lbs. per acre. All Districts in the San Joaquin Valley south of Sacramento and one District in the northern Sacramento Valley have indicated difficulties in killing with this insecticide at the present time.

DDT-oil solutions are used primarily for salt marsh control, larval control in highly polluted water and as aerosol for adult control. A few of the Districts use it for limited general control.

In the salt marshes 1 to 3 per cent Lethane is often added to the solution to insure better pupal kill. DDT dosages range from 0.96 to 2.4 lbs. per acre.

In highly polluted water dosages range from 0.96 to 4.0 lbs per acre.

In use as aerosol for adult control the percent solution varies widely from 2 per cent to 10 per cent. Opinion differs widely as to the efficiency of this method of control. Lethane or lindane may be added to the solution in varying amounts.

DDT 50 per cent wettable dust is used

in limited amounts. Pre-emergence treatment of riverbottoms for *Aedes vexans* has been successful using 1 to 1½ lbs. of DDT per acre. In the rice growing areas of the State 50 per cent wettable dust is added to seed rice to be planted by plane and put out in this manner at the rate of 1 to 2 lbs. per acre, giving control for three weeks.

Toxaphene is the next most widely used insecticide for mosquito control in California. It has replaced DDT in those areas where supposed resistance occurs with good success. It has not been found as reliable in salt marshes as DDT.

Dosages in fresh water range from 0.2 to 0.5 lb. per acre and may go as high as 1.0 lb. per acre for polluted water. Its short residual makes toxaphene less objectionable than DDT on pastures, etc., but limits use for pre-emergence treatment. The effectiveness of this material seems to be in direct ratio to the temperature.

DDD has been tried by a number of Districts with variable results. In general it seems to be effective in salt marshes at about ½ lb. per acre. One District reports poor kill at 0.66 lb. per acre.

In fresh water results have been variable. Some Districts report good results and some poor results. Generally, results have

been less satisfactory in hot weather. The price has also been high. Rates for fresh water application where DDD is used range from 0.2 to 0.5 lbs. per acre.

BHC (10 per cent gamma) and lindane have also been tried by a number of Districts with variable results. No record of use in salt marshes is available.

BHC has been found objectionable due to its odor.

Dosages of lindane range from 0.02 to 0.24 lb. per acre.

This material is less satisfactory in hot weather and quite expensive.

Several other insecticides are under development at the present time for use as fresh water larvicides.

Aldrin has been field tried with predictable results at from 0.075 to 0.10 lb. per acre.

Heptachlor shows considerable promise at 0.075 to 0.1 lb. per acre but few trials have been made.

Dieldrin has received very limited trials. One District reports apparent resistance after 3 applications at 0.052 lb. per acre.

One District reporting apparent resistance to DDT tried a mixture of DDT and toxaphene in oil at 0.2 lb. DDT and 0.3 lb. toxaphene per acre with unsatisfactory results.