ARTICLES

LARVICIDING FOR THE CONTROL OF MALARIA MOSQUITOES [1]

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The problem of malaria control has many approaches, some of which have been greatly advanced during the war years. Much progress has been made in the prophylactic and therapeutic use of new and established anti-malarial drugs. One of the most striking advances has been the use of DDT (dichloro-diphenyl-trichloroethane) to combat adult mosquito vectors, by the use of residual house sprays. In spite of many new approaches to the problem and startling advances in traditional procedures, the attack on the vector during its larval stage of devleopment continues to be an important method of malaria control, and recent progress of considerable importance has been made in the methodology involved.

There are certain difficulties which, so far, have prevented the attainment of the spectacular long residual larvicidal sprays that have characterized adult DDT sprays. DDT-oil treatments are nearly as toxic to other aquatic insects and to fish as to mosquitoes so that overdosing must be avoided. The low dosages that are safe to use must be uniformly distributed over the surface of the water to produce uniform larval kills. A surface film of DDT-oil is readily broken up by wind and wave action under usual circumstances. These small quantities of DDT are readily adsorbed by the organic constituents of the bottom mud.

On the other hand, DDT is toxic to mosquito larvae in extremely low dosages. In tests at this laboratory, one part of DDT in one hundred million parts of water killed over 50 per cent of insectary-reared larvae in twenty-four hours. In field studies 62 per cent control was obtained with as little as one one-thousandth of a pound of DDT per acre of water surface. However, if less than 1/20 of a pound was used the results were usually erratic. This dosage as applied by hand consistently produced better than 90 per cent control of all instars of larvae, killing the first instars as efficiently as the large larvae. It is not appreciably effective against either eggs or pupae. Indications are that it may kill appreciable numbers of adults as they emerge from the pupal case but field evidence on this point is lacking. Laboratory observations indicate that the DDT does not deter gravid females from ovipositing and such eggs definitely do hatch, and may survive if the DDT has been dissipated by the time of hatching. It is not known whether or not such ovipositing adults receive a lethal dose in the process but this is doubtful.

THE GALLON DDT-OIL FORMULA

A technique has been developed to permit the efficient and practical dispersal of small quantities of DDT solution which promises to replace a large proportion of the older oiling and even paris green

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dusting. The hand method requires inexpensive and readily available equipment and permits considerable savings in labor. In brief, the technique involves the use of a small (1½- to 4-gallon capacity) air pressure sprayer with suitable nozzle to atomize the DDT-oil solution, permitting the wind to carry the mist 30 feet or farther.

The sprayer can be any one of several compressed-air sprayers now on the market for garden or home use. The larger models, up to 4-gallon capacity, permit the treatment of two to three acres without refilling; the 1½-gallon model permits the treatment of only about one acre without refilling, but its light weight and convenience is apt to more than offset the more frequent trips to the supply truck for refilling. It should be filled not more than two-thirds full to permit sufficient air space for pressure. The pressure can be developed either by a built-in hand pump which is standard equipment on all such sprayers, or if desired, a tire valve may be welded into the top of the tank and the pressure can be obtained from a power compressor or spark plug adaptor when convenient.

The pressure should be initially 50 pounds per square inch and should not be allowed to drop below 30 psi. A petcock valve welded into the top of the tank permits the release of the air pressure before opening to refill, or at the end of the day. Opening the sprayer under pressure is harmful to the gaskets and may cause injury to the operator if the pump is blown out with sufficient force. All gaskets should be of oil-resistant material to minimize the frequency of replacement.

The nozzle is the key to the satisfactory dispersal of low volumes of solution. It should produce a uniformly small particle mist and deliver about three gallons per hour at a pressure of 40 psi. Several companies now have nozzles on the market that meet these specifications. They were originally designed for injecting fuel into oil burners of various types. The type of spray pattern is not important but the usual solid cone is entirely satisfactory.

The solution used consists of an appropriate amount of DDT (such as 0.625 per cent w/v) dissolved in a suitable fuel oil or diesel oil. Kerosene or No. 2 fuel oil is satisfactory. It is essential that the oil be clean to avoid unnecessary clogging of the very-fine-aperture nozzle. Since an entire acre of water surface is to be covered with a single gallon of solution, it is considered desirable to add a small amount of a suitable spreading agent. This insures good distribution of the film, even under difficult conditions such as a dirty water surface or dense vegetation. One-half of 1 per cent of *Triton B-1956*[3] has been found to be quite satisfactory though others are acceptable and it is believed that it would be possible to improve on any that have so far been tested.

The technique employed in a swamp or large shallow pond involves testing the wind direction and velocity by means of a short burst of spray. Paths are then mentally delineated across the pond at right angles to the wind direction and about 30 feet apart, designed to cover the entire breeding surface. Starting at the windward edge of the pond and walking somewhat back from the water's edge, the operator moves at the rate of about 75 feet per minute (that being about the tempo of a slow wedding march) holding the nozzle at a height designed to permit most of the mist to settle within a distance of thirty feet. If the wind is strong the nozzle will be held quite low and the first path may have to be several feet back from the water's edge. If the breeze is very gentle it may be necessary for the operator to hold the nozzle high above his head and possibly even walk in the water for the first swath. Having completed the first swath, the operator should walk downwind about thirty feet and again cross the pond at right angles to the wind, using the same technique as before, continuing with such 30-foot swaths until the entire area is covered.

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[3] A proprietary spreader manufactured by the Rohm and Haas Co., Philadelphia, Pa.

Care should be taken to repump whenever the pressure drops to 30 psi and to refill as necessary. It should be noted that the mist cannot always be seen for a full thirty feet but an experienced operator can judge how far it is traveling from the height and speed of the mist when it disappears. Moreover, it is often possible to see the oil film spreading on the water's surface at a distance of thirty feet if the light is just right. Often the mist will carry much farther, but if allowed to do so the dosage on the first swath will be light unless a slower pace is used. With even the gentlest breezes a 30-foot swath seems to be attained.

In deeper ponds, a boat can be used in place of wading and in some cases it is most practical to drift the mist for fifty to one hundred feet over an inaccessible channel by reducing the pace or retracing one's path.

In the case of narrow ditches the operator can walk along the windward bank, standing back far enough to insure that the mist is not over-shooting the water. If the banks are overgrown, the operator can wade down the center of the ditch moving the nozzle from side to side and keeping it low.

In all cases it is possible to keep clearing operations to a minimum because the fine mist spray will penetrate quite dense vegetative cover and the 30-foot swath permits sufficient flexibility for the operator to walk around obstructions.

In view of the desirability of an intelligent operator, and the compactness and convenience of the lightweight equipment, it should be possible in many cases to dispense with larviciding crews, permitting the controlman to check his known breeding areas by dipping and, when anopheline larvae are found, treating immediately. In such a way it should be possible for one or two good men to accomplish as much malaria control during the season as an entire dusting or oiling crew together with their foreman or supervisor. Moreover much unnecessary clearing could be avoided, further reducing the labor cost. Another important saving of this method over the use of paris green is that the DDT kills all stages of larvae including the small first instars, thus permitting a delay of several additional days before respraying should be necessary. Actually, combining in the one man the functions of checking infestations and spraying permits applying the treatment only when needed and avoids routine treatments when they are unnecessary. It often makes one trip to the pond suffice when two trips would be necessary under the traditional procedure. All of these savings in labor and efficiency make the not inconsiderable savings in cost of material seem incidental.

Recent reports from two months' use of the DDT-oil mist technique in eleven areas in Arkansas,[4] using slightly more than one gallon per acre, indicate the method to be equally as effective as straight oil larvicides, with the added advantages of greater ease in application and striking savings in labor and material costs. The following advantages and disadvantages of the method were reported, as a result of its first large scale practical use in mosquito control.

Advantages

1. Reduction of material costs ranging from 63 to 90 per per cent.
2. Savings in labor costs ranging from 20 to 80 per cent due to increased spray swath and less frequent refilling of cans.
3. Greater penetration of thick vegetation.
4. Less labor fatigue with the handling of lighter cans (2½ gals. instead of 5 gals.).
5. Loading time is reduced by use of concentrates.
6. Less chance of spillage and subsequent blistering to men.
7. Extremely long ditches may be finished without refilling.

Disadvantages

1. Requires better-trained control men.

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[4] The Arkansas Malaria Bulletin, Arkansas State Board of Health, 2: No. 3, 1–3, July 1, 1946.

2. Since mists are essentially wind-borne, success or failure of a treatment is due to type of breeze and proper application techniques.

3. Treatments have little effect on pupae.

A typical quotation from the report states: "Heavy breeding found in one area which had not been larvicided. After treatment with DDT enriched mist larvicide, breeding dropped to zero. Larval and adult station counts are 5 to 10 per cent lower than in 1945." Success with the use of the technique comes with proper training and experience.

AIRPLANE DISPERSAL OF DDT

The newer developments in airplane application are as important even though they do not involve so many different savings. In general, two types of airplane equipment have been developed for dispersal of DDT solutions.

Spraying equipment has involved a variety of details but in most cases, at least with the smaller planes that are apt to be more practical for peace-time use, the solution of DDT is pumped out of the storage tank through one or more nozzles which are designed to atomize the spray. Some nozzles have sufficiently small apertures to produce a small particle-size simply as a result of the pressure of the pump. Others are designed to make use of the air speed of the plane to break up the droplets. In some equipment the discharge from the nozzles impinges on a breaker bar which helps to break up the droplets. In all cases the mist produced is practically invisible unless the light is just right, so that the pilot cannot use the mist itself as a marker in delineating his lines of flight.

The second method has been labeled a "thermal aerosol" though there is some question as to the accuracy of the use of the term "aerosol" with droplets of the size actually obtained by this equipment. In this case the DDT solution is pumped from the storage tank into a venturi that is attached to the exhaust line of the engine. The heat from the engine breaks the droplets into a very small size and actually burns enough of the solvent to produce a dense white smoke which is mixed with the exhaust gases and is released into the slip-stream of the plane. This white cloud is readily visible for a considerable distance. It cannot be relied upon as a satisfactory marker, but it gives the pilot a method of checking to make sure that his equipment is working properly and that the cloud is going where it should.

The advantages of the spray nozzles are that they produce somewhat larger droplets that will settle faster and thus permit flying at a slightly higher elevation or with a stronger breeze. The thermal aerosol is preferred by some because it produces smaller particles that will give a wider and more uniform swath and better penetrate vegetative cover, and because the visible cloud acts as a positive and immediate check on faulty equipment or dispersal.

With both types of equipment it is desirable to use a solution containing as much DDT as is practical to handle and a solvent that is not too volatile and not too inflammable. Certain high boiling methylated naphthalenes have proved very satisfactory and permit the use of 20 per cent of DDT. Since in our tests a discharge of 0.1 pound of DDT per acre normally gave good larval control, one gallon of solution should treat about 17 acres. A typical plane that has been used successfully for such purposes is the Stearman PT-17, an open cockpit biplane, that cruises at about 85 to 90 miles per hour. A swath width of at least one hundred feet can be obtained, flying at about 30 feet above the water. If the system is calibrated to discharge one gallon per minute, 30 gallons of solution, which can be carried in a modified rear cockpit, will suffice for treating at least 500 acres in one-half hour, not counting time lost in turning. A typical spray operation required 25.1 gallons and 55 minutes flying time to treat two ponds totaling 455 acres, with no reloading. This is a considerable saving in both flying and reloading time over the older dusting methods. The efficiency of

the control so obtained has been adequately checked and has been found satisfactory.

DDT Dusts

At the present time DDT applied as a dust has little advantage over paris green. Since it is approximately ten times as toxic as paris green, a 1 per cent DDT dust is comparable to a 10 per cent paris green dust and can be applied in similar equipment at the same total rate per acre. The chief difference is that DDT should never be diluted with lime since alkali may decompose DDT by a process of dehydrohalogenation. DDT dusts have been notable in that they have been appreciably less toxic to fish and fish food organisms than the other forms of DDT tested.

Technical DDT has such gummy physical characteristics that it cannot easily be mixed with a diluent for dusting. It must have some sort of conditioner added and the process is such that it is impractical except on a commercial scale. Most malaria control agencies would prefer, therefore, to buy one or another of the commercially available dust concentrates. They are available with DDT concentrations ranging from 10 per cent up to 40 per cent or even higher. These concentrates may be further diluted with inert carriers in any simple dust-mixing machinery. It is possible that methods may be worked out to permit the application of a dust concentrate at a lower rate per acre, but at the present time it seems best to use a 1 per cent concentration of DDT and apply from five to ten pounds of finished dust per acre. Hand dusting equipment has, unfortunately, not been changed appreciably during the war. In general, wartime research has been more concerned with developing entirely new types of equipment, particularly for the application of small-particle mists and aerosols, rather than with the improvement of dusting machinery.

Equipment

Some of the new dispersal equipment developed during the war is quite spectacular. Military fog generators, used for producing smoke screens, have been modified to permit the incorporation in the fog of finely divided droplets of a DDT solution. Such generators are usually mounted on some type of truck for mobility. They depend upon the ignition of gasoline under forced draft for heat and so are quite noisy. The combination of the roar of the generator and the large clouds of smoke billowing from the discharge nozzles and being borne away by the wind is at least spectacular. The temperature of the discharge, which is automatically controlled, can be adjusted to give a relatively wider range of particle sizes. The most important limitation of the equipment is that it is so dependent upon proper meteorological conditions. Thus, the direction in which the cloud drifts is determined by wind direction; the distance that it is carried and the rate of deposition of DDT are determined by wind velocity and temperature on the ground as compared with the temperature at an elevation of six feet above the ground. Changing the particle size by adjusting the temperature control permits limited adjustment for wind velocity, but is a poor substitute for conditions of inversion.[5] Under ideal conditions the equipment can generate a DDT smoke that will kill anopheline mosquito larvae for a distance of several hundred feet; but since those ideal conditions are not too commonly encountered, it appears that this type of equipment is more apt to find a place in agricultural pest control or in the control of adult flying insects.

Another group of spectacular equipment has been developed under the general subject of pyrotechnics. These were designed primarily for use under combat conditions and it appears likely that their usefulness will be mostly restricted to military larviciding. Mortar shells containing DDT, DDT-containing bombs to be dropped from aircraft, and hand grenades or

[5] Temperature inversion is defined as the condition in which ground temperature is lower than air temperature: it results in downward air currents.

candles containing DDT are methods that may permit the application of DDT to otherwise inaccessible breeding areas, but they are very inefficient and their usefulness in peacetime malaria control is doubtful.

There has been little progress made on developing power equipment for ground aerosol dispersal other than the fog-generating machines described above, but this type of equipment has not proved too satisfactory for larvicidal use.

DDT EMULSIONS

If DDT is dissolved in fuel oil or another solvent and an oil-soluble emulsifier added, it can be emulsified in water and the dilute emulsion can be applied at 15 gallons per acre or some other convenient rate. This technique makes use of the older and awkward knapsack sprayers, or of power sprayers either from truck or boat. Some workers have experimented with the use of a small quantity of DDT-oil solution dispersed through boat-mounted pumps which mix the solution with water pumped from infested lakes, and discharge it through nozzles for a considerable distance.

Any of these methods should give satisfactory control of anopheline larvae and also of most culicine larvae; but there is always increased danger to fish and other aquatic organisms when the DDT is dispersed throughout the water, as it is when applied as an emulsion, rather than spread over the surface as a film. Therefore, in any such formula the emulsion should be as quick-breaking as possible and the dosage should be kept to the minimum of 0.05 pounds of DDT per acre. These methods cannot be recommended for indiscriminate use where fish or other aquatic wildlife are very important until more is known about them.

SUMMARY

In summation, DDT has not produced the spectacular residual effects against larvae that it has against adult mosquitoes; but due to the high toxicity obtained from minute amounts, it has permitted the development of new methods of larviciding, both by hand and by airplane, which give promise of displacing in large measure the older techniques of oiling and paris green dusting.

In experimental field tests the application of one gallon of fuel oil with 0.05 pound of DDT per acre has given excellent larval control, with evident savings in costs of labor and materials.