Since the Association has become in fact a national group, it is anticipated that the able committee now studying the organization to determine how it can best serve the needs of its membership will have a definite proposal to place before it at the annual meeting which should be held sometime between now and the end of December. Should there be any members who have not had opportunity to express their ideas on this subject and who desire to do so, it is suggested that they write the secretary. In any event, it is believed that the changes to be proposed will provide maximum opportunity for cooperation with all existing organizations of mosquito workers and will aid in developing unity of thought in the advancement of mosquito work wherever it is needed.

Meetings and Inspections

The current season has seen the mosquito control agencies constantly on the firing line, not only combatting mosquitoes, but also shortages of labor, materials, transportation and equipment, while at the same time a number of the technical personnel were leaving to take up new duties with the federal services—all during a period when wartime requirements called for more, not less, mosquito control. With the active agencies striving with all their remaining resources to turn in a creditable performance in spite of these severe handicaps, there has been no doubt that any inspection or meeting during the summer months when mosquito breeding was at its apex would have been poorly attended. Now however, with the summer nearly over, perhaps it will be feasible to arrange to see some of the interesting new developments and accomplishments of the year.

Mosquito News

The hard working publications committee has been depleted by several of its members entering the federal services, thus leaving a tremendous load upon those remaining. To keep up the high standard that has been set for "Mosquito News" it will be necessary that the general membership continue and increase its support of the commtitee, by writing up and submitting for publication accounts of the newer and better things that are being done. The response to date has been good, but there doubtlessly are many developments that would be of general value if published but which are now serving only a limited field. Do you not have some such item, which you may take more or less for granted, but which would be of distinct service to the rest of us if we knew about it?

Secretary.

WORLD WIDE MOSQUITO CONTROL

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LARVICIDES AND THEIR APPLICATION

Part I —Contact Poisons—In January Report
Part II —Stomach Poisons—In February Report
Part III—Application of Larvicides—In February Report

Part I—CONTACT POISONS

The application of larvicides is the primary method of mosquito control used in the program Malaria Control in War Areas. Although this is somewhat contrary to the usual practice in normal malaria control operations in which main reliance is placed on control by drainage and filling, the emergency nature of this program and the temporary character of the establishments being protected, made it advisable to use larvicides to control mosquito production where effective control can be achieved by such measures.

Control by larvicides is based on the fact that the larval and pupal stages

of mosquitoes are spent in water and that during these stages the immature mosquitoes must rise periodically and penetrate the surface of the water with their breathing openings in order to obtain oxygen for respiration. The larvae, in addition, obtain their food from among the particles lying on the surface of the water, in suspension in the water, or on the bottom. Larviciding consists of the addition of toxic materials to the breeding waters so that the larvae and pupae will be killed in the performance of these functions.

There are, in general, two types of larvicides:

1. Contact poisons, which kill upon contact with the external and certain internal tissues of the insect.
2. Stomach poisons, which must be ingested to exert a toxic effect.

PETROLEUM OILS

Petroleum oils are the most widely used larvicides for mosquito control. The oil, sprayed over the surface of the water, forms a film there which serves to kill the larvae and pupae breeding underneath.

For best results the oil should possess the following properties:

1. It should readily penetrate the larval and pupal breathing openings and kill the larvae and pupae within a short time after application.
2. It should spread rapidly on the water surface in order to penetrate all the hiding places of the larvae and pupae and produce a uniform, unbroken film on the entire surface.
3. It should form a relatively stable film.

A mosquito larva or pupa, while in the process of breathing on the water surface, will also draw some oil from the surface film into its respiratory system through the breathing opening. The toxic effect then exerted varies with the type of oil used. Oils of low boiling range and high volatility exert a direct toxic action within a very short time. A high boiling, nonvolatile, heavy oil, on the other hand, may slowly cause death within one or two days. In order to be effective, the latter type of oil must be present as a continuous, unbroken film over the surface of the water for a considerable period of time; a condition almost impossible to insure under field operating conditions.

The ideal oil, then, should contain enough of a low boiling petroleum fraction to insure quick penetration into the respiratory system and high toxicity, and a sufficient quantity of a high boiling fraction to leave a relatively stable film. Such an oil would have the following specifications:

Type of Oil	Light Distillate fuel or Diesel
Gravity (A.P.I.)	27-33
Flash Point	130° or higher
Viscosity S.U.	
(a) 100° F.	35-40

Distillation:

10%:	430°-450° F.—(killing fraction)
50%:	510°-550° F.
90%	630° F. or higher—(lasting fraction)

These specifications are quite similar to those used by the Navy Department for their Diesel engine oil. The usual No. 2 fuel and Diesel oils are also satisfactory for the purpose.

The use of waste crankcase and similar oils has been found to be quite unsatisfactory. Such oils generally are not very toxic to mosquito larvae and pupae, spread poorly on the water surface and leave an unsightly mess. When mixed with kerosene and sprayed over the water surface, the effect is not much greater than would be produced by the same amount of kerosene used alone. The sludge, and other suspended particles in crankcase oils will clog

the nozzles of the sprayers so frequently that the average oiler will soon discard parts of the nozzle so that it will emit a solid stream rather than a spray of oil. Should it become necessary in any area to use waste crankcase oil, it should be collected and stored well in advance of use, so that the sludge and suspended matter will settle to the bottom and the relatively clear supernatant oil can then be drawn off for use.

Generally, from five to fifty gallons of oil per acre are required, depending on the method of application and the amount of vegetation, flotage, and debris. Less oil per unit area is required for the control of anophelines than for pest mosquitoes. Except in a densely overgrown area where larger quantities are necessary, no more than 25 gallons of oil per acre should be used for malaria mosquito control.

Advantages

1. Cheap (in normal times.)
2. Readily obtainable (in normal times.)
3. Can be stored indefinitely.
4. Is relatively long lasting.
5. Can be used in certain situations where pyrethrum-kerosene emulsion is not effective.
6. Is effective against the larvae and pupae of both anopheline and culicine mosquitoes, excepting **Mansonia perturbans.**

Disadvantages

1. Requires considerable storage space and is messy and bulky to handle.
2. Cannot ordinarily be applied at any considerable distance from the sprayer.
3. Spreads poorly in vegetation or debris; much of it is wasted on the surface of emergent vegetation when such is present.
4. Destructive to the rubber hose and gaskets of the sprayer unless special equipment is used.
5. Is often objected to by wild life interests.

PYRETHRUM-OIL EMULSION

Under certain circumstances, as in ornamental ponds, fish ponds and drinking water supplies where oil or paris green is objectionable, it may be desirable to use a pyrethrum-oil emulsion for control. By the addition of pyrethrum to the oil, it is possible to apply a considerably thinner film of oil to the water surface and still obtain a successful kill.

Pyrethrum powder is the ground dried flowers of the plant **Chrysanthemum cinerarea-folium.** The active toxic ingredient of these flowers is the pyrethrins content; this is generally extracted from the flowers in kerosene or light oil. The stock emulsion of the pyrethrum-oil emulsion, as developed at the New Jersey Agricultural Experiment Station, contains the following ingredients:

1. Six gallons of kerosene or light oil containing 1140 cc. or 40 ounces of 2% pyrethrum extract in light oil.
2. Three gallons of water.
3. Six ounces of an emulsifying agent, sodium lauryl sulphate (Gardinol W.A. Concentrated) which is commonly used, or 24 ounces of liquid 40% potash soap.

To prepare this emulsion, the emulsifying agent is added to the water, which is agitated until foam begins to form. The light oil, into which the pyrethrum extract has been introduced, is then slowly added to the water, while continuing the agitation. Very violent and sustained agitation is required for the formation of a suitable emulsion; agitation by hand is not usually very satisfactory. The resultant solution constitutes the concentrated stock emulsion in which form the material may be stored. Before spraying, the stock solution is diluted with ten parts of water to each part of emulsion. The diluted emulsion is then sprayed at the rate of about fifty gallons per acre, more or less, depending on the breeding place.

Advantages

1. Is not messy and is acceptable to many property owners where oil is not; for example, to control breeding in outdoor swimming pools.
2. Will not injure vegetation in ornamental garden pools.
3. Not injurious to fish or bird life as normally applied; consequently, more acceptable to wild life interests.
4. Acts much more rapidly than oil, and like oil, is effective against both anophelines and culicines.
5. Can be stored and carried into the field in concentrated form and diluted just before spraying.

Disadvantages

1. Relatively short lasting; quickly loses toxic effect after spraying.
2. Of no value on highly polluted breeding places; toxic effect of both pyrethrum and kerosene rapidly destroyed by high organic content of such places.
3. Special mixing apparatus and care are essential to form a good emulsion.
4. Deteriorates somewhat upon storage, losing some of its toxic qualities; emulsion is permanently destroyed if it is frozen.
5. We are dependent upon a foreign source of supply for pyrethrum.

PHENOL LARVICIDE

These larvicides are purchased as prepared commercially with varying phenol coefficient. A phenol coefficient of ten to fourteen has been found most suitable for mosquito control work.

The concentrated larvicide is diluted with thirty parts of water before spraying. Applied at rates varying from 10 to 95 gallons per acre, this material was found to be less effective than kerosene. In the laboratory, the larvicide applied at the rate of 50 gallons per acre killed 100 per cent of fish but only

HAND ROTARY DUSTER

16 per cent of larvae. It is therefore not recommended for general mosquito control.

PART II—STOMACH POISONS

Paris Green

Paris green (copper acetoarsenite) is the only stomach poison widely utilized in mosquito control work. It is used as a dust consisting of from one to fifty parts per hundred of paris green mixed with some inert diluent such as soapstone, hydrated lime, finely powdered talc, road dust, etc. The degree of dilution of the paris green should vary with the maximum distance that the limits of the breeding area lie from the point of liberation of the dust and with the width of lethal path desired. When it is required that the dust be effective against mosquito breeding at some considerable distance from the duster, a more concentrated mixture should be used, and the mixture should become progressively more dilute as the extent of necessary dust cloud coverage decreases. For example, hand casting can be used to dust a radius of about 20 feet from the duster and a one to two per cent paris green mixture (one to two parts paris green to 99 or 98 parts inert diluent) is recommended for this method of distribution. The mixture for use with a hand blower, effective up to 200 feet, should be five to ten per cent; for a power duster effective up to 500 feet, it should be ten to fifteen per cent, and for dusting from an airplane, 25 to 50 per cent.

The amount of paris green necessary per acre varies with the type of area being treated and successful results have been obtained with from one-quarter pound to two pounds per acre, and as high as four pounds where the water surface was thickly covered with water hyacinths. This refers to the actual quantity of paris green in the mixture. As an indication of the toxicity of this material to anopheline larvae and the minute amounts re-

AIRPLANE DUSTING

quired under ideal conditions, it has been found in the laboratory that an application of paris green equivalent to one-half ounce per acre would produce a mortality of 80 percent. In this connection it has also been found that the finer the particle size the more efficient the powder as a larvicide. In general, an application of approximately one pound of paris green per acre is satisfactory for anopheline control.

Paris green conforming to the following specifications is an effective larvicide: It should contain a minimum of 50 percent arsenious oxide, no more than 2½ percent being soluble in water. At least 95 percent should pass a 325 mesh sieve in a machine or hand shaking test without preliminary desiccation. Pan tests of the dust, in the same paris green-diluent mixture and the same rate of application as that to be used in the field, should give a complete kill on second, third, and fourth stage anopheline larvae in two hours.

Paris green is an arsenical compound and is, therefore, poisonous to warm blooded animals, including man. Due care must be taken when handling this material and every precaution should be taken to prevent the powder from entering the mouth or from accumulating in crevices in the skin. When dusting, the laborer should stand on the windward side of the duster. However, when applied in the minute quantities required for mosquito control, paris green has not been observed to have a poisonous effect on aquatic plants, live stock or other animal life; repeated applications do not appear to result in any cumulative effect of arsenical poisoning in the area treated.

ENGINE-DRIVEN CENTRIFUGAL PUMP

Advantages

1. May be applied to areas for anopheline control where application of liquid larvicides is not practical.
2. Use can be made of favorable wind currents to carry the dust cloud over an area otherwise inaccessible.
3. Can effectively treat areas covered with emergent vegetation.
4. Is easy to store and transport.

Disadvantages

1. When applied to the water surface as a dust, second, third, and fourth stage **Anopheles** larvae are killed but all pupae and many first stage larvae escape.
2. As used for the control of anophelines, paris green is not effective against the pest mosquitoes.
3. Difficult to use under adverse wind and weather conditions.

The importance of a knowledge of the biology of the various mosquito species is well illustrated in connection with the use of paris green. Culicine larvae hang head downward from the surface of the water and feed there at a subsurface level or at the bottom of the breeding place. Anopheline larvae, on the other hand, rest parallel to and just below the surface film of the water. In feeding, they set up small currents with their mouth parts which bring into their mouths any small particles lying on the surfaee. Paris green dust, which consists of very fine particles, settles and remains on the surface of the water, and is ingested by anopheline larvae with fatal results. Mosquito pupae take no food, and therefore are not affected.

PART III—APPLICATION OF LARVICIDES

Although the control of mosquitoes through the use of larvicides is superficially a simple matter, it requires a well coordinated organization calling

COMPRESSED AIR SPRAYER

for intelligent well trained inspectors, conscientious oilers or dusters and competent, energetic supervision. The effectiveness of larvicidal operations cannot be judged on the quantitative basis of oil sprayed or paris green dusted or the extent of water surface covered per man daily, but rather on the control of mosquito production achieved. This should serve as the criterion for judging the effectiveness of the program, although the efficiency factors should certainly not be disregarded.

Given effective toxic agents and an understanding of their uses and limitations, the success of a larvicidal program depends on the proper application of these materials to the breeding areas. Since water surface and breeding area are not synonomous, water surfaces in the zone under control must be divided into those which breed mosquitoes and those which do not. In addition, on this program, it is necessary to further differentiate areas which breed **Anopheles quadrimaculatus** or, in some areas, **A. maculipennis freeborni** or **A. albimanus.** The first requisites to an effective larvicidal program are, therefore, adequate entomological surveys and inspection.

The two most common faults of field larvicidal operations are: (1) overtreatment of the area in general, i.e., too heavy an application per unit area; and (2) undertreatment, or complete lack of treatment, of some portions of the area. The correction of these faults requires intelligent, energetic supervision at the breeding area being treated. To avoid double application to some spots and none to others, the larvicidal crew should be so organized that each man has a specific area to treat. The form of such organization would depend on the topography and whether oil or dust is being used. In larviciding extensive swamps the crew may be formed into a row, the men a certain distance apart and all moving forward together as they apply the larvicide. When the end of the breeding area has been reached, the row of men wheels on the outside man and again moves forward, treating the adjacent lane. When treating shoreline, ditches, or small isolated pools and ponds, each man may be assigned a specific segment to treat.

Overtreatment may be corrected by demonstrating to the members of each larvicidal crew just how much larvicide should be applied so that they can recognize overtreatment. They should be instructed to keep moving steadily as they are applying the larvicide. The foreman and other supervisory personnel should check the laborers frequently as they are working and correct them if necessary. It is a very natural impulse, even among high-type personnel, to apply a larvicide until its presence is clearly indicated on the surface. Overtreatment is indicated by a green color on the water when using paris green, a milky color when using pyrethrum-oil emulsion, or a strongly oily appearance when using oil.

Using knapsack or orchard type hand sprayers, one man may be able to distribute from 10 to 50 gallons of oil per day depending on the character of the area. If the water areas are fairly continuous and in open country, then the greater amount of oil can be sprayed. If the breeding spots are smaller and further apart and the underbrush is heavy, then it may be expected that an oiler will spray the minimum amount.

Similarly, using a hand rotary duster, the amount of dust that a laborer can distribute is conditioned by the nature of the terrain. Where breeding areas are continuous, or nearly so, and the going easy, one man may distribute 100 or more pounds of dust per day. Under adverse conditions, the distribution of 35 to 50 pounds of dust may represent a good day's work.

Methods of applying larvicides vary from such crude means as the hand casting of paris green to the use of airplanes for dusting or spraying. Hand casting of paris green or the application of oil or other liquid larvicides from a sprinkling can are methods which may be used where more efficient means are not available.

The most usual method of application involves the use of hand sprayers or dusters. Hand sprayers are of the compressed air or knapsack types. The compressed air sprayer differs from the knapsack type in that an actual pressure is built up within the tank, and the oiler must stop at fairly frequent intervals to build up depleted pressure in the tank. This type of sprayer has but one strap which is looped over a shoulder of the oiler. It is not a preferred type because of the frequent stops necessary for repumping and because any damage to the tank may destroy its usability. This sprayer has one advantage when being used on treacherous terrain where it is possible that the oiler may fall into the water or into a hole in the ground, since under such circumstances the one strap can be thrown off quite easily. When using this sprayer, it should not be allowed to stay in the sun for any considerable period of time without allowing the pressure to escape. During lunch time, and overnight, the pressure should be released.

There are three types of knapsack sprayers. The first and preferred type is that which has a piston type pump. The pumping handle in this type may be overhead or under the arm. The former is often preferred in open country, while the latter is generally more useful when working in dense underbrush or in wooded areas. The second type of knapsack sprayer has a diaphragm pump, which formerly was not very suitable for oiling because the rubber diaphragm quickly deteriorated when exposed to oil. It is understood, however, that manufacturers of this type of sprayer are now using a synthetic oil-resistant rubber and such sprayers may prove more satisfactory in the future. The third type of knapsack sprayer, originally developed for fighting forest fires, is the so-called trombone type, which has the pump in the handle just behind the nozzle.

Hand rotary blowers are used for the application of paris green dusts. These are similar to the blowers used for dusting agricultural crops. The paris green must be thoroughly mixed with the diluent before being applied to the breeding areas. This can be accomplished in a drum mounted on an eccentric shaft, which is turned by hand. There are also several power mixers on the market.

Power sprayers and power dusters, mounted in boats, airplanes or automotive equipment, can be used for the application of liquid and dust larvicides to the larger breeding areas. There are in general two types of power sprayers: namely, the high pressure piston type pump which draws the larvicide directly from the tank and sprays it over the breeding area; and the water-oil type that consists of an engine-driven centrifugal pump which draws a small portion of its discharge from the tank and the remainder from the breeding water. The latter type is always mounted in boats while the former may be mounted in motorcycles, trucks or boats.

Airplanes have been found very useful for the distribution of paris green dust over extensive breeding areas which could not otherwise be efficiently treated. Airplanes have not thus far proven very suitable for the distribution of liquid larvicides.