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MONTANA MOSQUITOES

Part II Survey and Ground Applied Chemical Control

MONTANA DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES
Environmental Sciences Division
Environmental Services Bureau
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Table of Contents

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I. Philosophy

It is necessary to understand the life cycle and habits of mosquito species in order to effectively and efficiently control mosquito populations. Detailed surveys are essential for the planning, operation and evaluation of control programs. Survey and evaluation are continuing processes that must accompany control. A basic tenet for mosquito control is that only by treatment of cause (larval mosquito habitat) rather than effect (mosquito populations) can a problem become less severe. For this reason and since mosquitoes require shallow standing water for development, good water management practices/source reduction methods are the preferred approaches in mosquito control. As a practical matter, the use of chemicals will be required for the temporary suppression of mosquito populations. Chemical control should assume less importance as source reduction programs develop. In all cases, the least environmentally disrupting approach to mosquito control should be used.

Control programs conducted by mosquito control districts organized under state enabling legislation (R.C.M. 1947, 16-4201 through 16-4214) have been the most effective. Districts thus organized have more program continuity, higher levels of financing and a more reliable source of financial support. These advantages make environmentally sound source reduction and larviciding programs easier to attain.

The vector control specialist of the Environmental Services Bureau may be contacted for technical advice, information or assistance in forming mosquito control districts or for reviewing and consultation upon mosquito control programs and problems. A pesticide applicators license, obtainable from the Pesticide Control Division of the State Department of Agriculture, is required by all commercial and government applicators who supervise the application of pesticides.

II. Mosquito Biology - Some Practical Implications

There are 43 species of mosquitoes in Montana distributed among six genera (Aedes, Anopholes, Culex, Culiseta, Coquilletidia and Psorophora). Vector Control Bulletin #1, Montana Mosquitoes, Part I--Identification and Biology (obtainable from the Department of Health) may be consulted for detailed information. The most common mosquitoes are Aedes species. Most control efforts are directed at this group. The other common genera are Culex and Culiseta. The mosquito species Culex tarsalis is of public health importance in Montana because it is the principle vector of human and equine encephalitis. Other species have also been found to be naturally infected with the virus causing this disease.

All mosquito species have four distinct stages in their life cycle: the egg, the larva (wiggler), the pupa (tumbler) and the adult. The first three stages require water for development. Eggs of all species (except Aedes and Psorophora species) and all larvae and pupae will die if they are out of water. (Pupae can survive for short periods in a moist environment.) For this reason, source reduction (draining, ditching, filling, etc.) is effective at controlling mosquitoes. (See Section III, Classification of Breeding Places).

Aedes and Psorophora species normally lay their eggs in the mud along receding waters. (One rare Aedes species lays its eggs above the water line in tree holes or containers). Eggs of some Aedes species will hatch if the site is flooded again that season, others must be subjected to cold before they will hatch. Hence some species have only one generation each year; others may have several generations. Aedes are a temporary water mosquito, implying that they are produced in water which is retained on the surface for a minimum of about 7 days but which disappears during the course of the season. They may also be found in permanent or semi-permanent bodies of water which have periodic fluctuations in water levels. Water which has little fluctuation in water level will produce few Aedes. Eggs of some Aedes species retain the ability to hatch if flooded even after a period of 5 years on dry land. Hence two or three dry years do not solve most mosquito problems. Several years which are successively drier will result in several egg lines below the high water mark. If all egg lines were then flooded, a much larger than normal hatch could occur. Aedes over-winter in the egg stage.

Eggs of the Culex and Culiseta species are laid in rafts on the surface of permanent or semi-permanent bodies of water. Eggs of Anopholes species are laid singly on the water surface. Eggs of these permanent water mosquitoes must have water continuously to remain viable. While Coquilletidia over-winter in the larval stage, the Culex, Culiseta, and Anopholes species over-winter in the adult stage in sheltered sites. Since there is a high mortality of adults of these species during the winter, populations of these species do not usually build up until later in the season. The permanent water mosquitoes typically have several generations each year.

Water temperature is the most critical factor in the hatching of eggs and in the time required for development. Eggs of the predominant Aedes species may hatch when the daily average water temperature reaches about 50° but they do not hatch in large numbers until the daily average water temperature approaches 70° F. Besides water temperature, the rate of larval development depends on the species and amount of nutrient available. Larval and pupal development may be completed in as little as 5 days (more likely 7 or 8 days) in hot weather or development may take 3 weeks when the water temperature is cooler.

Larvae pass through 4 developmental instars (stages), molting or shedding their skin at the end of each instar in order to grow. Fourth instar larvae become pupae with the next molt. Recognition of the instar that larvae are in is of practical importance More time is available for an operator to larvicide if earlier instars are detected Less insecticide is required to kill 3rd instar larvae than 4th instar larvae. Pupae are more tolerant to attack by insecticide and control is apt to be less effective if larvae are allowed to pupate. All larvae (except Coquilletidia, which is fairly rare) must come to the surface to breathe: hence the effectiveness of oils which foul the breathing apparatus and cut off the air supply.

The adult mosquitoes feed mainly at night, being most active at dawn and at dusk. A few Aedes species will attack during broad daylight (especially if disturbed) but most prefer shaded situations if they bite at all during daylight hours. Different mosquito species show different host preferences. Culex tarsalis, the common encephalitis mosquito, readily bites man but prefers to feed on birds. Culex territans feeds exclusively on reptiles and amphibians.

The normal flight range of most Anopholes, Culex and Culiseta species is usually considered to be one mile or less. However, studies have shown that Culex tarsalis commonly fly from 3 to 10 miles, especially when seeking shelter in the fall. Most Aedes species are strong fliers and range several miles from their breeding places.

Individuals have been recaptured over 20 miles from their release site but most range three miles or less. Mosquitoes will normally fly no further from their breeding sites than is necessary to feed.

III. Classification of Mosquito Breeding Places

Not all water produces mosquitoes. Shallow, standing, sometimes stagnant water which has emergent vegetation (that protects larvae) and bodies of water which have gradual sloping banks are of primary concern. Large open expanses of water which are subject to wave action, ponds which have abrupt banks and little emergent vegetation and running water usually produce few mosquitoes. As indicated earlier, water with little fluctuation in levels produces few Aedes species.

Mosquito breeding places may be classed as temporary, permanent or semi-permanent. Temporary breeding pools remain for a limited period of time following each flooding. Permanent water remains throughout the year. Semi-permanent water areas remain throughout most or all of a mosquito season following an initial flooding.

Mosquito breeding places may also be classified as to their location. They may be classified as on field (including surface pools, irrigation laterals and drains) or off field (including road side ditches, or borrow pits, waste land areas, abandoned canals and laterals, drainage ditches, natural waterways, oxbows, sloughs and distribution systems). Over 95 percent of the total breeding area was associated with "on field" mosquito breeding places in one irrigated area studied in Montana. These accounted for over 70 percent of all mosquito production during the entire season. Thus in most areas suffering from severe mosquito infestations, more than 90 percent of all mosquito production may be associated with the use of water for irrigation. In non-irrigated areas, spring run-off and a rising water table account for higher percentage of the mosquitoes produced.

IV. Mosquito Surveys

Two types of surveys are widely used: the original basic survey and the operational survey.

A. Original Basic Survey. The original basic survey determines the species of mosquitoes, their source, location and seasonal density. Mosquito control maps are used for orientation and locating larval breeding places and adult sampling stations. When making the original basic survey, it is advisable to record the type of breeding place and, if known, the number of expected generations of mosquitoes (e.g. temporary, on-field (alfalfa), 3 generations). This information is of value for estimating the expected seasonal breeding acreage that would have to be treated each year (as opposed to the amount of acreage that can produce mosquitoes) and for estimating the types of control measures that may be used, the number of personnel needed, type of equipment and amount and type of insecticide.

B. Operational Surveys. The operational survey is a continuing evaluation of the mosquito control program and is extremely valuable in daily operations. Through operational surveys, one refines information on control efficiency, the times that larvae appear in each source, and the significance of each larval source according to the production indexes. Such surveys determine the population index (showing general fluctuations rather than determing the actual numbers of mosquitoes present). Operational surveys may be larval or adult mosquito surveys.

1. Larval Surveys. In conducting larval surveys, a dipper approximately 4 inches in diameter is scooped fairly through the surface of water near emergent vegetation. Aedes larvae are collected by a rapid skimming movement of the dipper with one side depressed below the water surface, ending the stroke just as the dipper is filled. Where clumps of emergent vegetation are present, it is easiest to collect Anopholes larvae by pressing the dipper into such clumps with one edge depressed so that the water flows from the vegetation into the dipper. A quicker motion is required for collection of Culicine larvae (Aedes, Culex, Culiseta and Psorophora) than for collections of Anopholes larvae since the Culicine larvae are more likely to dive below the surface when disturbed by shadows or movement. The number of dips made and the number of larvae found are recorded in order to calculate a breeding index. The breeding index may be defined as the number of larvae per square foot of water surface. Therefore, the number of larvae collected divided by the number of times that 4 dips are taken equals the breeding index (BI = # larvae ÷ # dips (¼). Unless the mosquito production source is very large, a mosquito breeding index of less than 1 is not normally controlled. One can determine the relative importance of each breeding site or station by calculating the production index (breeding index X the area = production index of the site or station). Both pre-treatment and post-treatment larval counts should be made, when possible, in order to determine control efficiency.

2. Adult Surveys. Adult surveys may be biting collections, resting collections, or light trap, carbon dioxide or baited trap collections. Adult mosquito surveys provide information on (1) the species present, (2) the mosquito population density, (3) the effectiveness of the control efforts throughout the season and (4) a means of evaluating the effectiveness of specific treatments. Adult light trap collections depend upon a phototropic response. Mosquito species differ in their response to light; some being attracted readily, others poorly. After being attracted to the light; a fan is usually employed to blow the mosquitoes into a bag or killing jar. Biting collections are carried out by capturing the adult female mosquito with an aspirator as she attempts to obtain a blood meal from a host. When making population estimates with the bite count method, a predetermined time period is established. The count per given period that will be tolerated by residents in an area varies from region to region and must be determined for each area. Biting and light trap collections are the most common forms of adult surveys. Resting station collections are made by aspirating the adults which remain inactive during the day, resting in cool, humid places. Resting stations may be in such sites as stables, chicken houses, culverts, and so forth. Egg samples or egg-sod surveys are not typically made in Montana but have been employed in large districts as a part of pre-larviciding operations.

V. Methods of Control

All methods of mosquito control require surveys to insure success. A number of general methods are employed. In order of preference, they are good water management, source reduction, biological control, larviciding, pre-larviciding, and adulticiding. The one instance in which adulticiding should provide the basis of a control project is in the event of an outbreak of mosquito-borne diseases, such as St. Louis encephalitis or Western equine encephalitis.

A. Source Reduction. Source reduction is accomplished by the removal of free, shallow, standing water contributing to mosquito production or by the elimination of harborage present within that water. Source reduction or permanent control may involve diking, ditching, draining, dredging, deepening, filling or water level management.

B. Pre-larviciding. Pre-larviciding consists of applying approved insecticides to areas known to produce mosquitoes but which contain no larvae at the time of application. Granules of either the coated or clay type and containing either 1 or 2 percent concentrate (e.g. Abate, chlorpyrifos or fenthion) may be applied to the ice of snow melt pools or to low spots that collect the annual run-off and which are known to produce an early hatch of mosquitoes. Precisely outlining this area depends upon experience, accurate surveys and records. Areas to be treated by pre-larviciding should be carefully selected to insure that the insecticide will not be flushed from the area and contaminate potable water supplies or water containing valuable resources.

C. Larviciding. It is at the larval stage of development that mosquitoes are most effectively controlled. More mosquitoes are killed per given quantity of insecticide by larviciding than adulticiding because mosquito larvae are concentrated in a restricted location and less toxicant is needed to affect control, (i.e. since insecticide is applied over given areas at approximately the same dosage whether adulticiding or larviciding, more insecticide is required after adults disperse). Larviciding should not be conducted without surveying a site and establishing that mosquito larvae are present in sufficient numbers to merit control. Larviciding is conducted by the application of fuel oil, fuel oil plus spreader, highly refined oils, insecticide granules, emulsifiable concentrates or solutions to a body of water. The choice of approach and chemical depends upon the registration of the chemical, its use directions and the environmental conditions present.

Besides being of value in pre-larviciding, granules are an excellent means for applying insecticide through heavy foilage. They will tumble through the vegetation to the water surface rather than deposit upon the surface of vegetation as liquid formulations do. (The use of liquid formulations in heavy cover may result in ineffective control from the application of less than toxic amounts of insecticide to both the water and the foliage.)

The use of fuel oil should be restricted to waste land areas not possessing valuable vegetation. Fuel oil applied at the rate of 15 to 20 gallons per acre may burn vegetation and leave an unsightly appearance. Fuel oil with a spreading agent applied at 2 to 3 gallons per acre is slightly less objectionable. The more highly refined mosquito control oils have not been reported to have this toxic effect.

When applying an insecticide for mosquito control, the applicator must insure that the insecticide is also registered for application to crops in that area. For example: a flooded alfalfa field containing mosquito larvae should be treated with a chemical registered for both mosquito control and for use on alfalfa pests.

D. Adulticiding. Adulticiding is conducted through the use of thermal fogging, misting or ULV equipment. Adulticiding is the most difficult form of mosquito control to practice in terms of applying the correct dosage and obtaining the proper coverage that is necessary for efficient control. Disadvantages are that there is less control over exposure of non-target organisms, more insecticide is used per mosquito killed, the effect is more temporary than it is with other forms of mosquito control and a repellent effect may occur. Routine adulticiding or adulticiding only on the basis of telephone complaints can be a useless and expensive procedure. Nonetheless, adulticiding can be a valuable supplement to other forms of mosquito control. It is widely used to combat outbreaks of mosquito-borne disease.

Mists, fogs, and ULV applications depend upon direct contact of the insecticide with the adult mosquito. For this reason, they are most effective while the mosquito is on the wing in the early morning or early evening hours. Under ideal conditions, the wind does not exceed five miles per hour, there is a temperature of 65 to 75° F, and the relative humidity is 60 to 80 percent. ULV application of malathion should not be made if the temperature exceeds 82° F. Space spraying is conducted as near as possible at right angles to the wind. Low wind currents are depended upon to disperse the insecticide over the 300 to 400 foot swath width which may result under favorable conditions with thermal fog or ultra low volume applications.

The movement of the extremely small thermal fog particles is very unpredictable. These particles are more subject to climatic conditions than are the larger ULV or mist particles.

ULV adulticiding (the application of ½ gal. or less of undiluted concentrate per acre) results in the distribution of more uniform particle sizes which are of a size sufficient to kill the adult mosquito. It is the cheapest form of adult mosquito control (about ¼ that of thermal fogging) and results in less environmental contamination (the use of diesel fuel is eliminated and it is only necessary to apply approximately 1/2 to 2/3 the dosage needed for thermal fogging). However, since pure or concentrated insecticide is dispensed, chemical and equipment use directions must be followed rigorously and the performance of the machine must be continually assessed to assure that accidents do not occur. The hazard of spotting of automobile paint increases with droplet size.

Misting machines disseminate a wide array of different sized particles. This may result in wastage of some chemical but enables applicators to use the machine during daylight hours and under more adverse wind and temperature conditions. Misters can be used for short term residual mosquito control in parks and in bushes and trees in rural or urban residential areas. Under these conditions the mist is directed at a lower angle than the customary angle of 45° above the horizontal that is used when space spraying. If vegetation is tall, the mist should be directed at the upper part of it. The vehicle speed should be 5 mph or less when treating low sparse vegetation and 3 mph or less when vegetation is dense. In the latter case or under hot, dry conditions, the effective swath width may not exceed 100 feet. Under more ideal conditions, it may be 200 feet. Although one can larvicide with misters, it is usually best to larvicide with equipment designed for that purpose rather than attempt to employ adulticiding equipment in this fashion. If equipped with a granule hopper, however, mist blowers can be used to effectively larvicide with granules as well as mist for adults.

E. Biological Control. Most forms of biological control remain in the experimental stage. The use of the mosquitofish <u>Gambusia affinis</u> has been effective in Montana on a limited basis. Other experimental efforts to use fish for mosquito control should be attempted whenever possible. The Fish and Game Department should be notified prior to such attempts. Algae, protozoa (particularly microsporidia), nematodes, fungi (e.g. Coelomomyces), irridescent viruses and the crystaloid toxicant produced by the bacteria <u>Bacillus thuringiensis</u> are examples of experimental control efforts not yet reaching field use.

VI. Chemicals for Mosquito Control

A variety of insecticides are registered for mosquito control. Since registrations are periodically reviewed and certain restrictions may be imposed, applicators should consult with the State Department of Agriculture and State Department of Health and Environmental Sciences prior to using them. Label directions should be followed. The following table indicates pesticides currently used in mosquito control.

Pesticides Currently Employed in Mosquito Control[a,d]

Type Application	Toxicant[b]	Dosage	Remarks
Residual Spray	malathion	100 - 200 mg per square ft.	For use as an interior house treatment. Effective for 3-5 months on wood surfaces.
Continuous Vapor Treatment	dichlorvos	1 dispenser per 1,000 cu. ft.	In resin; dispensers hung from ceilings. Gives 2½ - 3½ months control. Do not use where infants, ill or aged are confined or in food preparation or serving areas.
		<u>lb/acre</u>	
Outdoor, Ground Applied, Space Spray	chlorpyrifos[e] (Dursban)	0.0125	Dosage based on estimated 300 foot swath width. Mists and fogs are applied from dusk to dawn. Mists are usually dispersed at 7 to 25 gal/mi. and at a speed of 5 mph. Fogs are applied at a rate of 40 gal/hr @ 5 mph (occasionally at higher rates and greater speeds). Finished sprays have 0.5 - 8 oz/gal actual insecticide in oil or (with non thermal foggers) water. In ULV ground applications[d] technical grade malathion is used at 1-1.5 fl. oz/min at 5 mph or 2-3 fl. oz/min @ 10 mph; some ULV pyrethrins at 2-2.25 fl. oz/min @ 5 mph or 4-4.5 fl. oz/min @ 10 mph; chlorpyrifos fog concentrate at 2/3 - 1 1/3 fl. oz/min @ 10 mph.
	fenthion[c] (Baytex	0.001-0.1	
	malathion	0.075-0.2	
	naled	0.02-0.1	
	pyrethrins (synergized)	0.002-0.0025	
Larvicide	abate	0.05-0.1	Apply by ground or air at up to 10 quarts finished spray/acre depending on concentration used. Use oil or water emulsion formulations in areas with minimum vegetative cover; granular formulations where vegetative cover is heavy. Fenthion provides longer residual in contaminated water at 5 times the dosage listed Chlorpyrifos has long residual toxicity in water with a high organic content (e.g. 12 weeks in septic tanks) while abate is fairly labile in polluted water. Apply fuel oil at 15-20 gal/A in open water courses or with 0.5% spreading agent (e.g. T-Det-MC, Dal-Com W) apply at 2 - 3 gal/A.
	chlorpyrifos[c,e]	0.0125-0.05	
	fenthion[c,e,f]	0.05-0.1	
	malathion	0.2-0.5	
	pyrethrin tossit	1/100 sq. ft.	
	fuel oil	2 to 20 gal/A	
	Flit MLO	1 to 5 gal/A	

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[a] Modified from "Public Health Pesticides" Technical Development Laboratories, Center for Disease Control, U.S. Department Health, Education and Welfare (1973)

[b] Other compounds such as Lethane 384 and ronnel may have uses in some categories. If so, follow label directions.

[c] For use by trained mosquito control personnel only.

[d] Adhere <u>STRICTLY</u> to <u>ALL</u> label specifications and directions.

[e] Do not apply to waters with valuable fish.

[f] Label requires a 3 week interval between applications except for adulticiding.

VII. Equipment for Ground Application

A. Introduction

Information on the types of equipment available for larviciding and adulticiding is available in the American Mosquito Control Association Bulletin #2, Ground Equipment and Insecticides for Mosquito Control, 101 pp. Only brief description of the more commonly used types of equipment will be included herein. Bulletins such as <u>A Guide for the Safe Use of Pesticides</u> and <u>Respiratory Protection Against Pesticides</u> are available from the Environmental Services Bureau of the State Department of Health and Environmental Sciences.

B. Types of Larviciding Equipment

In nearly all public health insect control projects, the compressed air sprayer is standard equipment. These sprayers are small 1 to 4 (usually 2 or 3) gallon cylindrical tanks equipped with an air pump, hose and spray gun (wand and nozzle). After filling the tank about 3/4 full, air is compressed into the remaining space for use in forcing the liquid through the nozzle. Desirable features include stainless steel construction, a pressure gauge, a large filler opening, synthetic rubber gaskets and a pressure release valve. (If no pressure release valve is present, turn the sprayer over and release pressure through the nozzle before opening). A flat fan nozzle is usually used for applying residual sprays to walls, while a hollow cone nozzle is ordinarily used for applying insecticide to vegetation and mosquito breeding sites. A stock of spare parts should be kept on hand.

The hydraulic power sprayers, with capacities of from 50 to 300 gallons (usually 50 - 150 gallons) can pump a maximum of from 1 to 10 gallons of spray per minute. Most which are used for mosquito control are mounted on skids or on the beds of 3/4 ton trucks. This sprayer consists of a tank (usually with an agitator), a pump, a power source (usually a gasoline engine), a pressure regulator and relief valve and one or more hoses and hand guns (and/or occasionally a boom). Hoses are usually 50 to 200 feet long. For longer lengths of hose it is advisable to use one with a ½ inch I.D. since there is less frictional loss of pressure than with ¼ inch or 3/8 inch hose.

Two types of hand operated granule applicators are commonly used in larviciding. One is the rotary slinger plate type of grass seeder. When used in tall grass and cattails, the moving parts can get clogged unless a protective sheet of metal is mounted below and ahead of them to divert vegetation. The most common type of hand operated granulator in Montana is the "sling" seeder (horn seeder). This is a tear-drop shaped granule bag with a tapered metal tube. An applicator feeds granules into the 3 foot long tube and dispenses them through the adjustable gate by whipping the tube back and forth.

Power granulators are of several types. One kind commonly used is a power driven rotary plate type of seeder. Granules are fed from a hopper to a rotating plate by gravity flow and slung out in a fairly uniform swath by centrifugal force. The other type of power granulator commonly used is a modified mist blower. Granules are discharged into the air exhaust duct and moving air transports the granules to the target. Back-pack dusters can be modified in a similar manner.

C. Types of Adulticiding Equipment

Equipment most commonly used for adult mosquito control is of three types: Ultra low volume (ULV, misting and thermal fogging. (See Section V D, Adulticiding, for a discussion of principles governing adulticiding with each type of equipment and factors influencing their effectiveness and versatility.

Thermal fog generators break insecticide into aerosol sized particles by means of blasts of hot exhaust gases. The following recommendations upon equipment for fogging were developed by the Entomological Research Center of the Florida State Board of Health. Mention of any brand does not constitute endorsement by the Montana Department of Health and Environmental Sciences.

Equipment for Fogging:

Dyna Fog Sr.

1. Machine operation - Operated as recommended by the manufacturer with respect to engine speed and formulation pressure, i.e., 6 - 12 p.s.i.

2. Wind and Temperature* - Operate when air temperatures are 65° or above and in winds up to, but not greater than 3 mph.

Leco 80 & 120

1. Machine Operation - Burner temperature: 850° - 900° F; engine r.p.m.: 2000; formulation pressure; whatever is required to produce 40 gallons per hour. When applying 80 gph (model 120) the burner temperature should be 1000° F.

2. Wind and Temperature - This machine can be effective when air temperatures are 60° - 64° but best results were obtained at 65° and above. Present data indicate effective results in winds up to 9 mph.

Leco 40

1. Machine Operation - Burner temperature: 1200°F; engine r.p.m.: 3400; formulation pressure: whatever is required to produce 40 gallons per hour (usually 6 to 8 p.s.i.)

2. Wind and Temperature - Best results were obtained when atmospheric temperatures were above 64° F and with winds up to 8 mph.

See Fog (Tifa SF-50)

1. Machine Operation - As recommended by manufacturer: Gas pressure: 38 p.s.i.; steam pressure: 25 p.s.i.; water pressure 45 p.s.i.

2. Wind and Temperature - Operate when air temperatures are 70° and above; present data indicate that this machine is effective in winds up to 6 mph.

Tifa 40-E

1. Machine Operation - Burner temperature; 1000°; formulations pressure: 25 p.s.i.; engine r.p.m. 2200.

2. Wind and Temperature - This machine is effective at air temperatures of 60° - 64° but best results are at 65° and above. Data indicate that the TIFA can be used effectively in winds at least to 9 mph, but better average kills were obtained at the lower wind velocities, as with all other machines tested.

NOTE: Recommendations with respect to wind and temperature conditions are based only upon test results using malathion or malathion-Lethane. Similar data for other insecticides are not presently available for most of the machines listed.

Mist blowers are essentially large capacity power driven air turbines which drive air at high velocity through a tube. Several models discharge 5000 cubic feet of air per minute at 150 mph. Sprays are pumped at low pressure and volume into a discharge tube where it is atomized by a nozzle. In addition to granule hopper attachment modifications already discussed, "mini-spin" nozzles have been inserted into insecticide lines to disperse insecticide concentrates.

Ultra low volume equipment for adulticiding is of relatively recent origin. Special nozzles or attachments break insecticide concentrates up into relatively uniform particles measured in terms of microns. Advantages have already been discussed (Section V, D).

D. Equipment Selection

The equipment selected must fit the various local needs in an area. Careful survey and analysis of the extent and types of breeding areas will provide the basis for equipment selection. If an area has extensive ditches, ponds, small swamps and temporary pools which are accessible by road, power driven sprayers and granulators mounted on trucks or jeeps are suitable. If these areas are inaccessible, compressed air sprayers and hand held granulators are used. Large swamps and irrigated areas are treated with power equipment mounted on trucks; if inaccessible they are treated with power equipment mounted on all-terrain vehicles. Where there are extensive larval populations distributed over extensive inaccessible areas, contracted spraying by air craft may be the most effective means of control.

Other factors that are important considerations are budgetary limitations, labor costs and equipment versatility and serviceability. Equipment that can be effectively operated by one man will pay for itself in one or two seasons if compared to the labor cost of crew served equipment. A similar cost-benefit analysis can be applied to more expensive equipment that can be operated in several ways by a crew of two but which has the capability of covering the same area that 3 or 4 crews cover with more inexpensive equipment. An appropriate example may be cited for regions which have extensive sloughs (which are relatively inaccessible) and sluggish overgrown ditches. If an all terrain vehicle (ATV) were outfitted with a hydraulic sprayer and power granulator, the area becomes accessible and can be treated much more rapidly. While being trailered, one could also use it to treat roadside borrow area.

VIII. Chemical Application

A. Equipment Calibration

Prior to any attempt to control mosquitoes an applicator must familiarize himself with the equipment and calibrate it. To "calibrate" is to determine the quantity of chemical that the equipment dispenses each second, minute or hour. The quantity dispensed will vary with various equipment settings (such as RPM or pressure) with various attachments (different disks and nozzles) and, in some cases, with the temperature and viscosity of the chemical. Equipment manuals which accompany the sprayers or granulators normally contain sufficient instruction for calibration and operation and are, hence, only briefly discussed.

In calibrating compressed air or hydraulic sprayers, spray into a container for an established period of time and measure the amount of material dispensed in order to determine the discharge rate/second or minute. (See also Section VIII F(3), Varying the Discharge Rate). Since the spray pattern and discharge rate vary with the pressure being used, it is advisable to calibrate and use the compressed air sprayer over a 30 to 50 psi pressure range. In this way, the average pressure will be suitable for producing the delivery rate and spray characteristics for which many nozzles are designed.

In calibrating mist blowers or thermal foggers, the tank is filled to a mark with water or fuel oil respectively. The equipment is operated for a period of time and the quantity of material necessary to replace that dispensed is measured. The discharge rate is usually measured in terms of gallons per hour. (See also Section VIII C (2), Computation of acreage for adulticiding).

Power granulators are usually calibrated in terms of pounds of granules dispensed per minute, hour of mile of travel at a set speed. The rate of discharge selected will depend on the swath width that is obtained with the type of granule selected and the recommended dosage rate of the chemical selected. (Smaller heavier granules will give a wider swath width and the discharge rate needed will be greater). Steps to be followed are (1) measure the swath width; (2) calculate the acreage covered per mile of travel (swath width (in feet) X 5280 ÷ 43,560); (3) multiply by lbs of granules desired per acre (to get lbs/mile of travel); (4) multiply by the desired rate of vehicle speed (to get lbs per hour) and (5) by trial and error adjust the flow rate of granules to meet the desired pounds/hour. (See Section VIII E(3), Dosage rates for granules and dusts for an example.)

In the hand operated "sling" or horn seeders, an adjustable gate regulates the gravity flow of granules. The amount that the gate will be opened will depend on swath width and rate of travel. These variables will be balanced against each other as indicated in Section VIII B, Standardizing Application Rates.

Operation manuals which accompany ultra low volume (ULV) equipment should be consulted for calibration. Flow rates are again determined by swath width and the recommended dosage rates. Flow rates vary with the temperature and viscosity of the insecticide and calibrations should extend over the temperature range. The calibration of ULV equipment also includes rigorous regulation of droplet size and coverage.

B. Standardizing Application Rates

Applying the correct volume of finished spray or weight of granules is largely a matter of practice. Two approaches are used. One approach is based strictly on the time required to apply the correct quantity to a given area. One can develop a table that will show the number of seconds required to dispense required volumes or weights over a series of areas. The other approach is based on the development of a particular constant rate of movement by the applicator, nozzle or equipment. The rate of movement or the time that chemical is actually being dispensed is dependent upon the discharge rate of the equipment (in turn determined by nozzle type, pressure, etc.)

In developing the appropriate rate of movement, measure and stake out a test area and use one of the following approaches (1) fill the equipment to a certain mark, (2) spray the test area uniformly, (3) measure the amount of material required to fill the equipment to the original level, (4) compare with the amount of material which should have been used and (5) adjust the rate of application accordingly. Or, (1) place only the volume or weight of material required for treatment in the equipment, (2) spray or granulate the test area and (3) try to adjust the rate of travel/application so that the chemical runs out just as the area has been completely and uniformly covered (i.e. just as the applicator reaches the stake at the other end of a linear area or returns to the starting stake in a more circular or rectangular area).

C. Computation of Acreage

Since insecticide labels usually express the limits for dosage rates as pounds or fluid ounces of active ingredient per acre, it is necessary to calculate the acreage of each site to be treated. Methods used to compute acreage are given below.

1. Computation of acreage for larviciding

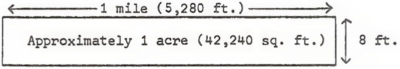
In smaller areas, the acreage may be estimated by pacing off the length and width of the area to be treated. If the area is relatively square or rectangular, a multiplication of length x width will give the area in square yards. (Although the average "normal" step is about 30 inches, one can develop a step of about 36 inches with little practice). If the area is more triangular in shape than rectangular, the length x width value should be divided by 2. It is then necessary to convert square yard measurements to acres. This may be done by dividing the number of square yards by 4840 (1 acre = 4840 square yards = 43,560 square feet). It is more convenient, less time consuming and there is less chance for mathematical error if a table such as below is consulted.

Square yards	Acres	Square yards	Acres
25	.0052	650	.1343
50	.0103	700	.1446
100	.0206	750	.1570
150	.0309	800	.1653
200	.0413	850	.1756
250	.0537	900	.1858
300	.0619	950	.1962
350	.0723	1000	.2066
400	.0826	2000	.4132
450	.0929	3000	.6198
500	.1033	4000	.8264
550	.1157	5000	1.0330
600	.1239		

Additional columns can be added to the table to further reduce the chances for error and save time. One can e.g. calculate the gallons or pounds of actual and mixed chemical required for each area involved and/or the number of seconds the trigger valve would have to be open to deliver the required amount of chemical.

It is suggested that conversion tables be maintained in the spray vehicles. It is further suggested that the acreage at each mosquito source be recorded. Although the acreage at each site may vary from season to season and time to time, some ponds have rather stable boundaries and some areas are flooded to about the same extent with each irrigation.

For larger areas or for long ditches or borrow pits, the acreage may be more rapidly estimated by the simple field calculation noted in formula 1 below. This is based upon a figure of 8 feet swath width for one mile of travel.



One square mile = 640 acres.

Formula 1 $$\text{Acreage Treated} = \frac{\text{mileage covered} \times \text{swath width}}{8}$$

Example 1. Calculate the acreage treated by larviciding an area ½ mile long and 12 feet wide.

$$\text{Acreage Treated} = \frac{0.5 \times 12}{8} = .75 \text{ acres}$$

2. Computation of acreage for adulticiding

In space treatments (misting and fogging) the acreage treated is a variable figure dependent upon the swath width taken. The first step then is to determine the swath width. This may be done by setting out cages of mosquitoes and adulticiding; using visual observations of a fog; or setting out strips of paper and spraying a dye solution (minus insecticide). While this may be practical in calibrating a machine, an operator would not find it practical to conduct such tests routinely. As a practical consideration, the swath widths in urban areas are usually taken as the length or width of the city block. The approximate acreage treated by space application of insecticides may be determined by Formula 1 above as e.g.

Example 2. Calculate the acreage treated by a mister traveling 4 miles where the swath width is 200 feet.

$$\text{Acreage Treated} = \frac{4 \times 200}{8} = 100 \text{ acres}$$

D. Formulations

Insecticides for mosquito control are sold in Montana in a number of formulations (forms): emulsifiable concentrates, non-emulsifiable concentrates, granules, tossits, (encapsulated insecticides) or as finished sprays (ready to use). Emulsifiable concentrates are normally mixed with water (or occasionally with fuel oil) prior to use while the non-emulsifiable concentrates are normally diluted with fuel oil to make a finished spray. Granules, tossits and finished sprays (such as 95% ULV malathion) are ready to use as received.

Pesticide container labels give directions for dilution prior to use. The level of dilution which you use should fall within the limits specified on the label. However, other factors need consideration: (1) The more concentrated the finished spray is, the more closely the application rate must be controlled, i.e. slightly over or under spraying of a more dilute solution has less effect on the amount of active ingredient applied than slightly over or under spraying a more concentrated solution. (2) The more carrier (oil or water) used, the less finished spray that can be held in the spray tank. (3) The more carrier used, the higher the carrier cost.

The actual dilution used will be based upon the equipment characteristics (discharge rate) and rate of application. If the equipment puts out a large volume in a short period of time, the finished spray may be more dilute or the rate of application very fast.

E. Determining Amount of Mixed Chemical Needed.

After determining the size of the area needing treatment (in acres), one can determine the amount of finished spray needed. This will depend on: (1) the allowable dosage rate (pounds or fluid ounces of active ingredient per acre) specified on the insecticide label and (2) the degree to which the insecticide concentrate has been diluted. The following formula may be used to determine the quantity of insecticide needed.

<u>Formula 2</u>.

$$\text{Gallons finished spray needed} = \frac{\text{Dosage rate x acreage treated}}{\text{Insecticide (lbs. or fl. oz.)/gal. finished spray}}$$

Example 3. A dosage rate of 0.06 lbs. of fenthion/acre is desired on 4 acres of standing water in a field. The finished spray contains 0.08 lbs. of active ingredient per gallon. (To obtain this, one could mix e.g. 2 gallons of Baytex 4 EC (4 lb/gal) with 98 gallons of water). How much finished spray should be used? By Formula 2:

$$\text{Gallons needed} = \frac{0.06 \text{ x } 4}{0.08} = 3 \text{ gallons}$$

Formulas 3 and 4 below may be revised to determine the gallons of liquid insecticide needed (given percent concentration or specific gravity) or pounds of insecticide granules needed respectively.

F. Computation of Dosage Rates.

After determining the acreage treated and amount of insecticide used, one can establish that the correct dosage rate was used. Remember, the rates applied must fall within the limits specified on the insecticide label.

1. Dosage rates for liquid formulations given pounds active ingredient/gallon in the finished spray may be calculated by the following revision of Formula 2:

$$\text{Dosage Rate} = \frac{\text{Gallon applied x insecticide/gallon (lbs)}}{\text{Acreage treated}}$$

Example 4. An area 2 miles long and 200 feet in depth was treated with 40 gallons of fenthion emulsion containing 0.08 lbs of active ingredient/gallon. Calculate the dosage rate.

Using Formula 1: Acreage treated $= \frac{2 \times 200}{8} = 50$ acres

Using Formula 2: Dosage rate $= \frac{40 \times 0.08}{50} = 0.064$ lbs./acre

2. Dosage rates for liquid formulations (given various percentages).

The strengths of liquid concentrates are often given as percentage of active ingredient rather than in pounds/gallon. Occasionally the specific gravity of the concentrate is given. The following formula may be used.

Formula 3.

a. Dosage rate $= \frac{\text{gallons applied} \times \text{wt./gal of formulation} \times \text{\% conc.}}{\text{acreage treated}}$

or (where given specific gravity)

b. Dosage rate $= \frac{\text{gallons applied} \times \text{sp. gr.} \times 8.345 \times \text{\% conc.}}{\text{acreage treated}}$

3. Dosage rates for granules and dusts may be calculated by:

Formula 4. Dosage rate $= \frac{\text{Pounds applied} \times \text{\% of concentration}}{\text{acreage treated}}$

Example 5. A 2% fenthion granular formulation is used for larviciding a swampy wasteland area which is 1 mile long. The swath width is 16 feet. The rate of application is 20 lbs/mile of travel (100 lbs/hour at 5 mph). Calculate the dosage rate.

Using Formula 1: Acreage treated $= \frac{1 \times 16}{8} = 2$ acres

Using Formula 4: Dosage Rate $= \frac{20 \times 0.02}{2} = .2$ lbs/acre

G. Methods of varying the Dosage Rate

There are generally three methods used to vary the dosage rate: (1) varying the formulation strength; (2) varying speed of travel; and (3) varying the discharge rate. Most often in space treatment, the simplest and most practical method is to use a more or a less concentrated formulation. In this way, it is possible to maintain the optimum speed of travel (5 mph) and the standard discharge rate giving the best droplet size and coverage. In larviciding, it may be practical to vary the formulation strength for different larger jobs where the terrain may dictate different average speeds. There may be several reasons for wishing to vary the speed of travel. Heavy vegetation at a particular larval station may require higher dosage rate; the physical situation may require that a different swath width be taken, etc. In some situations, it may be more practical to vary the discharge rate. The terrain may be such that the speed of travel has to be temporarily reduced or such that the speed of travel could be more rapid than normal.

1. Adjusting formulation strength

If one wished to maintain a standard discharge rate (e.g. 100 gal/hr) and standard speed (e.g. 5 mph) over the same swath width, one could vary the dosage rate by varying the dilution of insecticide concentrate. One can determine the formulation strength needed to obtain a given dosage rate by the following rearrangement of formula 2:

$$\frac{\text{Insecticide (lbs)}}{\text{gal. finished spray}} = \frac{\text{(Dosage rate) (acres treated)}}{\text{gallons applied}}$$

Example 6. You wish to reduce the dosage rate in example 4 from 0.064 lbs/acre to 0.05 lbs/acre and still maintain a discharge rate of 20 gal/mile where, due to a 200 foot swath width, 25 acres were covered each mile. Compute the gallons of 4 lb/gal concentrate needed to make 100 gallons of finished spray. Using the above formula:

$$\frac{\text{Insecticide (lbs)}}{\text{gal. finished spray}} = \frac{0.05 \times 25}{20} = 0.0625 \text{ lb/gal} = 6.25 \text{ lb/100 gal.}$$

Thus one would have to use 1.56 gallons of concentrate containing 4 lbs of active ingredient per gallon to get the 6.25 lbs per 100 gallons desired in the finished formulation. (This would amount to using 25 pints of concentrate and diluting it to 100 gallons--determined as: 1.56 gal x 16 pints/gal = 24.96 pints). NOTE: For a different dilution swath width, discharge rate, vehicle speed or dosage rate, a different dilution would be appropriate.

2. Varying the speed of travel

Doubling the rate of travel doubles the acreage treated and halves the dosage rate if other variables are maintained. Conversely any decrease in speed would result in a proportionate increase in the dosage rate. From the formulation strength, discharge rate and desired dosage rate, one can compute the needed vehicle speed for any given swath width. By rearranging formula 2, one can obtain the gallons of finished spray needed per acre. By dividing the discharge rate (gal/hr) by gallons per acre applied, one obtains the number of acres which need to be covered per hour. One can then consult the coverage rate table below to determine the appropriate rate of speed (modified from the Depts. of Air Force, Army and Navy Insect and Rodent Control Manual and the Cascade County Mosquito Abatement District manual).

Example 7. A mister delivers 100 gal/hr of a formulation containing 0.0625 lb/gal. The operator desires a dosage rate of 0.05 lbs/acre over a 200 ft. swath width. Calculate the appropriate vehicle speed. By substituting in a modification of Formula 2, one obtains:

$$\frac{\text{gallons}}{\text{acre}} = \frac{\text{dosage rate}}{\text{insecticide/gal}} = \frac{0.05}{0.0625} = 0.8 \text{ gal/acres}$$ as the needed application rate for the finished spray.

The acreage treated/hr at a discharge rate of 100 gal/hr $= \frac{100 \text{ gal/hr}}{0.8 \text{ gal/acre}} = 125$ acres/hr.

From the following table, one can observe that, where the swath width is 200 feet, the appropriate speed is about 5 mph.

Rate of Coverage for Given Rates of Travel and Given Swath Widths

Rate of Travel (mph)	Yards Traveled Per Hour	Acreage covered/hr. for given swath widths						
		12.5 ft.	15 ft.	25 ft.	50 ft.	100 ft.	200 ft.	300 ft.
0.5	880	0.75	0.91	1.5	3	6	12	18
1.0	1,760	1.5	1.8	3.0	6	12	24	36
1.5	2,640	2.25	2.7	4.5	9	18	36	54
2.0	3,520	3.0	3.6	6.0	12	24	48	72
3.0	5,280	4.5	5.4	9.0	18	36	72	108
4.0	7,040	6.0	7.2	12.0	24	48	96	144
5.0	8,800	7.5	9.05	15.0	30	60	121	181
6.0	10,560	9.0	10.8	18.0	36	72	144	216
10.0	17,600	15.0	18.1	30.0	60	121	242	362

In the absence of a table or with a different swath width, one could estimate the appropriate speed of travel by the following modification of Formula 1:

$$\text{Speed (mph)} = \frac{\text{Acres treated/hr.} \times 8\text{ ft.}}{\text{swath width (ft.)}}$$

$$\text{In example 7: Speed} = \frac{125 \times 8}{200} = 5\text{ mph}$$

If one knows the dosage rate resulting from a particular speed of travel, he can apply any other dosage rate over the same area by changing the speed of travel. Since speed is inversely proportional to the dosage rate, one can set up a simple ratio: $\text{Speed}_1 \times \text{Dosage Rate}_1 = \text{Speed}_2 \times \text{Dosage Rate}_2$

Example 8. A 57% Malathion EC (5 lb/gal) is to be misted over an irrigated alfalfa field adjacent to town because of residual larval pools and extensive cover being afforded to adults. The formulation strength and discharge rate were such that a dosage rate of 0.2 lbs/acre was delivered in town at 10 mph. The operator wished to apply 0.5 lbs/acre over the field. Compute the appropriate speed.

$$0.2 \times 10 = 0.5 \times \text{speed}_2$$

$$\text{speed}_2 = \frac{.2 \times 10}{.5} = 4\text{ mph}$$

3. Varying the discharge rate

This method of varying the dosage rate is most often used while larviciding. In discharging liquid formulations, the dosage rate may be varied by changing the spraying pressure or nozzle tips or disks. Increasing the spraying pressure has the disadvantage of decreasing the droplet size and consequently increasing the potential drift of the insecticide. A change in pressure does not result in a proportionate change in the discharge rate. (The table below illustrates this). Larger changes in the discharge rate are more effectively brought about by changing the nozzle tips. The following table (taken from the Cascade County Mosquito Abatement District Manual) illustrates the discharge rate that various nozzle sizes emit at various pressures.

Data for Trigger-Valve Hand Guns

	Rate (gal/min)			
Nozzle	200 psi	300 psi	400 psi	500 psi
D-4	1.2	1.5	1.6	1.9
D-5	1.8	2.2	2.6	2.8
D-6	2.5	3.0	3.4	3.8
D-7	3.3	4.0	4.4	4.9
D-8	4.3	5.2	6.0	6.6

Selected References

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