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VECTOR TOPICS

NO. 1

Control of St. Louis Encephalitis

JUNE 1976

Reprinted 1981

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
CENTERS FOR DISEASE CONTROL
BUREAU OF TROPICAL DISEASES
VECTOR BIOLOGY AND CONTROL DIVISION
ATLANTA, GEORGIA 30333

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APPENDICES

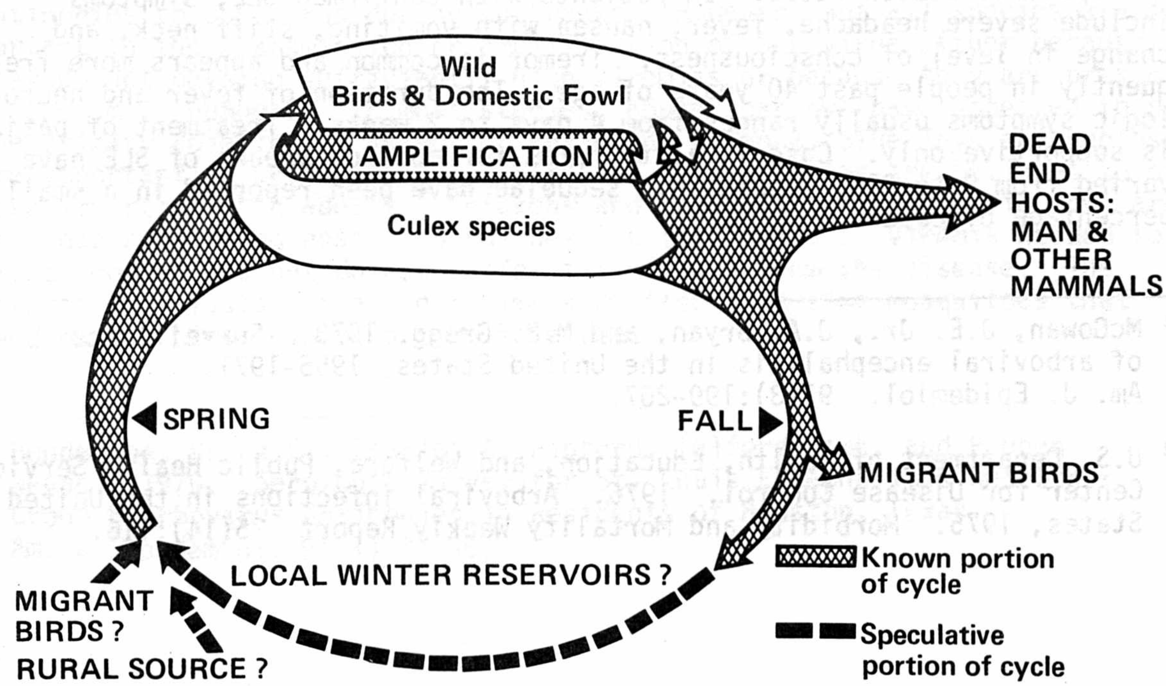
ST. LOUIS ENCEPHALITIS

The Disease

St. Louis encephalitis was first recognized during an epidemic in the St. Louis, Mo., area in 1933, although retrospectively the first known outbreak of the disease was found to have occurred in 1932 in Paris, Ill. The St. Louis encephalitis (SLE) virus is enzootic or epizootic in bird populations and is transmitted from bird to bird by several species of mosquitoes. Humans may become infected through the bites of certain mosquitoes which have previously fed on birds carrying the virus (Figure 1). Although virus isolations or antibodies have been reported from Panama, Jamaica, Trinidad, and Brazil, outbreaks of the disease in humans have not been reported from outside the United States except as isolated cases.

Figure 1

SLE virus cycle in U.S.



Human cases of SLE typically occur in late summer. Approximately 80% of cases of SLE which were reported as encephalitis during the period from 1955-1971 had dates of onset in August and September.[1] It is important to keep in mind that transmission of SLE virus to humans via the mosquito took place 5-15 days prior to onset of the disease.

The largest number of cases of SLE on record for a single year occurred in 1975 when more than 2,000 cases were reported from 30 States. The majority of cases were located in the Mississippi and Ohio River Valleys, occurring in Illinois (569 cases), Indiana (305 cases), Ohio (285 cases), Mississippi (189 cases), Kentucky (77 cases), Tennessee (85 cases), with smaller numbers of cases occurring in Iowa, Missouri, Arkansas and Louisiana.[2]

Prior to 1975 the following major outbreaks occurred:

Location	Date	Cases	Deaths
St. Louis, Mo.	1933	1,097	221
" " "	1937	431	107
Hidalgo Co., Tex.	1954	373	10
Louisville, Ky.	1956	110	12
Cameron Co., Tex.	1957	114	3
Tampa Bay area, Fla.	1962	222	43
Houston, Tex.	1964	243	27
Dallas, Tex.	1966	172	22

With SLE, both age-specific attack rates and mortality rates are higher in older people. There is no consistent, large difference in sex-specific attack rates. In patients with confirmed SLE, symptoms include severe headache, fever, nausea with vomiting, stiff neck, and change in level of consciousness. Tremor is common and appears more frequently in people past 40 years of age. The duration of fever and neurologic symptoms usually ranges from 4 days to 2 weeks. Treatment of patients is supportive only. Case fatality rates for most outbreaks of SLE have varied from 2 to 20%. Neurologic sequelae have been reported in a small percentage of cases.

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[1] McGowan, J.E. Jr., J.A. Bryan, and M.B. Gregg. 1973. Surveillance of arboviral encephalitis in the United States, 1955-1971. Am. J. Epidemiol. 97(3):199-207.

[2] U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control. 1976. Arboviral infections in the United States, 1975. Morbidity and Mortality Weekly Report 25(14):116.

Most infections of SLE virus in humans do not result in illness. As many as 250 subclinical infections have occurred for each case of encephalitis, as shown in the Houston, Tex., SLE epidemic of 1964.[3] Many mild cases show aseptic meningitis or fever only.

Case Definition: Cases of SLE are generally categorized as clinically suspect, presumptive, or confirmed. Laboratory tests are required to rule out SLE or to categorize the clinically suspect case as being presumptive or confirmed as defined in Appendix I. Confirmation of the cause of death of an individual who dies from SLE may be impossible because death has occurred prior to a substantial change in antibody levels. Histopathologic changes in brain tissue may be characteristic of viral encephalitis but the specific etiology cannot be ascertained. On occasion, SLE virus can be isolated from brain tissues from a person who dies from the disease.

Transmission Cycle: St. Louis encephalitis virus exists primarily as an infection of birds transmitted by mosquitoes. It may be enzootic in some areas but occasionally epizootics may occur in which a large percentage of birds in the area become infected. Under these conditions human infection may also occur as sporadic cases or as epidemics. Therefore, an important part of surveillance and epidemiologic investigation of an outbreak of SLE in humans is the sampling of wild and domestic birds for evidence of virus infection. Attempts may be made to isolate SLE virus and/or to determine if SLE antibody is found in blood from individual birds, indicating previous SLE infection. Many species of birds may become infected during epizootics of SLE. House sparrows, pigeons, blue jays, goldfinches, cardinals, robins, common grackles, catbirds, flickers, mockingbirds, chickens, ducks, geese, and others have yielded SLE virus or antibodies to SLE virus during outbreaks. However, not all species are important in the transmission or amplification of SLE virus either because they do not develop sufficiently high viremias or because they are present in too small numbers. In most studies, house sparrows have appeared to play the primary role in the infection chain and pigeons, blue jays and robins are important as well. Nestling birds of these species are believed to be more important than adults. Chickens and probably other domestic fowl are not good amplifying hosts. Birds develop the levels of viremia needed to infect mosquitoes but do not suffer ill effects from the disease. The viremia only lasts for a short time and after that time mosquitoes that feed on the birds cannot become infected.

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[3] Henderson, Brian E., Charles A. Pigford, Telford Work, and Reuben Wende. 1970. Serologic Survey for St. Louis Encephalitis and Other Group B Arbovirus Antibodies in Residents of Houston, Texas. Am. J. Epidemiol. 91(1):87-98.

Humans and horses acquire SLE infections from mosquitoes but apparently do not develop a sufficient amount of virus to infect mosquitoes that feed on them. The role of other vertebrates, particularly bats, rodents and marsupials in the maintenance cycle of SLE virus is presently not clear.

Mosquito Vectors of St. Louis Encephalitis

Members of the *Culex pipiens complex*, *Culex pipiens pipiens* (the northern house mosquito) and *Culex pipiens quinquefasciatus* (the southern house mosquito) are the main urban vectors of St. Louis encephalitis. *Culex tarsalis* is the chief vector in rural areas in western States, and *Culex nigripalpus* was the vector in the Tampa Bay area in Florida in the early 1960's.

During 1975 two additional species, *Culex salinarius* and *Culex restuans*, assumed heretofore unappreciated significance when infection rates for these species were shown to be similar to or greater than those for *C. pipiens* in some localities.

Culex pipiens complex: *Culex pipiens pipiens* and *Culex pipiens quinquefasciatus* are closely related subspecies and are difficult to separate. They are brown mosquitoes of medium size with rounded cross bands of white scales on the abdominal segments but without other prominent markings. *Culex pipiens pipiens* occurs throughout the northern United States and is found as far south as Georgia and Oklahoma. *Culex pipiens quinquefasciatus* occurs in all southern States from coast to coast. Separation is usually on a geographical basis. One or both of these two subspecies are found in every State.

These mosquitoes are the most common species in many urban communities and rural premises. They readily enter houses and feed on man. Members of the *C. pipiens* complex are important vectors in urban epidemics of St. Louis encephalitis, particularly in the Midwest and Texas.

Mosquitoes of the *C. pipiens* complex breed prolifically in rain barrels, tanks, tin cans, and practically all types of artificial containers. Heavy production of these mosquitoes is often found in water with high organic content, especially in storm-sewer catch basins, poorly drained street gutters, polluted ground pools, cesspools, open septic tanks, and effluent drains from sewage disposal plants.

Females of the *C. pipiens* complex lay their eggs in clusters of 50 to 400. These clusters, known as egg rafts, float on the surface of the water. The eggs hatch within a day or two in warm weather. From 8 to 10 days are required for completion of the larval and pupal stages. In somewhat cooler weather of early spring or late fall the aquatic stages may require 2 weeks or more. Breeding continues throughout the warmer months of the year. The over-wintering stage is the adult female. These mosquitoes usually migrate only short distances. Ordinarily, when adults are present, larvae will be found nearby. These species are active only at night and may be found resting during the day in and around houses, chicken houses, outbuildings, and various shelters near their breeding places. They are attracted to light traps, but the numbers collected may not represent an accurate index of their actual abundance. Diurnal resting places offer convenient collecting sites, especially for C.p. quinquefasciatus, which seems less attracted to light than its northern counterpart. Females of the C. pipiens complex show a preference to avian blood, but appear to accept mammalian hosts, readily attacking man. Feeding is usually restricted to hours of darkness, peaking in associated periods of changing light intensity at dusk and dawn. Feeding occurs inside or outside of dwellings.

Culex tarsalis: This mosquito is a medium-sized, dark species with a broad, white band at the middle of the proboscis and white bands at each end of the tarsal segments. Culex tarsalis has been found naturally infected with the virus of St. Louis encephalitis, and is considered to be the most important vector of this and other encephalitis viruses to man and horses in the western States. It is widely distributed and abundant west of the Mississippi River and occurs less commonly eastward to Ohio, Virginia, and Florida, and in southwestern Canada and northern Mexico.

Culex tarsalis larvae develop in a wide variety of aquatic situations. In the arid and semiarid regions, they utilize almost all types of water and are most frequently found in temporary to semipermanent bodies of water associated with irrigation. These include canals, ditches, borrow pits, impoundments, ground pools, and hoof prints. They may be found in effluent from cesspools and other waters containing large quantities of organic material from human wastes, and in artificial containers of various types, such as cans, jars, barrels, drinking troughs, ornamental ponds, and catch basins. Females deposit egg rafts that contain from 100 to 150 eggs each. The eggs usually hatch within 48 hours. The larval and pupal stages develop rapidly in hot weather. Breeding continues from early spring until late fall. Adult females hibernate in the northern areas of the United States.

Adults are active chiefly from dusk to dawn with peak activity occurring just after sunset. During daylight hours the adults remain quietly at rest in secluded spots. They can frequently be found on porches, on shaded sides of buildings, in privies, or under bridges. The majority, however, rest in grass and shrubs, or along cut banks of streams. This mosquito has a wide range of hosts, shows some preference for birds, but also feeds on cows, horses, and humans, and may enter buildings in search of a blood meal. Dispersion studies have shown that C. tarsalis are able to fly 10-15 miles, although the majority may not move that distance. They are taken in considerable numbers in light traps and in traps using dry ice (carbon dioxide) as the attractant. The females are fierce biters and readily attack man and avian hosts as well as other domestic animals. They bite outdoors and freely enter houses. Feeding is during hours of dusk and darkness.

Culex nigripalpus: The adult mosquitoes are medium-sized, dark Culex with the abdomen unbanded. The larvae are common in ditches, fresh-water marshes, and grassy pools in central and southern Florida, where the species appears to have largely replaced its near relative, Culex salinarius. Elsewhere, they are usually of scattered or rare occurrence, but have been found as far north as Tennessee and North Carolina. The species is much less inclined to attack humans than is C. salinarius, seemingly preferring larger domestic animals, cows being favorite hosts. Adults are attracted to light traps, and occasionally have been collected in houses. Culex nigripalpus was demonstrated to be a vector of SLE in Florida.

Culex salinarius: Culex salinarius occurs throughout most of the eastern United States. It is especially common along the Atlantic and Gulf Coasts. It bites readily out-of-doors at night and is at times an important pest. Larvae are found in grassy pools of both fresh and brackish water, along lake margins, and in marshes, cattail bogs, ponds, and ditches. Adults may be collected from diurnal resting shelters or by use of light traps. The species feed readily on man, mostly out-of-doors but occasionally entering buildings. Feeding is heaviest at dusk and the first hours of darkness but may continue into the night. In 1975, SLE virus was isolated from C. salinarius and C. restuans, in Illinois.

Culex restuans: This species is widely distributed east of the Rocky Mountains from the Gulf of Mexico into Canada. Some observers report that Culex restuans is often abundant and annoying in the eastern States, while others say that it rarely bites man. At best, this species is an occasional feeder on man usually out-of-doors beginning at dusk and continuing sporadically through the night. This mosquito is similar in appearance and habits to the C. pipiens complex, although it is not usually as important a pest and is more rural in its occurrence.

Culex restuans ordinarily breeds in static water especially that containing decaying grass or leaves. Favored breeding places are rain barrels, tin cans, woodland pools, ditches, and pools in streams. It appears early in the season and continues breeding throughout the summer. Adults are attracted to light; they may be collected from sheltered resting places in the daytime.

Preventive Measures

Mosquito Surveillance: Locating breeding places and defining the distribution and density of adult populations of the target mosquito species in relation to human populations is essential to the success of any program aimed at controlling mosquito vectors of disease. This surveillance should be begun early enough in the season to detect seasonal changes in population levels and distribution so that baseline data are available to compare populations. Surveillance data are used (1) to plan control strategy in terms of where and when to apply pesticides, (2) to locate areas where cleanup campaigns are needed, and (3) to provide information on the effectiveness of the control program.

Surveillance should begin with early season mapping of likely breeding areas, and the map should be maintained to show larval and adult collecting sites as the season progresses. The map will also help locate water deposits, bridges, culverts, etc., that might be useful as sampling sites.

Adult and larval surveillance should go hand-in-hand, i.e., location of a breeding site should yield a corresponding adult sampling station; and conversely, a natural shelter harboring adult specimens or an area of high frequency of mosquito annoyance should indicate a nearby breeding site. A high frequency of males in a collection generally indicates a nearby breeding area.

Notwithstanding the method of collection, data should be plotted to yield curves showing density of mosquitoes as a function of time for each target control area. Such data will ensure more effective control measures -- doing the right thing in the right place at the right time -- and also provide a means for evaluation of control effectiveness.

Techniques for collecting larval and adult mosquitoes are detailed in Appendices II and III.

Mosquito Control: Success in mosquito control is dependent upon knowledge of the species of mosquitoes and their habits in the particular region where they are to be controlled. With this knowledge, efforts to reduce mosquito production can be more successful. Preventive measures in mosquito-borne disease control principally involve reduction or elimination of the water in which mosquitoes breed or appropriate naturalistic methods rendering such water unsuitable for mosquito breeding. If, after this has been accomplished, some mosquito breeding still remains, then this residual production may be controlled with larvicides. Mosquitoes that escape the larvicides may be controlled with space-spray applications of a chemical to which they are susceptible. But larvicides and space spray must always be looked upon as a secondary method of attack with the primary method being elimination of breeding sources through cleanup campaigns, drainage, filling, flooding, controlled reflooding and other water management practices.

This primary preventive control methodology continues throughout the year, with the use of chemical control only during the breeding season. A consistent long-term effort will produce better ultimate results than an intense attack one year and neglect in subsequent years.

Methods used to control mosquitoes are outlined in Appendices IV and V.

Virus Surveillance in Birds and Mosquitoes: Because epizootics of St. Louis encephalitis appear to occur in birds prior to outbreaks in humans, a useful predictive tool is surveillance of known vector species and bird populations for virus activity during the spring and summer. Routine surveillance activities are usually limited in scope for practical considerations such as costs and the capability of the laboratory to process large numbers of specimens. However, limited repetitive sampling of birds or mosquitoes in the area for evidence of SLE virus and antibodies can provide early warning of potential transmission of the virus to humans. For example, the finding of SLE virus in mosquitoes or SLE antibodies in birds (wild or domestic) in the area may provide warning that there is a possibility of transmission to humans and therefore mosquito control efforts should be initiated or intensified. Sampling of juvenile wild birds is especially useful because it provides an estimate of the incidence of infection in the current year. The percentage of birds or mosquitoes that are infected and their geographic distribution will suggest the type of mosquito control and level of effort needed to reduce risk of transmission to humans. In general, a prevalence of SLE antibody (usually measured by the hemagglutination-inhibition (HI) test) in a representative sample of wild birds of 3% or less indicates a low level of enzootic virus transmission with low risk of human disease; whereas, a prevalence of over 5% is warning of possible occurrence of associated human cases. More useful than prevalence data obtained from single surveys, however, is information gained by repetitive sampling;

weekly increases in antibody prevalence of 1.0-2.0% have been associated with subsequent outbreaks.

In some areas "sentinel flocks" of chickens or other birds are held in outdoor cages and bled periodically for detection of SLE antibodies. Their use may also establish the presence of SLE virus in the area. The finding of SLE virus in the blood of nestling birds also demonstrates that local transmission has already occurred and that there may be potential for transmission to humans.

Presence of SLE antibody in the blood of wild birds could be a result of prior infection in some other area. Therefore, knowledge of the residence status and migratory habits of the species involved is essential. If only one bird species yields SLE antibody and it is a migratory species, one would suspect the birds were infected elsewhere. Conversely, if permanent resident bird species in the area have antibody to SLE virus, it is likely they acquired it in the area.

One of the limiting factors in the usefulness of these surveillance methods in mosquitoes or birds is the difficulty of obtaining rapid laboratory reports of virus or antibody activity in specmens submitted. When there is a high level of interest in an area because of suspect human cases, there may be little difficulty in getting rapid analysis and reporting for that area; but where there is no special interest in an area, specimens may not be analyzed and results reported in sufficient time to provide an early warning before human cases are observed. Efforts should be made to reduce the time lost in packaging, shipping, testing, and reporting results to health officials responsible for directing mosquito control activities.

Detailed procedures for collecting and processing arthropods and vertebrates for arbovirus surveillance have been described in two Center for Disease Control publications: "Collection and Processing of Vertebrate Specimens for Arbovirus Studies" and "Collection and Processing of Medically Important Arthropods for Arbovirus Isolation."

Emergency Measures

A multidiscipline approach to secure and evaluate the necessary virologic, entomologic and human disease data is essential for planning and managing emergency control measures in an SLE epidemic. The techniques employed for virus identification and definition of the vector situation require time and effort. It is urgent, therefore, that a well organized assessment of the situation be quickly undertaken to expedite decision on emergency measures. With optimal environmental and climatic factors, proliferation of vectors and amplification of the virus reservoir accelerates. Impact of control measures on the course of the epidemic will be greatly diminished by even small delays in proceeding.

Important considerations in design of the emergency control plan include assessment of the following factors:

1. infection rates in mosquitoes and birds,
2. size of the adult mosquito population,
3. extent of human disease,
4. extent of mosquito breeding,
5. anticipated changes in mosquito activity due to seasonal effects, and
6. climatic factors which may affect mosquito production and behavior.

An emergency vector control plan based on the use of adulticides will consist of four essential activities including: (1) intensified mosquito surveillance, (2) human case surveillance, (3) area-wide adult mosquito control, and (4) public information.

Intensifying Mosquito Surveillance: The abundance and geographic distribution of mosquito vector species should be known in emergency situations. For this purpose, adult mosquito sampling sites should be established immediately, and each site should be sampled at least once every 3 or 4 days in a consistent manner. (See Appendix III.)

When vector mosquitoes are abundant and large numbers of live adult mosquitoes are obtained with normal sampling of the established sites, these same mosquitoes may also be used for surveillance of SLE virus activity. However, it is frequently necessary to make special collections of mosquitoes for this purpose in order to have sufficient numbers in suitable condition for virus isolation to be successful.

Human Case Surveillance: A simple and practical system of human case surveillance facilitates recognition of the disease in the community, decisions to institute emergency control measures, and assessment of the effectiveness of control programs. The clinical signs and symptoms of SLE are not unique and many cases are quite mild; therefore, active surveillance for human cases should be established in areas where a human case has occurred and/or where SLE virus activity has been found through mosquito and bird surveillance. Daily communication with each hospital or clinic in the area speeds reporting of cases and also alerts hospital personnel of the need to consider arboviral disease in the differential diagnosis of patients presenting with febrile CNS diseases.

Confirmation of the disease as SLE requires laboratory procedures which are time-consuming (Appendix I). Thus, in order to obtain as rapidly as possible the confirmation of cases, serum samples should be collected from the earliest suspect cases. Serologic confirmation of SLE is based on a significant change in antibody titer, which requires collection of a second serum sample; the time period between samples may be 10 days or more, and to this can be added the time necessary to process the samples. Further, the onset of illness may occur 5 to 15 days after the patient has been bitten by an infected mosquito. Thus, considering that in most SLE epidemics the peak of cases has occurred approximately 4 to 6 weeks after the initial case, early confirmation of initial cases is essential to assure the timely initiation of emergency control measures designed to prevent further transmission of the disease. Because of their involved nature, the time required for the arrangement of emergency mosquito control measures may also produce a significant delay in the institution of these measures.

Area-wide Adult Mosquito Control: When the presence of SLE virus in mosquitoes or birds is determined and human cases have occurred, the existing infective adult mosquitoes must be killed as rapidly as possible to prevent more human cases. Once adult mosquitoes become infective with SLE virus they remain so for life. Adult mosquitoes may live a month or longer.

Ultra-low volume (ULV) application of insecticides, using ground or aerial equipment, has been used successfully for adult mosquito control in emergency situations. Where large areas are involved, aerial ULV application is most appropriate; adequate coverage of a large area by this method is effective in killing a high percentage of the adult mosquitoes and in preventing rapid reinfestation from surrounding areas. While a single efficient application may halt transmission of the virus, retreatment may be necessitated by a variety of factors, such as the size of the area covered, the percentage kill resulting from the prior treatment, and the seasonal timing of the application, i.e., repeat applications might be required when the initial spraying is done early in the season, while in late season a single application might suffice.

Specific instructions on methods of control and insecticides approved for use by these methods are in Appendix V. Generally, space spray operations (ground and aerial ULV, fogging, misting, and dusting) are conducted during late afternoon-early evening, at night or early in the morning. During these hours there is usually an inversion of air temperature and a lower wind velocity, which will hold the droplets close to the ground and allow for good mosquito kills. If the winds are stronger than 6 mph or the ground temperature is high, the treatment will most likely be ineffective. Rising air currents and strong winds will disperse and dilute the treatment.

The effects of mosquito control measures must be determined periodically to ensure that they are still achieving their purpose. Results of ground or aerial insecticide applications should be monitored to ensure that proper droplet size and distribution as well as reduction of vector species are achieved (Appendix V). Poor results and/or resistance to an insecticide can occur and alternative methods or a different insecticide must then be employed. Methods of evaluating chemical control are outlined in Appendix VII.

Area-wide mosquito control programs may be augmented by other methods in localized situations, for example, residual treatment of catch basins or other areas where adult mosquitoes rest in large numbers (Appendix V).

Public Information: Release of accurate and well timed information to the public is extremely important because an informed populace is much more likely to cooperate with and support mosquito control efforts; further, they may even be encouraged to protect themselves personally and to reduce mosquito breeding on their own property.

The public should be made aware of the real threat of disease and to understand the role mosquitoes play in its transmission. It is very important for them to know the character and extent of mosquito control operations, the schedule and locations of spraying, and how the mosquito control operations may affect them. Announcement of these should be made immediately preceding their application so that the public is not surprised by either the smell of insecticide or the noise associated with its application. In addition, simple measures for personal protection against mosquito bites should be disseminated (Appendix VI). This can be augmented by community participation and reduction of peridomestic mosquito breeding by eliminating water-holding containers which act as breeding sources.

Information dissemination is most efficiently handled if centralized under the responsibility of one individual. Effort should be made to reach the largest population quickly and in the most efficient manner. Radio and TV spot announcements, along with newspaper coverage, will generally reach most of the population of an area. Well prepared presentations to key civic groups or at public gatherings can be useful in certain emergency situations during any mosquito-borne disease outbreak. There will be numerous telephone inquiries. One particularly important aspect of good public relations is providing well prepared responses to these callers. To do so requires the personnel of the health department and vector control group be current on all aspects of the situation.

In an epidemic information should be released as early as possible and continued on a daily basis for as long as necessary.

Human Safety and Environmental Considerations: Current standards of practice of mosquito control through use of pesticides require a high level of care in their application so as to assure safety of the operator and the public, and to avoid adverse environmental effects. Only those pesticides approved by the Environmental Protection Agency for the specified use should be considered. When used according to labeled directions and local, State, and Federal regulations, these compounds are not considered hazardous to people. Experience to date indicates no adverse human health effects following ultra-low volume aerial applications in SLE control. In one study of people working in an urban area during a large-scale emergency control application, risks to human health were determined to be negligible.[4]

Adult mosquito control operations, especially aerial applications, can present a hazard to certain nontarget species. Honeybees are particularly susceptible to such treatments, although most public health aerial ultra-low volume applications have not resulted in serious harm to bees because of the low dosages used. It is important to take precautions by notifying beekeepers of a planned application; they may protect their hives by closing them or turning on sprinklers over the hives before daylight (when early morning applications are used) to keep the bees inside during the spray application. The beekeepers association and/or State experiment station should be contacted for advice regarding methods of protecting bees. During the last ten years a few instances of fish kill have occurred following aerial ULV applications. These have occurred in shallow, warm water where there appeared to have been other environmental stresses on the fish prior to the insecticide application.

In planning control measures in areas where delicate ecosystems could be disrupted by mosquito control practices, assistance should be sought from competent conservationists, fish and game specialists, and biologists.

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[4] Gardner, A.L. and R.E. Iverson. 1968. The effect of aerially applied malathion on an urban population. Arch Environ. Health 16:823-826.

[illegible] safety [illegible] standards [illegible]. Since effective control through use of pesticides requires a high level of [illegible] so as to assure safety to the operator and the public, and to avoid adverse environmental effects. Only [illegible] Environmental Protection Agency for the [illegible] should be [illegible]. When used [illegible] the compounds are [illegible] adverse [illegible] following [illegible] low volume [illegible] application [illegible] during [illegible] were [illegible].

[illegible] evaluations [illegible] public health [illegible] to protect their [illegible] to keep the [illegible] should be conducted [illegible] methods [illegible] protecting [illegible] to have been [illegible] insecticide application.

[illegible] planning [illegible] integrated systems [illegible] mosquito control practices, assistance should be sought from [illegible] specialists, and biologists.

[illegible] 1968. The effect of aerially applied [illegible] Arch. Environ. Health 16: [illegible]-826.

APPENDIX I: Criteria for Classification of Human St. Louis Encephalitis Infections

Clinical Categories

I. Encephalitis -- including meningoencephalitis, encephalomyelitis (both signs under A & B)

A. Acute febrile illness (temperature $\geq$ 100°F).

B. One or more signs under (1) or (2) or both.

1. Profound alteration in state or level of consciousness (confusion, disorientation, delirium, lethargy, stupor, coma, etc).

2. Objective sign of CNS dysfunction (tremor, dysarthria, hyperreflexia, rigidity, cranial nerve palsy, convulsion, paralysis, etc).

II. Aseptic Meningitis (all signs under A, B, and C)

A. Acute febrile illness (temperature $\geq$ 100°F).

B. Occurrence of either (1) or (2) or both.

1. One or more signs of meningeal irritation (stiff neck, positive Kernig or Brudzinski signs).

2. Pleocytosis (5 or more WBC/cc).

C. Absence of encephalitis and meningitis of bacterial or other nonviral etiology.

III. Other Illness

Febrile headache or other syndromes, but not encephalitis or aseptic meningitis.

IV. No Clinical Disease

No symptoms

V. No Clinical Data

Unable to obtain any clinical information.

VI. Case Under Investigation

Aware of existence of case or possible case, but clinical data pending.

LABORATORY CATEGORIES

I. Confirmed SLE

A. 4-fold or greater rise or fall in antibody titer by CF, HI, or 1.3 logs by neutralization testing, or

B. Isolation of virus from patient.

II. Presumptive SLE

Single serum titers - HI $\geq$ 1/80
CF $\geq$ 1/16

III. Inconclusive

A. Highest titer HI < 1/80 or CF < 1/16 and not satisfying criteria for confirmed or negative case, or

B. Unsatisfactory serologic data.

IV. Negative

No titer or stable low titers (e.g., HI in range of 10-20) in appropriately paired sera and no virus isolation.

V. No Laboratory Data

APPENDIX II: Techniques and Equipment for Larval Mosquito Surveys

Mosquito larvae are found in all types of aquatic habitats. Any survey for larvae of the Culex pipiens complex should include artificial containers, cisterns, discarded utensils, confined groundwater, catch basins, cesspools, gutters, rain barrels, sewage effluent, septic tanks, industrial wastes, and, in general, static water deposits characterized by varying degrees of pollution and often shaded. It is not unusual to find all stages, from egg rafts through the four larval stages and the pupal stage, in a given breeding site at a given time. This is in contrast to other genera of mosquitoes with long air tubes, which are sometimes mistaken for Culex during the summer months. Populations of Aedes and Psorophora are usually more homogeneous and are more frequently represented by the predominance of a single developmental stage in a given collection.

An experienced person may be able to spot the probable mosquito-breeding places in a specific area by means of a rapid reconnaissance survey. These places should be carefully numbered and marked on the map. More detailed inspection is then required to determine the specific breeding sites and to establish larval sampling stations. Larval surveys show the exact areas in which mosquitoes breed and their relative abundance, and are valuable in evaluation of control operations.

Equipment for Larval Mosquito Surveys

A white enamel dipper about 4 inches in diameter is most often used for collecting mosquito larvae. The handle of such a dipper may be extended to a convenient length by inserting a suitable piece of cane or wood.

Inspection of small artificial containers or cisterns can call for a flashlight or mirror with which to reflect light into the shadowed area. Wide-mouth pipettes (eye droppers) are used for removing larvae from a dipper or pan. Small vials, preferably with screw caps, containing 70% ethyl alcohol can be used for killing, preserving, and storing larvae for later identification. Screen-bottom spoons or tea strainers can be substituted for pipettes if the larvae and egg rafts are to be transferred to wide-mouth bottles or disposable cups.

Inspection Procedures

In larger bodies of water, mosquito larvae are usually found where surface vegetation and/or debris are present--ordinarily only in the marginal areas. It is necessary to proceed slowly and carefully in searching for mosquito larvae. If the water is disturbed, or a shadow is cast on them, the larvae often dive to the bottom. Culex require a quicker and deeper motion of the dipper, since these larvae hang down from the water surface and are agile.

An inspector should always record the number of dips and the number of larvae found. The larvae are transferred to small vials by a wide-mouth pipette and labeled and preserved for later identification. It is possible to get an approximate idea of the breeding rates by computing the number of larvae per dip. The number of dips required will depend on the size of the area, but for convenience they should be made in multiples of 10. Inspections should be made at frequent intervals during the breeding season because areas which are entirely free of larvae at one time can have many larvae at other times.

Culex tarsalis has a wide range of larval habitats, from irrigation water to polluted waste water. This species is particularly abundant in marshes, irrigation water, waste and seepage water, and roadside ditches over wide areas. Culex nigripalpus larvae are found in ditches, fresh-water marshes and grassy pools in central and southern Florida. Culex salinarius breeds in grassy pools of both fresh and brackish water, along lake margins, and in marshes, cattail bogs, ponds and ditches. Culex restuans is found in rain barrels, tin cans, woodland pools, ditches and other still water.

APPENDIX III: Techniques and Equipment for Adult Mosquito Surveys

Daytime Resting Places

Adult mosquitoes of the *Culex pipiens* complex and *C. tarsalis* are inactive during the day, resting quietly in dark, cool, humid places. Careful counting of mosquitoes in daytime shelters gives an index to the population density of these mosquitoes. These sampling sites are also a source of specimens for various tests. Mosquito resting stations are divided into two general types: natural and artificial.

Natural resting stations are the resting stations usually present in an area, such as houses, barns, stables, chicken houses, privies, culverts, bridges, caves, hollow trees, and overhanging banks along streams. With experience one becomes capable of evaluating the suitability of shelters as adult mosquito resting stations. Dwellings, especially when unscreened, often prove to be satisfactory resting stations. They are especially important when mosquito-borne diseases are being investigated. Under such conditions they furnish an index to the number of mosquitoes which could bite man and transmit SLE. It is essential that collections from shelters be done in the same manner and at the same time of day each time a collection is made for valid comparison of results.

Artificial resting stations may be constructed when suitable resting stations are not available in sufficient numbers to give a satisfactory evaluation of the mosquito population. It may be necessary to construct special shelters or to use boxes, barrels, kegs, etc., as resting stations. Many different types of artificial shelters have been used. They should always be placed near the suspected breeding places in shaded, humid locations. The principal vectors of SLE enter such shelters at dawn, probably in response to changes in light intensity and humidity, and ordinarily do not leave until dusk. Artificial shelters built as boxes, one cubic foot in size with one side open, and painted red on the inside, have been used successfully in the United States.

Light Traps

Many mosquito species are attracted to light, making it possible to sample adult populations between dusk and dawn.

The mosquito light trap is mounted on a post or hung from a tree, so that the light is about 6 feet above the ground. It should be located 30 or more feet from buildings in open areas near trees and shrubs. It should not be placed near other lights, in areas open to strong winds, or near industrial plants that give off smoke or other fumes. The traps should be operated on a regular schedule from 1 to 7 nights per week from just before dark until after daylight. An automatic time clock or photo-electric cell can be used to turn the trap on and off or it can be operated by hand. The collection should be removed each morning and placed in a properly labeled container until mosquitoes can be sorted and identified.

The CDC miniature light trap was developed for greater portability in making live mosquito catches in remote areas which could not otherwise be sampled. The CDC miniature trap is lightweight and can be disassembled readily for easy transport; it has a collapsible catching bag. The large plastic or aluminum canopy protects the operating mechanism, even in the heaviest rainstorms. It can be operated with one 6-volt battery or four 1 1/2-volt flashlight "D" cells, which provide sufficient power for one night.[5] The CDC trap does not compete well with other light sources and may give poor results on nights when there is a full moon.

Wide differences have been noted in the reactions of different species of mosquitoes to light. Light trap collections, therefore, must be used in conjunction with other methods of sampling mosquito populations. Light traps have proven very useful in measuring densities of *Culex tarsalis*, but less so for *C. pipiens quinquefasciatus*. *Culex pipiens pipiens* in northern areas may be collected in light traps. The addition of carbon dioxide in the form of dry ice, placed near the trap may improve trapping results, especially when trapping *C. tarsalis*. The dry ice should be insulated by wrapping in heavy paper (newspaper or padded envelope) or by placing it in a plastic bag with the opening constricted by a rubber band.

Carbon Dioxide Traps

Solidified carbon dioxide (dry ice) will attract large numbers of some mosquito species. An economical portable mosquito bait trap utilizing dry ice as an attractant has been developed in California. This trap, made from a 12-inch lard can with two inwardly directed screen funnels, is baited with about 3 pounds of dry ice wrapped in newspaper. It is effective in capturing large numbers of female *Culex tarsalis*.

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5 Sudia, W.D. and R.W. Chamberlain. 1962. Battery Operated Light Trap; An Improved Model. Mosq. News 22(2):126-129; and Johnston, J.G., Jr., Weaver, J.W., and Sudia, W.D. 1973. Flashlight Batteries as a Power Source for CDC Miniature Light Traps. Mosq. News 33(2):190-194.

APPENDIX IV: Control of Mosquito Larvae

Larval control should concentrate on those techniques which eliminate the breeding site permanently and at the same time are environmentally acceptable.

Filling open ditching, subsoil drainage, pumping and diking, if well constructed and maintained, can eliminate mosquito breeding sites. Open storm sewers are frequent problems because vegetation has been allowed to grow up in them. In many instances these ditches are present but are ineffective because of improper maintenance.

Fresh-water ponds and sewage stabilization lagoons are frequent mosquito-breeding sites. Steep, clean shorelines with little or no vegetation will reduce the amount of mosquito production in such sources.

On irrigated lands mosquito breeding occurs in vegetation and flotage in any water collections which are allowed to accumulate and persist, such as in borrow pits and in seepage areas. Borrow pits should be constructed with steep shorelines, cleared of vegetation and maintained. Properly graded fields will practically eliminate the problem of standing water and the associated mosquito production.

Mosquito-eating fish such as Gambusia and guppies are quite effective in cisterns, water tanks, garden pools and marshy areas. These and many other species of fish can effectively reduce mosquito breeding if water surfaces are relatively clear of vegetation and flotage so that the fish can get to the larvae. There are other organisms such as viruses, bacteria, fungi, protozoa or nematodes which are natural enemies of mosquitoes and which may become available in the future for their control.

An integrated control strategy which includes all methods that reduce mosquito populations and exerts minimal harmful effects on the environment is the preferred approach. This includes environmental management and judicious application of insecticides plus the use of predator fish and insect growth regulators. This approach is especially necessary in areas where there is widespread resistance to insecticides and it may retard development of resistance in areas where little or none exists.

If areas cannot be drained or filled at acceptable cost and impounding or biological control is not possible, larviciding is a reasonable alternative. Dusts, pellets, granules, wettable powders, emulsions of insecticides or oil solutions with a spreading agent may be used. Insecticides that are currently registered for use as larvicides are listed in Table 1.

Table 1. Insecticides currently registered for use as larvicides.

(These recommendations are guidelines only. User must ensure that pesticides are applied in strict compliance with label and local, State and Federal regulations.)

INSECTICIDE	RATE OF APPLICATION AI/A	REMARKS
Organophosphates chloropyrifos(Dursban)®	0.0125-0.05 lb/acre	Mix 0.8-1.6 oz chloropyrifos 2E with water, kerosene, or fuel oil to make a gal. Apply at 1 gal/acre. In heavy vegetation apply at 1.6-3.2 oz chloropyrifos 2E per gal. Apply at 1 gal/acre.
fenthion(Baytex)®	0.05 lb/acre	Apply 1.5 oz in sufficient water, kerosene, or diesel oil to obtain uniform coverage, or in 1.5 gal of water. Allow at least 3 weeks between applications.
malathion	0.4-0.5 lb/acre	Mix 2.5 oz of malathion 57E with water to make 1 gallon. Apply up to 5 gal/acre depending on flotage and vegetation.
parathion, ethyl	0.1 lb/acre	Mix 1 gal of ethyl parathion 4EC with 39 gal of water (0.1 lb/gal). Apply by airplane at 1 gal/acre.
parathion, methyl	0.1 lb/acre	Mix 1 gal of methyl parathion 4EC with 39 gal of water (0.1 lb/gal). Apply by airplane at 1 gal/acre.

Continued--

Table 1 (cont'd)

INSECTICIDE	RATE OF APPLICATION AI/A	REMARKS
temephos(Abate)®	0.05-0.1 lb/acre	Apply 5-10 lb. of 1% Abate sand and celatom granular per acre. Apply 2.5-5 lb. of 2% Abate sand and celatom granular per acre. Apply 1-2 lb. of 5% Abate sand and celatom granular per acre.
temephos (Abate)®	0.1-0.5 lb/acre	In some tidal water, marshes, and water with high organic or pollution content apply up to 25 lb. of 2% Abate sand and celatom granular, or up to 10 lb. of 5% Abate sand and celatom granular.
temephos(Abate)®	0.016-0.048 lb/acre	Mix 0.5-1.5 oz of Abate 4E per gal of water. Apply at 1 gal/acre.
Chlorinated hydrocarbons		
lindane (gamma isomer BHC)	0.1 lb/acre	For ground larviciding, dilute 12% lindane EC to 0.4% spray. Apply in a fine mist at 3 gal/acre.
	0.1 lb/acre	For aerial larviciding, add 3 parts of 12% lindane EC to 4 parts of fuel oil to make a 5% solution. Apply at 2 gal/acre.
methoxychlor	1 lb/acre	Apply up to 2 lbs of 50% methoxychlor WP on snow or ice, or dried-up breeding places, as a prehatch treatment.
Petroleum oils		
Diesel fuel oil No. 2 without spreading agent	10-20 gal/acre	Dosage depends on amount of flotage and vegetation in water. In catch basins cover water surface.
Diesel fuel oil No. 2 with spreading agent	1-5 gal/acre	As above
Proprietary mosquito control oils (as Flit MLO, ARCO larvicide, and GB-1313)	1-5 gal/acre	As above

Continued--

Table 1 (cont'd)

INSECTICIDE	RATE OF APPLICATION AI/A	REMARKS
Insect Growth Regulators		
Altosid®	0.025-0.05 lb/acre	Mix 3-4 oz of 10% Altosid in ½ to 5 gals. of water and apply to 1 acre. Apply to watered areas with 2nd, 3rd, and 4th instar larvae. Altosid does not kill pupae or adults.
TH-6040 (DIMILAN)®	0.02-0.04 lb/acre	Thoroughly mix 0.85-1.7 oz 25% TH-6040 WW powder with water to make 1 gallon of spray. Apply at 1 gal/acre

E or EC = Emulsifiable concentrate
WP or WW = Water wettable powder
AI/A = Active insecticide per acre

Environmental Aspects:

Control measures aimed at mosquito larvae can have adverse effects on other species requiring care in choosing a method for control and in performing the control operation. Vectors of SLE often result from man-made sources which can be eliminated or physically altered to prevent mosquitoes from developing without impact on other species. In other situations where natural accumulations of water are producing *Culex pipiens pipiens* or *C. p. quinquefasciatus* because of introduced pollution, it may be possible to reduce the production of these vector species by eliminating the sources of pollution.

Assistance should be sought from competent conservationists, fish and game specialists, and others in planning control measures in areas where delicate ecosystems could be disrupted by mosquito control practices. In mosquito control aimed at disease prevention, only those pesticides approved by the Environmental Protection Agency for the planned use should be considered.

This appendix is divided into sections dealing with: ultra-low volume application with ground equipment; ultra-low volume aerial applications; thermal fog and dust applications; and other methods of mosquito control.

Control of adult mosquitoes by space spraying of any kind is only temporary since mosquitoes from nonsprayed areas could move rapidly into the sprayed area following spray applications. Also, aquatic stages are not affected by space spraying and emergence of new adults will continue.

Space spraying operations are conducted during the late afternoon and early evening, at night, or in the early morning when the air is cool and wind velocity does not exceed 6 miles an hour. If air movement is excessive the small droplets used in space spraying are dispersed so swiftly that effectiveness is reduced or prevented. Similarly, during the middle of a hot day the droplets are dispersed by rising currents of warm air known as thermals. At night there may be an inversion of air temperatures so that small droplets are held close to the ground usually producing excellent control of mosquitoes.

Outdoor space treatments with ground or aerial applications have been carried out effectively against many species including vectors of SLE. Susceptible populations of mosquitoes can be reduced effectively by space application of insecticides listed in Tables 2 and 3.

Ultra-low Volume Application with Ground Equipment

Ultra-low volume (ULV) application with ground equipment is becoming the most frequently used method of adult mosquito control in the United States and can be very effective in control of vectors of SLE. Ultra-low volume treatment is defined as the application of less than two quarts of insecticide per acre, usually 0.5 to 3 ounces per acre. During the five years from 1970 to 1975, great advances have been made in the development of ultra-low volume equipment and a number of ULV ground application machines are now sold commercially. ULV equipment utilizes insecticide concentrate without a diluent or carrier resulting in savings in fuel, loading time, and cost of the fuel oil required in thermal foggers. Other advantages of ULV aerosols are that they do not produce the dense fogs -- as do thermal fogs -- which constitute a traffic hazard by reducing visibility. The ground ULV machine is relatively small. Its insecticide tank is usually of 5- to 10-gallon capacity; and, it is usually mounted on a small vehicle such as a ½-ton pickup truck.

Performance requirements for ground ULV equipment have been published as follows:[6]

1. The ULV cold aerosol nozzle for dispersal of malathion to control adult mosquitoes must have the minimum capability of producing droplets in the 5 to 27 micron range. Large droplets may permanently damage automobile paint. The average diameter should not exceed 17 microns. Determination of droplet size should be made by depositing a sample of the aerosol on a silicone-coated glass slide and measuring the droplets under a microscope with an ocular micrometer.

2. Tank pressure should not be less than 2 to 3.5 pounds nor greater than 6 pounds per square inch (psi).

3. Flow rate must be regulated by an accurate flow meter. Flow meter data such as that in Table 2 should be recorded at the end of each day's operation.

4. The nozzle should be in the rear of the truck and pointed upward at an angle of 45° or more.

5. Vehicle speed should not be greater than 10 miles per hour. The ULV machine should be shut off when the vehicle is stopped.

Six insecticides have EPA label approval for application as ULV aerosols by ground equipment: chloryprifos (Dursban), fenthion (Baytex), malathion, naled (Dibrom), pyrethrum, and resmethrin (SBP-1382). These insecticides are listed in Table 2.[7]

Ultra-low Volume Aerial Applications

Airplanes have been used for many years to apply insecticide dusts, pellets, sprays, and aerosols. Since 1964, aerial ULV has been used many times for control of mosquitoes in disaster areas and for control of epidemics of SLE and other mosquito-borne diseases. The ULV method was used in 1966 to kill infected Culex quinquefasciatus during the Dallas, Texas, epidemic of St. Louis encephalitis; in 1967, to kill species of Aedes, Psorophora, Culex, and Anopheles in a 3-million acre flooded area in Texas; in 1969, in Ohio to kill Aedes, vectors of California encephalitis during an epidemic; in 1972 and 1974, in New England to kill species of Aedes; Coquillettidia, and Culiseta during an outbreak of

[6] American Cyanamid Company, 1972. Modern Mosquito Control, 3rd ed. American Cyanamid Co. Princeton, N.J. 30 pp.

[7] Rathburn, C.B. and A.H. Boike Jr. 1975. Ultra low volume tests of several insecticides applied by ground equipment for the control of adult mosquitoes. Mosq. News. 35(1):26-29.

Table 2. Insecticides Currently Used for Control of Adult Mosquitoes with Ultra-Low-Volume Ground Equipment.

(These recommendations are guidelines only. User must ensure that insecticides are applied in strict compliance with label and local, State and Federal regulations.

INSECTICIDE	FORMULATION	REMARKS
chlorpyrifos(Dursban)®	Dursban Dow Mosquito Fogging Concentrate®	At vehicle speed of 10 mph, 2/3 to 1 1/3 fl. oz/min. Maximum flow rate 0.3 to 0.62 gal/hour.
fenthion(Baytex)®	Baytex Liquid Concentrate®	At vehicle speed of 10 mph, 1 fl. oz/min. Maximum flow rate of 0.5 gal/hour.
malathion	Cythion ULV Concentrate®	At vehicle speed of 5 mph, 1-2 fl. oz/min. Maximum flow rate of 1 gal/hour.
		At vehicle speed of 10 mph, 2-4 fl. oz/min. Maximum flow rate of 2 gal/hour.
naled*(Dibrom)®	10% Dibrom 14® in HAN®	At vehicle speed of 10 mph, 6-12 fl. oz/min. Maximum flow rate of 6 gal/hour. At this rate persons may have serious irritation of eyes and respiratory tract.
	1% Dibrom 14® in fuel oil with 1% Ortho additive	At vehicle speed of 10 mph, 40 fl. oz/min. Maximum flow rate of 20 gal/hour.
pyrethrum	5% pyrethrins - 25% piperonyl butoxide	At vehicle speed of 5 mph, 2-2.25 fl. oz/min. Maximum flow rate of about 1 gal/hour.
		At vehicle speed of 10 mph, 4-4.5 fl. oz/min. Maximum flow rate of about 2 gal/hour.
resmethrin	10% SBP-1382®	At vehicle speed of 5 mph, 3/4 fl. oz/min. Maximum flow rate of 0.42 gal/hour.

Note: mph = miles per hour; fl. oz. = fluid ounce; HAN - Heavy Aromatic Naptha.
*With naled, tank pressure should not be greater than 1.5 lbs. psi because of overatomization and poor mosquito control.

Eastern encephalitis; and in 1975, in North Dakota and Minnesota to kill infected Culex tarsalis during an outbreak of Western encephalitis.

The aerial ULV technique uses the application of 0.5 to 3 ounces of highly concentrated insecticide per acre for the control of adult mosquitoes. These insecticides are currently approved for adult mosquito control by the ULV method of application from airplanes: malathion at 3 fluid ounces per acre, and naled at 0.5-1 fluid ounce per acre. On occasion, car spotting and bee kills have occurred as a result of ULV aerial applications.

Special airplane equipment for the ULV involves special tanks, electrically-driven pumps, spray booms, and 8001 to 8008 Tee-Jet nozzles.

In general, airplane ULV applications should be made only:[8]

1. When temperatures are below 80°F (usually early morning).

2. With droplet size of not more than 50 to 60 microns MMD (Mass Median Diameter) no more than 10% of the droplets should exceed 100 microns. In some areas damage to car paint has occurred when larger droplets were dispersed or more than 10% of the droplets exceeded 100 microns. Effectiveness against adult mosquitoes requires 10 or more drops per square inch. Determination of droplet size should be made by depositing a sample of the aerosol on a silicone-coated glass slide and measuring the droplets under a microscope with an ocular micrometer.

3. By multi-engine aircraft flying at a height of 100-150 feet, at speeds of about 150 miles per hour or more, with swath widths of 300-1000 feet with pump pressures and nozzle sizes and positions adjusted to provide the proper droplet size. Single-engine fixed wing and rotary wing aircraft are undesirable for this technique because of their slower air speed and resulting problems with droplet break-up. There are additional factors related to safety over urban areas with single-engine aircraft and with their limited "pay load" which need to be considered.

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[8] Kilpatrick, J.W. 1967. Performance specifications for aerial ultra-low-volume application of insecticides for mosquito control. Pest Control 35(5):80, 82, 84.

Thermal Fog and Dust Applications

Thermal fog applications have been used successfully for adult mosquito control for many years. Thermal fogs require the addition of a fuel oil carrier and depend on a high temperature system to produce the fog droplets. Tests have shown ULV and thermal fogs to be similar in effectiveness. Disadvantages of thermal fogs include the hazard of the dense fog produced and the expense of carrying and using the fuel oil carrier.

In past years there has been much interest in the use of dusts for adult mosquito control and they can be effective. Tests in Georgia and Florida with ground-dispersed dusts (19% and 7.5%) of carbaryl produced 99% reduction of adult salt-marsh mosquitoes at dosages of 0.2 and 0.3 pound of carbaryl per acre.

Table 3. Insecticides Currently Used For Adult Mosquito Control With Ground Foggers, Misters, and Dusters.[9]

(These recommendations are guidelines only. User must ensure that insecticides are applied in strict compliance with the label and local, State and Federal regulations)

INSECTICIDE	DOSAGE(AI/A)	REMARKS
carbaryl(Sevin)®	0.2-1.0 lb/acre	Dosage based on swath width of 300 feet. Apply as mist or fog from dusk to dawn. Mists are usually dispersed at rates of 7 to 25 gallons per mile at a vehicle speed of 5 mph. Fogs are applied at a rate of 40 gal/hr dispersed from a vehicle moving at 5 mph; occasionally 80 gal/hr and 10 mph. Finished formulations for thermal foggers contain from 0.5 to 8 oz per gallon actual insecticide in oil. For nonthermal foggers or misters, water emulsions can be used. Dusts can also be applied with ground equipment.
chlorpyrifos(Dursban)®	0.025-0.05 lb/acre	
fenthion(Baytex)®	0.01-0.1 lb/acre	
malathion	0.075-0.2 lb/acre	
naled(Dibrom)®	0.02-0.1 lb/acre	
propoxur(Baygon)®	0.05-0.07 lb/acre	
pyrethrins(synergized)	0.002-0.0025 lb/acre	
resmethrin(SBP-1382)®	0.007 lb/acre	

AI/A = Active insecticide per acre

[9] Center for Disease Control, 1973. Public Health Pesticides; Pest Control 41(4):17-50.

Other Methods of Adult Mosquito Control

Residual treatment outdoors for mosquito control does not always provide good control. However, limited relief from biting mosquitoes can, at times, be obtained in small city parks, playgrounds, picnic areas, patios, and yards. Water suspensions or emulsions with a low percent of insecticide (rather than oil solutions) are used in order not to "burn" vegetation. These applications can be made with power sprayers or with hand sprayers using nozzles which provide a broad fan or cone and a coarse spray, such as the Tee-Jet 8004. The insecticides used for such outdoor applications include methoxychlor (50% wettable powder, 2 lb. per 100 gallons of water) and fenthion (Baytex 4 Emulsifiable Concentrate, 2 to 4 ounces per gallon of water).

Apply the methoxychlor spray to vegetation, trunks of trees, outside walls of buildings, walls and fences in a drenching spray to the point of run-off. The fenthion spray should be applied at a rate of 2 gallons per 1000 square feet.

Residual spraying is a primary method of controlling mosquitoes which breed in catch basins. In many large cities with thousands of catch basins along the edges of streets, surveys indicate that often one catch basin in every ten holds enough water to produce broods of mosquitoes of the Culex pipiens complex. The application of petroleum oils, or granular insecticides, to these catch basins is not the complete answer to this type of mosquito control because a single shower produces enough run-off to flush the larvicide into the storm sewer. Therefore, a special nozzle has been developed which produces a radial spray pattern and deposits a coating of insecticide on the walls of the catch basin. Some of these insecticides are not readily soluble in water. The residual insecticide remains on the walls of the catch basin for weeks or months. It kills the adult mosquitoes after they emerge from their pupal cases as they rest on the walls while their wings and body harden sufficiently for flight.

The organophosphate insecticide, dichlorvos, is formulated into resin strips which release an insecticide vapor. Usually one resin strip per 1000 cubic feet (10'x10'x10') provides good control of mosquitoes for 3 to 4 months. Results of tests with such strips for control of adult mosquitoes in catch basins, cisterns, etc. have been variable. Studies in Savannah, Ga., and elsewhere have shown good control as tested with caged Culex pipiens quinquefasciatus for 11-18 weeks when one resin strip was wired to the grating of a catch basin.[9]

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[9] Ibid.

Environmental Aspects

Assistance should be sought from competent conservationists, fish and game specialists, and others in planning control measures in areas where delicate ecosystems could be disrupted by mosquito control practices. In mosquito control aimed at disease prevention, only those pesticides approved by the Environmental Protection Agency for the planned use should be considered.

APPENDIX VI: Personal Protection from Mosquitoes

People can protect themselves from mosquitoes by using proper window screens, protective clothing, or repellents. The principal vectors of SLE, Culex pipiens pipiens, Culex pipiens quinquefasciatus, and Culex tarsalis are active from dusk through the evening hours. Consequently, in an actual or potential epidemic situation people should be encouraged to avoid mosquito contact at that time of day. The ordinary window screen with 16x16 or 14x18 meshes to the inch will keep out most mosquitoes including vectors of SLE. Frequently mosquitoes follow people into buildings or enter on the human host. For this reason, screen doors should open outward and have automatic closing devices. Residual insecticide applications on and around screen doors give added protection.

Long-sleeved clothing of tightly woven material offers considerable protection against mosquito bites. Sleeves and collars can be kept buttoned and trousers tucked in socks when mosquitoes are biting. This type of protection may be necessary for people who must work in areas where infected vector mosquitoes are particularly abundant. The use of mosquito netting to protect infants in their cribs may also be indicated in high risk circumstances.

Relief from mosquito attack may usually be obtained by applying insect repellents to the skin and clothing. A number of these have given adequate protection against mosquitoes. Effective protection may be obtained through the use of diethyl toluamide or deet, dimethyl phthalate, Rutgers 612, and 6-2-2. Repellents are available as liquids in bottles, pressurized spray cans, and in stick form.

When applied to the neck, face, hands, and arms, liquid repellents will prevent mosquito bites for 2 hours or more, depending on the person, species of mosquito attacking, and abundance of mosquitoes. These repellents can also be sprayed on clothes to make them repellent. Many repellents are solvents of paints and varnishes, and plastics such as watch crystals, rayon fabrics, and fountain pens. Diethyl toluamide will not affect nylon. Care should be taken not to apply repellents to the eyes, to the lips, or to mucous membranes.

Pressurized aerosol insecticide dispensers can be used in the home to kill adult mosquitoes. Most of these contain pyrethrum or allethrin because these insecticides have low human toxicity and cause a quick knockdown of mosquitoes. These aerosol dispensers may also contain a synergist such as piperonyl butoxide and another insecticide such as diazinon to kill the insects. Release of the aerosol for a few seconds usually kills most insects in an ordinary-sized room, tent, or trailer. These aerosols are not hazardous if used as directed on the container, except in rare cases where persons are allergic to pyrethrum or the synergist.

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APPENDIX VII: Methods for Assessing Chemical Control of Mosquitoes

Evaluating the results of the treatments applied as larvicides and adulticides is important to any control effort. Resistance to the insecticide being used may become a problem, or improper application techniques may reduce the effectiveness of the method, or possibly increase the risk of killing nontarget species. Standard resistance/susceptibility test kits are available from the World Health Organization, Geneva, Switzerland, and periodic tests may indicate a change in the susceptibility of a mosquito species from an established baseline.

The basic approach used in evaluating larviciding or adulticiding applications is comparison of the number of specimens per collection made before and after the application. For this purpose collections should be made on each of several days before and after the application and as many sampling sites as possible should be included.

Another useful method is that of bioassay tests with caged specimens. A bioassay test for space sprays may be done by using the following technique:

> Treatments may be applied by fog, dust, mist, or ULV machine mounted on a vehicle and moving at 5 mph or 10 mph at the recommended label dosage. Field collected, caged specimens (100-150/cage) are hung 6 ft. above the ground at stations 150-300 ft. from the point of discharge of the machine along each of three streets (270-300 ft. apart). Ten to 15 minutes after exposure the cages are removed and the insects are transferred to holding cages, given food and held for a 24-hour female mortality count. Seventy percent or better kill is expected.
>
> If the kill at either the 150' or 300' station is less than 70%, then the equipment and timing of application of insecticide should first be examined, and adjusted. If, after these adjustments have been made and the kills are still unsatisfactory, then a change of insecticide should be recommended.

Bioassay tests for larvicides are of less value than sampling of natural larval habitats for larvae before and after an application is made. A useful technique to improve reproducibility of larval sampling is that of placing numbered stakes at various sites and then taking a prescribed number of dips at the site each time it is sampled. A 70% or greater reduction in the number of larvae per dip is expected.

 *U.S.GOVERNMENT PRINTING OFFICE: 1978--740-265/3910 Region No. 4.

Request for

VECTOR TOPICS

TO: Center for Disease Control
Attn: Bureau of Tropical Diseases
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