It should be noted that not all of the breeding and resting places of *Aedes aegypti* can be reached by road. Equipment should, therefore, include the portable or backpack ultra-low volume equipment. It is available from a number of manufacturers (see Annex IV). The performance of some of these approaches that of true ultra-low volume, while others merely have manufactured nozzle modifications for mist blowers. Since the latter equipment is used extensively in agriculture, this may provide a source of equipment during emergency situations. Although with portable equipment there is a tendency toward overdosing, it has been noted that overdosing produces a short-term residual effect that can be advantageous during disaster related emergencies. There should be two spraymen, working in shifts of thirty minutes, assigned to each piece of equipment. Workers should be provided protective gloves, respirators and clothing. Their uniforms should be changed daily and should be washed after each use, and, if possible, monthly routine cholinesterase determinations should be made on all spraymen.

Aerial ultra-low volume application is exceedingly rapid, and has been reported to be successful. Aerial applications have been successfully used in Puerto Rico, Mexico, Trinidad, the Bahamas, Honduras, and Jamaica for control of *Aedes aegypti* during dengue epidemics. Success of application, however, depends on the expertise with which it is performed. Aerial ultra-low volume application can be performed by specialized companies under contract. These companies generally use multi-engined aircraft that are capable of transporting insecticide over a great distance. The relatively large size of these airplanes makes it possible to treat a large area at one point in time. It is preferable to select companies that are experienced in public health spraying. Highly skilled pilots should be trained to carry out applications at the proper speeds and heights.

The single-engined aircraft and the helicopters that are used to apply insecticides and herbicides for agricultural purposes should also be considered for use of ultra-low volume application. Local and civil aeronautic regulations may restrict the use of such aircraft, but waivers can usually be obtained for some emergency usages. If aircraft used for agricultural purposes are employed, it should be noted that there is much greater coverage per acre/hectare of ultra-low volume application of pesticides than there is when agricultural pesticides are applied. Thus, the costs should not be the same. It should also be noted that the pilot of the aircraft may have to practice the application of the public health insecticide before it is actually carried out, because the method by which it is applied differs from that used for agricultural purposes.

The insecticides that can be used in aerial ultra-low volume application are malathion, fenitrothion, naled, pirimiphos-methyl and resmethrin. Unless there is an indication of resistance, or other insecticides are more readily available, an ultra-low volume formulation of malathion applied at 219 ml/ha to 440 ml/ha (3 to 6 oz.) is recommended. Multiple treatment is usually required for effective control, and entomological evaluation should be undertaken to decide upon frequency of treatment. If this is not possible, the insecticide should be applied weekly or twice-weekly, until the adult *Aedes aegypti* population is negligible.

When insecticides are applied, it is important to follow the instructions on both the equipment and the insecticide label. There are also a number of other factors which should be known if the equipment is to be safely used, and if it is to perform efficiently. One consideration concerns the droplet size of the insecticide. Droplets that are too small tend to drift out of the target area and may present a respiratory hazard, while allowing droplets to be too large wastes insecticide and may lead to damage to automobile paint. Nozzles for ultra-low volume ground equipment should be capable of producing droplets in the 5- to 27-micron range at the minimum. For malathion, the mass median diameter (MMD) should not exceed 17 microns. These limits change when the insecticide is applied from aircraft. When malathion is aerially applied, the nozzles should be capable of delivering droplets less than 50 microns (MMD); when naled is aerially applied they should be capable of delivering droplets of less than 30-80 microns (MMD).

Photo J Moquillaza

Portable backpack mistblowers such as the one above being demonstrated in Venezuela, are useful for adult control of *Aedes aegypti*, *Culex* sp, and malaria vectors, especially when breeding and resting places cannot be reached by road.

The speed and time of application are important to consider when insecticide is applied by ground vehicle. The vehicle should not travel faster than 16 kilometers (10 miles) per hour, and when wind speed is greater than 16 kilometers (10 miles) per hour, or when the ambient air temperature is greater than 28°C (82° F), the insecticide should not be applied. The best time for applications is in the early morning approximately (0600-0830 hours) or late afternoon (approximately 1700-1930 hours). However, operations during the entire evening are applicable to *Culex* and pest mosquito control.

The information that should be known about aerial application of insecticides varies according to the types of aircraft, insecticide and equipment used. For application of malathion, the altitude of the aircraft should be between 30 to 65 meters (90 to 150 feet) and aircraft speeds should be between 160 to 260 kilometers (100 to 162 miles) per hour. Swath widths will vary according to the altitude. Early morning applications are preferable to application at other times of day. Temperatures should be less than 27°C (80°F) and wind velocity below 16 kilometers (10 miles) per hour. In addition, there should be a temperature inversion (when ground temperature is cooler than air temperature) when the insecticide is applied.

When insecticides are applied with small, portable equipment, care must be taken that the correct fuel mixture is used, that the insecticide does not leak and the engine does not overheat. Further details about the use of space spray equipment can be found in publications concerning vector control.

Evaluation of Control Measures

Evaluation of emergency control measures is often done poorly or is completely ignored because of inadequate planning and lack of resources and trained staff. If an epidemic is curtailed, or fails to develop, the operation is essentially considered to have been successful.

This practice should not be overly criticized; emergency operations should not be delayed because there has been no opportunity to evaluate them However, it is always advisable to evaluate control measures, since proper evaluation can save valuable time and money during all stages of emergency operations, and can contribute to the guidelines to be used in future emergencies.

Evaluating entomological control measures provides important information that can be used as the basis for deciding when and in what exact areas insecticides should be applied. It also allows the effectiveness of the insecticides, and of the overall program to be assessed. Evaluation of the procedures used and of the quality and amount of work performed will point to failures and ways in which failures can be remedied.

The same information is needed about the success of control measures taken after natural disasters and other emergencies. Thus, if procedures have already been adopted for evaluating existent vector control programs in the area, their use can be extended to the evaluation of the entomological control measures taken during the emergency.

The population sampling methods that have been described above in regard to surveillance can also be used for the evaluation of chemical control measures. Larval surveys in which the House, Container and Breteau Indices are used, may yield indication of pretreatment and posttreatment changes in the size of larval populations. These surveys are especially helpful if larvicides have been applied. To some degree they can also be used to determine the extent of public acceptance of the treatment, if the presence or absence of sand granules or miniquets is noted. However, in evaluating emergency adulticidal action, larval surveys will show little or no immediate response.

Space spray operations by either ultra-low volume applications or thermal fogs should lower the adult population immediately. Pretreatment and posttreatment comparisons of adult resting or landing collections will show not only the immediate effect of treatment on the population at the end of twenty-four hours; if comparison is made after treatment at two or three day intervals, the results can be used to schedule additional insecticide applications. Similar timed collections made in an untreated area will show the effect of climatic changes upon changes in population densities, or other unrelated fluctuations which may be taking place simultaneously. If there is a trained technician available, it is worthwhile, but not essential, that the technician dissect the organisms to obtain pretreatment and posttreatment parous rates.

Ovitraps can also reflect immediate changes in the adult female population. If sufficient numbers are used, they may reveal population recovery and indicate where there have been misses or weakness in coverage.

Use of bioassays, of insectary-reared *Aedes aegypti* or other species, is a valuable method of evaluation. Wild-caught mosquitoes may be used, but if they are it will be necessary to adjust the sample size to compensate for lack of uniform age of the sample. Three- or four-day-old, blood-fed females are usually used for adult bioassays, and third or early fourth instar larvae are used for the larval bioassays. The latter are, however, of limited value for the evaluation of space spray applications.

Adult bioassays are performed by placing thirty to one hundred adults in a cage. Excellent, reusable cages can be constructed with galvanized screen wire although it is also possible to use inexpensive, disposable cages that can be made with paper cups, cardboard tubes, or wire frames covered with a fine mesh fabric such as tulle. The cages should be placed at thirty to one hundred meter intervals across the path of an aerial swath, or at right angles to the path of ground equipment, in the direction of the spray. One hour after exposure, the cages are collected and the insects are transferred to clean holding cages. There they are given food and held for a 24 hr. mortality count. It is usually true that the closer the source of spray, the higher is the mortality rate. Mortality rates should be plotted against site of the cage. The results should give indirect indication of mortality rates of the natural populations, and of swath width, unsatisfactory coverage and other breakdowns in application

Immediately following a natural disaster, or during a vector-borne disease epidemic, the possibility of insecticide resistance is sometimes forgotten. The World Health Organization has kits for testing the susceptibility of adult and larval mosquitoes to insecticides. If these kits are not available, field bioassays of various available insecticides can be performed. In the Americas, there is resistance of *Aedes aegypti* to organochlorine insecticides, and in certain areas tolerance to some of the organophosphate insecticides may exist. Even where there are no routine vector control programs, the use of agricultural and household pesticides may increase the potential for resistance development.

When ultra-low volume equipment is used, it may be necessary to calibrate dosage and determine the droplet size. The technical brochures provided by the equipment or insecticide supplier should contain information about these procedures.

Chapter 6

Anopheline Vectors of Malaria

Malaria control or malaria eradication programs are found in most malarious countries. Depending on the state of the program, its administrative structure and function may vary. Natural disasters, such as hurricanes and floods, may affect the breeding sites of anopheline mosquitoes. In areas where malaria is endemic, the likelihood of an increase in malaria cases two or more months after the disaster must be considered and appropriate action taken.

Surveillance of Malaria

Malaria surveillance can be directed toward the detection of human cases or toward changes in the mosquito population. In malaria control programs, case detection is of greater priority.

Epidemiological Surveillance of Human Cases

Most malaria programs entail both active and passive case detection. These activities include the taking of blood slides by either voluntary collaborators or program staff members, who make house-to-house visits following established procedures, and at clinics, hospitals and health offices. The information should be studied that is yielded from the yearly and monthly blood slides made in all areas directly or indirectly influenced by the disaster.

Once the eradication program of a country is in the maintenance phase, there are certain circumstances in which there is great potential for reestablishment of transmission. The threat of transmission is posed when there are a large number of imported cases of malaria, suitable environmental conditions and a relatively high abundance of anopheline vectors.

Areas within the range of disasters of potential risk of malaria transmission can be delineated according to the above factors. Malaria surveillance should be upgraded after a disaster. If there is relocation of populations or changes in community life and activities, this may involve considerable reorganization. Voluntary collaborators should be on the lookout for a sudden rise in the number of fever cases. All government and private medical facilities should also be alerted, and activities undertaken in the field and in laboratories should be evaluated.

An alert of this type is always capable of overtaxing the capacities of laboratory facilities. When there is great concern that a malaria epidemic may occur, there should be an attempt to increase the size of laboratory staff or that of any other laboratory with qualified technicians, such as those of medical schools, hospitals and private clinics. It should be noted, however, that redirection of slides will cause additional logistical problems for the epidemiologist who is gathering statistics.

The epidemiological program may face a number of other problems. Census data and maps may be inaccurate because of the movement of families after a natural disaster. Officials in the malaria control program should establish surveillance systems in new settlements which allow them to correct such inaccuracies.

Officials of the epidemiological surveillance service should know which malaria parasites are present in a community, and should monitor any changes in prevalence. An evaluation should be made of the changes in risk, and to indicate the existence of areas or populations in which complimentary control measures are required. Control tactics encompassing chemoprophylaxis, case detection and treatment, and vector control activities should be developed. An appropriate monitoring system should exist in which staff members are alerted to necessary changes regarding the timing of their strategy. Both the stocks of antimalarial drugs and the ordering of new supplies should receive periodic review.

In the interval between the onset of disaster and the period of possible increase in malaria infections, the director of the malaria control program should ensure the complete reestablishment of the full surveillance operation, with voluntary collaborators, field staff and health services. This will entail the provisioning of adequate supplies of antimalarial drugs for both prophylaxis and case treatment.

Epidemiological and entomological vigilance should be intensified and pertinent data should be displayed on a large, schematic map which usually facilitates the assessment of areas that require priority attention. The extent and the distribution of both confirmed and suspected cases of malaria should be shown. The major agricultural growing area, and the areas of high-risk of disease transmission should be delineated according to three factors. These are the size and distribution of vector populations, increases of larval breeding sites, and the presence of potential disease reservoirs.

The epidemiologist should meet with members of the program's vector control and entomology staff to study the increases that may have occurred in malaria infections and changes in vector population densities.

Entomological Surveillance

Entomological surveillance in malaria control programs has not historically received adequate attention. The entomological surveillance system will thus probably be less effective after a natural disaster than the epidemiological system. However, vector control personnel may have been involved in the evaluation of antivectorial measures and may have valuable information about the insecticides and the vectors. Specifically, they may know about the state of insecticide susceptibility, duration of residual effect, and spraying cycles. Concerning the vectors, they may have information about the delimitation of seasonal and geographic aspects of vector influence, the habitats and behavior of primary and secondary vectors, and the vectorial capacity of these mosquitoes.

The foundation of most malaria control programs lies in the activity of vector control personnel. Consequently, it is members of the vector control staff who will have maps, be able to provide up-to-date information about insecticide treatments, and have a thorough knowledge of the communities. They will also know the epidemiological situations (attack, consolidation, and maintenance) of various areas, and thus they make plans for emergency control accordingly.

If there are entomological and vector control personnel available in the malaria program, a postdisaster survey should be taken in the suspect endemic area. The survey should entail gathering the following information from those potential risk areas:

(1) Location of larval site sampling stations, classified according to future productivity of vector species and plotted on contour maps
(2) Adult mosquito densities determined by.
   (a) human and/or animal collections
   (b) resting and/or pyrethrum knockdown collections
   (c) light traps
   (d) other methods of collection that can be undertaken if there is available staff and time and equipment.

(3) Anopheline species determined to be involved in the area and the possible flight ranges from the various breeding sites
(4) History of insecticide treatment, and the results of insecticide susceptibility tests as well as bioassays of the walls of structures that have been treated recently with insecticide.

Once these initial surveys have been completed, permanent study sites can be located in which the monitoring of larval and adult anopheline densities can be continued. Meteorological events in the areas, especially of rainfall, should be recorded. Vector densities should then be compared with changes in these events. The type of agriculture, and human and domestic animal movement into or away from the risk areas should be noted.

Night bait collection of anophelines will be necessary because of their biting habits. This will require overtime work and additional transportation costs for the entomology teams.

In the section of Chapter 5 entitled "Surveillance," a detailed discussion on larval and adult collection methods is presented. Specific points to be considered in anopheline surveys include the following facts:

(1) Not all of the species of anopheline mosquitoes are vectors of malaria
(2) Various anopheline species may have different host preferences
(3) The biting times of the different anopheline species vary
(4) Not all of the anophelines enter light traps
(5) Some anophelines are endophilic, and some are exophilic, while others are both
(6) Flight ranges of the various anophelines are not the same.

A comparison of the findings of geographical reconnaissance and preliminary surveys, and routine surveys in the risk area should give the entomologist information with which to assist the vector control specialists in planning control activities. The basic information to be obtained includes knowledge of the following:

(1) The vectors that are present in the area, and their breeding sites
(2) The seasonal variations and relative densities of the vectors
(3) The vector's host preferences and feeding, flight and resting habits
(4) Susceptibility of vectors to insecticide
(5) The extent of man-host contact
(6) The presence or absence of active malaria transmission

(7) The proper application and current residual effect of insecticides in dwellings, which may be difficult to evaluate if vector control staff members have not kept records of the previous spraying, dates and chemicals applied
(8) Alternate insecticides that are in stock or can be ordered
(9) The local geographical, meteorological and hydrological conditions that determine breeding season and sites.

Anopheline Control

Mason and Cavalié reported (1965) on a malaria epidemic that followed Hurricane Flora in Haiti. They observed that the majority of the population was without shelter or lived in temporary shelters with the maximum exposure to mosquitoes. They also noted an almost complete removal of insecticide coverage in existing houses, and an increase in population movement. In Hurricane David in Dominica in 1979, approximately eighty percent of the roofs were blown off the dwellings, exposing interiors to heavy rainfall. Under such circumstances, there is little likelihood that much residual insecticide will be left on the structures. Factors such as these, as well as potential changes in vector densities, must be considered when control activities are planned.

The control approach to be taken should reflect the influence of such factors as the status of the routine spraying operations, the results of wall bioassays in treated houses, the predisaster malaria situation, and mosquito breeding sites and adult population densities. Housing conditions and human population movements should also be reflected in control measures. Antimalarial drugs will undoubtedly be part of any prevention or control campaign, but only vector control measures will be discussed here.

A basic anopheline control program may consist of the following elements:

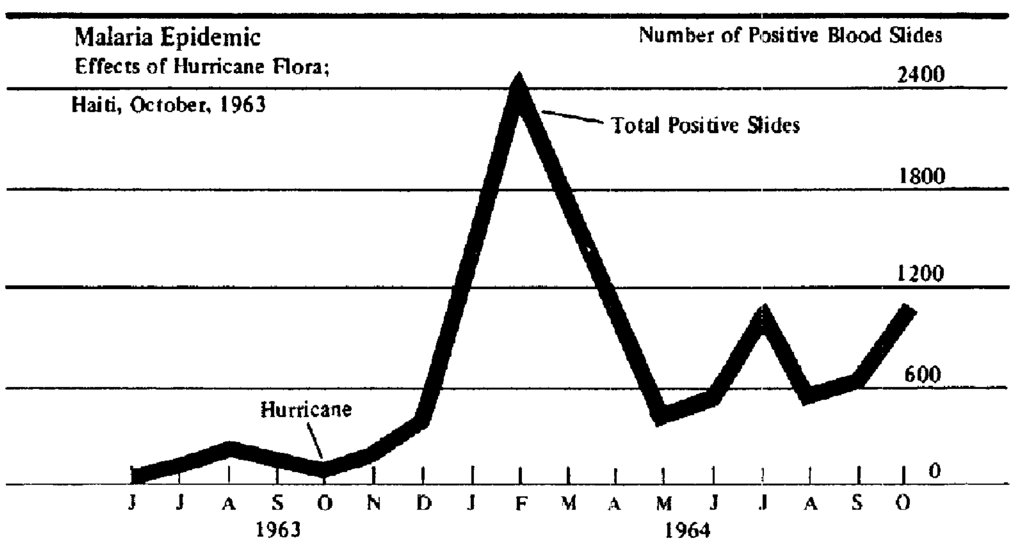
(1) Source reduction, by filling and draining breeding areas
(2) Larval Control through these measures:
  (a) Introduction of larvivorous fish
  (b) Focal treatment of larval habitats with mosquito larvicides
(3) Adult Control through the following:
  (a) Residual applications using hand compression sprayers
  (b) Perifocal treatment in small or isolated areas with knapsack mist blowers
  (c) Peridomestic treatment in large accessible areas with vehicle-mounted aerosol generators
  (d) Aerial dispersal for the control of emergency outbreaks that can not be handled by ground equipment.

Larval Control

In malaria programs larval control measures have generally been taken secondarily to adult control measures. However, if the disaster has taken place in a country in which larval control is practiced, an attempt should be made to reinitiate these measures as soon as possible. The type of larval control measures that should be taken depends upon the breeding sites of the vector involved, and requires entomological guidance.

In areas in which environmental management is used, aerial reconnaissance should provide information about the condition of drainage facilities and standing water, and engineering observations regarding remedial actions. Some work can be started, either manually or with available equipment. However, environmental management is usually slow to initiate and it is too expensive at the start to play more than a superficial role in emergencies.

Biological agents, especially larvivorous fish, have been used in routine larval control. It is possible that these agents will be destroyed or widely dispersed during the disaster, and thus be of little value in control. If these agents have been used, however, their current status should be determined. High-risk areas should be restocked as soon as possible if fish breeding programs are present outside of the disaster area.



Although infectious disease outbreaks do not usually follow upon disaster, the potential for the transmission of vector-borne disease can increase through disruption of vector control efforts in some areas. During the five month period following the hurricane that struck Haiti in 1963, seventy-five thousand cases of *falciparum* malaria occurred.

Chemical control measures are more effective for epidemic conditions. Where larvicides have been applied routinely, their use can be continued if the biology and habitats of the vector warrant it. Insecticide susceptibility should be tested with field-collected larvae before larvicide is ordered or used.

There are various kinds of application equipment that can be used to treat water surfaces. These include hand compression sprayers, orchard and agriculture ground equipment, and aerial spray systems. A different technique and nozzle is used in larviciding with hand sprayers than in residual wall application. Products such as "Tossits," briquetts, and granules can be dispersed by hand.

Besides the more routine organic chemicals, petroleum oil products, non-petroleum monolayers, and insect growth regulators can be used for larval control. Perhaps in the future, bacterial and other biological agents can also be employed.

Adult Control

In emergency situations, adult control is the best approach for suppressing anopheline populations. Most malaria control programs in fact utilize adult control as the basic tool of their mosquito control effort. However, if it is to be effective, the vector must be susceptible to the insecticide used and must come into contact with it. A hand compression sprayer with an appropriate nozzle is the method of choice for residual application of insecticides on the walls of houses and on the other resting sites of anophelines.

The selection of the types of insecticide to use should depend upon entomological information such as the results of susceptibility tests and wall bioassays, and on the availability of the product. In an active malaria program, there is no reason to substitute insecticides or to change the routine approach. Spray teams should enter the area to be treated as soon as possible after a disaster, where they should treat temporary housing, and, when necessary, retreat permanent housing. They should keep abreast of the movement of people and of all new construction. Community involvement should be increased for several months following the disaster.

Wettable powder formulations are usually used in malaria programs. Emulsifiable concentrates can be used in houses with painted walls, where deposits left by wettable powders may be deemed objectionable. After natural disasters, however, the choices are quite often dictated by current availability or the speed of delivery.

Photo J Moquillaza

In Villavicencio, Colombia, a vector control worker obtains a sample of insecticide droplets upon a glass slide. ULV equipment should be calibrated and droplet size determinations made before use. Droplets that are too large or too small waste insecticide.

Space spraying plays a role in control of disease outbreaks beyond that of residual spraying of insecticides on mosquito resting surfaces. In many malaria programs, thermal foggers are used in the consolidation and maintenance phase to spray around houses in which there are active malaria cases. This type of application is usually done at dusk, or immediately before the biting activity of the vectors. Ultra-low volume equipment can be used for the same task. When resting places and principal breeding sites of the vector have been identified, thermal fogging and ultra-low volume application can take place in and around the area. Aerial application of insecticides by ultra-low volume has been successful in use against anopheline mosquitoes in Haiti. (*Am J. Trop. Med. Hyg. 24* (1975): 183-205). In an emergency, these methods can be considered, especially if sufficient ground vector control personnel are otherwise lacking or ineffective.

Special concern should be given to the situation in emergency or refugee camps. The vector control staff should be consulted in the initial stages of planning camp locations, and entomological surveillance performed on a continuing basis. If at all possible, camps should be placed away from vector hazards, such as existing or potential mosquito breeding places. Once the camp sites have been established, attempts should be made to exclude the vector from the habitat of man. Whenever possible, screen windows and doors should be furnished and those individuals who are not protected should be provided mosquito nets and encouraged to use them. If this step cannot be taken, reliance must be placed upon personal prophylactic measures. When breeding places near the camp cannot be drained, they should be treated with oils or larvicides. Insect repellents, such as DEET and pyrethrum coils, can be used on either an individual or a group basis. Regular use of antimalarial drugs should be recommended in malaria endemic areas.

Health education, combined with individual and community involvement, can minimize the effect of an epidemic. Thus, it also makes the work of the vector control staff easier.

Evaluation of Control Measures

No increase of malaria infections, or the rapid, drastic reduction of cases during an emergency are true signs that control measures for malaria are effective. Current epidemiological data should, therefore, be available to guide the activities of control personnel.

Evaluation of the effectiveness of the level of entomological and vector control should take into account the results of bioassaying the walls of structures to ascertain the extent of insecticide coverage and residual activity. The number of houses sprayed, not sprayed and refusals, must also be recorded, and the current status of susceptibility of vectors to insecticides needs to be evaluated.