Emergency Vector Control after Natural Disaster

Study Guide and Course Text
Emergency Vector Control after Natural Disaster

A Study Guide for C280-BC10

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To be used in conjunction with
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This Study Guide is one in a series of five prepared by the University of Wisconsin-Extension, Department of Engineering and Applied Science, Disaster Management Center with financial support from the Pan American Health Organization (PAHO). This self-study series is designed to use scientific publications of the Pan American Health Organization as texts for the study of health-related issues in disaster management. Each module of the series includes a PAHO text, a study guide, pretest, self-assessment tests and a final examination.

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Foreward

In the event of a natural disaster, a nation, region, community or individual will return to normal more quickly if there has been advance planning on the use of available resources.

A plan to mobilize a country’s resources for disaster management is a complex undertaking, as illustrated below.

The health sector must cooperate with other groups involved in the overall plan. In addition, they must work within the framework and priorities established by those in higher authority. Within the overall plan is a section dealing specifically with health and subplans for various units of the health sector. (See illustration.)

Organization of a National Emergency Committee

![Diagram of Organization of a National Emergency Committee]

Coordination of Health Relief Activities

* NGO = Nongovernmental organizations (also called voluntary agencies)
Introduction

How To Get Started

This self-study course is designed to assist those responsible for health to meet the needs of people experiencing a sudden natural disaster. It is designed for health professionals and paraprofessionals and those in training, as well as public health officials. It will also serve as a basic review for entomologists, sanitarians, epidemiologists, and vector control specialists.

This course provides detailed basic information about vector control, and how those principles and procedures can be applied after sudden natural disasters such as destructive storms, earthquakes, volcanic eruptions and sea surges.

The course is based on the scientific publication, *Emergency Vector Control after Natural Disaster*, published by the Pan American Health Organization, with supplementary materials from numerous other sources.

The procedure of self-study is:

- Complete and score the pretest. Do not be disappointed if you had a low score. If you had a high score, you probably do not need this course.

- Read the outline of course content, to get a general idea of what is covered in the course.

- Read the learning objectives to get a general idea of what you are expected to learn from the course.

**Turn to Lesson 1: The General Problem.**

- Review the study guide, receive a brief description of the lesson and any special suggestions on how to study.
- Again read the learning objectives.
- Carry out the learning activities listed.
- Complete the self-assessment test at the end of the lesson and score it using the answer key provided. If you have not answered most of the questions correctly, re-study the module.

**If you score well on the self-assessment test, proceed to Lesson 2.**

Continue to study each lesson, and complete the self-assessment test until you have finished the course of study.

Complete the final examination and disaster development problem and return them for scoring. They will be returned to you.
Pretest

Multiple Choice
Circle the correct answer(s):

1. Which of the following determine areas to receive vector control efforts?
   a. recent history of disease transmission
   b. relative density of potential disease vectors
   c. significant increases in new breeding sites
   d. all of the above

2. Which of the following is usually not defined in a contingency plan?
   a. who will be involved
   b. where personnel will be based
   c. when to begin activities (surveillance, prevention, control)
   d. what these activities will be
   e. how they will be done with available resources

3. Disasters may increase transmission of diseases through:
   a. altering the distribution of vector species
   b. disrupting routine vector control programs
   c. causing increase in the movement of population
   d. all of the above

4. Which of the following is not a good method for collecting adult mosquitoes?
   a. dipper collections
   b. animal bait traps
   c. landing/biting collections
   d. window traps

5. For malaria control during an emergency, which of the following should not have priority?
   a. epidemiological surveillance
   b. chemoprophylaxis
   c. case detection
   d. Culex larval and adult control

True/False
Indicate T or F:

8. Hurricanes and earthquakes cause the same kind of vector- and rodent-related problems.
9. Vector control specialists have little to do immediately following a disaster since problems in their field arise much later.
10. Private firms should not be included in a vector control contingency plan since they are much the same worldwide.
11. In evaluating emergency adulticidal action, larval surveys will show little or no immediate response.
12. Aedes aegypti is the vector of dengue and breeds largely in artificial containers in and around human dwellings.
13. Since Aedes aegypti fly for only short distances, it is not necessary to survey roadsides or vacant lots.
14. The adult Anopheles mosquito deposits its eggs in clumps in polluted water.
15. Paddles used in ovitraps are usually changed daily.
16. In areas of high risk for disease transmission, the epidemiologist must consider the size and distribution of vector populations, increases of larval breeding sites and the presence of potential disease reservoirs.
17. In emergency situations, adult control is the best method for suppressing anopheline mosquito populations.
18. 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.
19. The Breteau Index is the percentage of houses examined and found positive for Aedes aegypti adults.
20. In evaluating a malaria control program, a decrease in human cases is a better measure than changes in the mosquito populations.
21. Dengue, jungle yellow fever and eastern equine encephalitis are important diseases transmitted by *Aedes aegypti*.

22. Sewage effluents, swamps, irrigation wastes and rock holes may be breeding sites for pest mosquitoes.

23. The common name for *Rattus norvegicus* is the roof rat.

24. To control body lice in an emergency, the method of choice is mass delousing of the population with insecticide dust.

25. Red squill is less effective against the Norway rat than the roof rat.

26. Active fly control measures are usually included in most vector control programs.

27. The most important diseases transmitted by fleas are plague and murine (endemic) typhus.

28. In dealing with synanthropic flies, prevention is recommended over control.

29. Flies may mechanically contaminate food and drink with pathogens on their legs, body, and proboscis.

30. Pest control operators may be an excellent source of assistance in rodent and fly control.

31. Do not apply DDT or lindane to cats or puppies.

32. Since space sprays have long-lasting effects on flies, monthly treatments should be sufficient.

33. Rodents are reservoirs of rabies, spotted fevers, and rickettsial pox.

34. All pesticides are toxic to some forms of life and to some biological systems.

35. One of the first steps in evaluation of a control program is to determine if the measure selected is correct.

36. During outbreaks of epidemic diseases, larvicides are more effective than adulticides.

37. Vector control is traditionally a vertically structured operation with lines of authority extending from the parent ministry to the community level.

38. In planning basic strategy for an Integrated Pest Management (IPM) program, a choice must be made between residual or transient insecticide treatments.

39. Political endorsement is not of major importance for a vector control program if it is well planned and adequately funded.

40. The surveillance system required following a sudden natural disaster is usually quite different from an on-going surveillance system.

41. Since a number of control measures involve community participation, the community can also play a role in surveillance and evaluation.

42. Personnel involved in collecting survey samples in the field require extensive training.

43. In an emergency vector control program the best pesticide to use is the one normally used in agricultural spraying in the area involved.

44. A major problem in field operations for a vector control program is ensuring a constant flow of information to the statistics and evaluation unit and feedback of analysis to those in the field.

**Answer Key**

<table>
<thead>
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<th>1. d</th>
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Outline of content

**Module I - Disaster Preparedness**
Lesson 1 - The General Problem
Lesson 2 - Contingency Plans
Lesson 3 - Postdisaster Action
Lesson 4 - Vector-and Rodent-Related Diseases

**Module II - Control Measures for Specific Vectors**
Lesson 5 - *Aedes aegypti*
Lesson 6 - Anopheline Vectors
Lesson 7 - *Culex quinquefasciatus* and Other Pest Mosquitoes
Lesson 8 - Synanthropic Flies
Lesson 9 - Other Vectors
Lesson 10 - Rodents

**Module III - General Control Action**
Lesson 11 - Program Management
Lesson 12 - Epidemiology and Vector Control
Lesson 13 - Pesticides and Application Equipment
Lesson 14 - Surveillance and Evaluation Course Objectives

Course objectives

**Module I - Disaster Preparedness**

**Lesson 1 - The General Problem**
- Appreciate the value of predisaster planning.
- List five ways in which environmental changes due to natural disaster may increase transmission of endemic diseases.
- Describe the types of professions involved in contingency planning for vector control.

**Lesson 2 - Contingency Plans**
- List the three steps in developing a vector control contingency plan.
- List the five types of current information required for an effective vector control program.

**Lesson 3 - Postdisaster Action**
- Be aware of actions that should be taken following all disasters, and specific actions required after certain types of disasters.
- Be able to set priorities for implementing control efforts, using the established criteria.

**Lesson 4 - Vector- and Rodent-Related Diseases**
- Be aware of the variety of vector borne diseases that may be the delayed effect of natural disasters.
Module II - Control Measures for Specific Vectors

Lesson 5 - Aedes aegypti
- Know the various surveillance methods used to measure larval and adult populations, and the advantages and limitations of each.
- Know the control methods available, and the advantages and limitations of each.
- Understand the importance of evaluation of control methods.

Lesson 6 - Anopheline Vectors
- Be aware of the special problems that may require upgrading of normal malaria surveillance following a disaster.
- Know the factors that affect the control approach to be taken following a disaster.
- List the three elements of a basic anopheline control program.
- Realize the importance of evaluating control measures.

Lesson 7 - Culex quinquefasciatus and Other Pest Mosquitoes
- Describe the various methods available to collect mosquitoes.
- Know the control measures appropriate for Culex quinquefasciatus.

Lesson 8 - Synanthropic Flies
- Identify problems related to increases in synanthropic flies following a disaster.
- Describe surveillance and survey methods for synanthropic flies.
- Specify principles for fly prevention and control and ways in which control measures can be evaluated.

Lesson 9 - Other Vectors
- Identify the role of other arthropods in producing disease and related problems following natural disaster.
- Understand the importance of general sanitation and health education in prevention.
- List possible control measures for these arthropods.

Lesson 10 - Rodents
- Identify the major species of commensal rodents.
- List the four most important infectious diseases that they transmit to people.
- Outline simple methods of surveying rodent populations.
- List measures used for prevention and control of rodents.

Module III - General Control Action

Lesson 11 - Program Management
- Understand the decision-making process involved in developing a control program.
- Chart the organizational structure of a control program.
- Chart the organizational structure of the survey and control functions of a field operations plan.
- Be aware of the choices available in techniques and insecticides when implementing a vector control program.
Module I - Disaster Preparedness

Lesson 1 – The General Problem

Study Guide
This introductory lesson points out the value of a flexible contingency plan to control the risks of vector-borne disease following a natural disaster. It lists ways in which changes in the environment may increase transmission of diseases that already exist in the region affected.

Learning Objectives
• Appreciate the value of predisaster planning.
• List five ways in which environmental changes due to natural disaster may increase transmission of endemic diseases.
• Describe the types of professions involved in contingency planning for vector control.

Learning Activities
Read pages 3-6 in the manual. Read the summary in this lesson.

Evaluation
Complete the self-assessment test.

Notes
Lesson 1 Summary
We think of most natural disasters as sudden happenings that cause social disruption and possible outbreaks of epidemic disease and famine. The consequences by type of disasters are as follows:

<table>
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<tr>
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<th>Volcanic Eruptions</th>
<th>Tsunamis (sea surges)</th>
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<tr>
<td>• Destructive winds</td>
<td>• Earthquake (and its consequences)</td>
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<td>• Heavy rains</td>
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Each natural disaster may cause certain types of vector and reservoir host problems. But disasters do not generate new diseases.

Among the effects of natural disasters that can contribute to the occurrence of vector and pest problems are:
- proliferation of vector breeding sites
- increase in human vector contacts
- disruption of vector-borne disease control programs
- disruption of water supply and solid-liquid waste disposal
- disruption of basic hearth services

Vector control is seldom a health priority immediately following a natural disaster. Proper planning at that time may control disaster-related increases of vector-borne disease. It is important that health authorities bring in malaria or other vector control staff to be part of any team to plan postdisaster strategies.

Some potential problems to consider if the disease is endemic in the area or known to exist in close proximity are:

**Malaria**
- increase of available breeding sites (ground pools, etc.)
- displacement of human populations
- parasite activity

**Yellow Fever - Dengue**
- increase of available breeding sites (water storage)
- displacement of human population
current viral activity

**Arboviruses**
- as with dengue

**Pediculosis**
- overcrowding
- lice present
- unsanitary facilities

**Plague**
- crowding
- unhygienic conditions
- ineffective rodent control

**Leptospirosis**
- contamination of food
- ineffective rodent control
- contaminated water

**Salmonellosis**
- overcrowding
- contamination of food
- ineffective rodent and fly control

**Typhus Fever (Endemic Louse-Borne)**
- crowding
- unhygienic conditions
- ineffective rodent control (in some cases)

Many of the above listed diseases have occurred in disaster situations, but the potential may be unknown or rare. As mentioned the pathogen must be already present in the environment. The disaster produces ecological changes that may increase the risk of the disease. Therefore, vector surveillance will be an important function of a vector control service following a disaster.

It is recommended that countries have a national emergency committee or civil defense agency to plan for mobilization of resources after a natural emergency. This allows for a single agency to direct the operation in accordance to existing legislation. Usually a number of governmental and nongovernmental agencies are involved. A health coordinator should have membership in the committee and the coordinator should be the single focal point for the health sector. This coordinator should establish a health relief committee on which vector control is represented.

Vector control may overlap other activities such as environmental health and epidemiologic surveillance. Consequently, besides entomologists and vector control specialists, health administrators, sanitarians, sanitary engineers, and epidemiologists may be involved in vector surveillance and control. Many aspects of vector control lend themselves to community participation. To enhance the role of the community, health or sanitary educators will have an important function.
Lesson 1 - Self-assessment test

True/False

Indicate T or F:

_____ 1. Disaster may increase transmission of diseases by altering the distribution of vector species.

_____ 2. Vector control specialists function quite independently after a disaster since their responsibilities are very different from those of other health personnel.

_____ 3. Having people in camps following a disaster makes vector surveillance and control easier because it concentrates the risks in a small area.

_____ 4. With effective predisaster planning it is possible to predict future vector control needs very accurately.

_____ 5. Vector control has a low priority immediately following a disaster.


Answer Key

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Lesson 2 - Contingency Plans

Study Guide

As part of predisaster planning, a vector control subcommittee with updated information and the power to act when necessary is important. This lesson lists the types of information an ongoing vector control program requires to function effectively after a disaster.

Learning Objectives
• List the three steps in developing a vector control contingency plan.
• List the five types of current information required for an effective vector control program.

Learning Activities.
• Read pages 7-9 in the manual.
• Read "Emergency Vector Control Procedures for the Americas," in this lesson.
• Read the summary on page 14 of this study guide.

Evaluation

Complete the self-assessment test.

Notes
Supplementary reading
The following report does not involve a sudden natural disaster, but describes how a country or region can prepare to cope with the danger of vector-borne disease.


Introduction
Although this communication deals mainly with yellow fever and dengue and in particular with Aedes aegypti, the methodologies discussed apply equally well to the emergency control of other Diptera, especially in urban situations.

The aim of emergency control is to kill as many of the vectors as quickly as possible and, by reducing their density, to interrupt transmission and break the epidemic. In the case of yellow fever, vector control also buys the time needed for an area-wide immunization program, and therefore should be continued for at least ten days after the administration of vaccine.

The essence of emergency control is speed, thus the main thrust of the reaction is directed against the adult mosquito, and not to the more time-consuming and expensive methods of larvicidal control. Similarly, the emergency campaign should be planned and directed by a central command formed by a multidisciplinary council endowed with wide-ranging powers for the duration of the epidemic, as would be the case in times of natural disaster.

The C. V. E.
Each country should give careful consideration to enacting legislation towards the creation of a national "Committee for the Prevention and Management of Vector-borne Emergencies" (C.V.E.), which should enjoy the wide-ranging powers of, and be affiliated to, the national disaster committee.

Ideally this will be a small multidisciplinary executive committee with key representation from the government, armed forces (air), private sector and international aid. selection would be based on professional training and/or management of plant used for insect control sensu Latu (e.g. agriculture, banana growers, etc.) plus senior representatives from the Ministry of Finance and international aid organizations.

This standing committee should be directly responsible to the high-level governmental office both during and between emergencies and should have the legal power to co-opt both temporary members as needed, and stocks and equipment during an emergency.

Terms of Reference
Broadly speaking, these should be:

1. The C.V.E. will formulate a master plan for emergency vector control in their country.
2. Detailed plans and logistics will be prepared for each city and for rural situations. If the disease is not endemic, priority will be given to international points of entry and if it is endemic priority will be assigned to known and potential risk areas.
3. The C.V.E. should institute and keep updated an inventory of national resources for vector control, available from both government and private sectors.
4. In the light of number 3 above, they should prepare lists of equipment needed, but unavailable, that will have to be found outside the country in the event of an epidemic.
5. The professional manpower resources should be examined, and suitable training of nationals initiated.

6. The epidemiological and vector status of the country must be constantly monitored, in order to determine the state of permissiveness to vector-borne diseases, and to identify the course of any unseasonal rises of unexplained ailments. To cope effectively with this most important function, all hospital returns, sentinel physician reports and vector density and distribution survey summaries will have to be sent to the committee each month and displayed in the committee’s office in tabular or graphic form. The more background data (yearly records) the easier it will be to detect abnormal changes in disease and vector density patterns.

7. The identification of gaps in local knowledge, and arrangements for their investigation.

8. The dissemination of incoming epidemiological intelligence, which may threaten the region and the country, to medical and vector control authorities.

9. The identification of ecologically important areas of the country, assigning to them surveillance priorities, in terms of transmission potential, and to allow for these sensitive areas in planning under numbers 1 and 2 above.

10. The preparation of a graded warning system which will trigger an escalating response depending on the gravity of the situation and advising the appropriate officials when such emergency thresholds are reached.

11. Following number 10 above, the C.V.E. will assume the sole direction in initiating and directing countermeasures to the emergency, until the epidemic is arrested, at which time it will resume its monitoring and planning function, updating and improving plans in the light of this recent experience.

When to Declare an Emergency

To a large extent this will depend on the availability of sophisticated diagnostic facilities within the country, and is basically left to the consideration and decision of the C.V.E. of each country (see number 10 above). However, it should not be based only on laboratory-provided, indigenous cases as this may cause long delays.

Obviously if an epidemic is in the region, and vector densities in any country are high and receptive to its transmission, the C.V.E. should act on clinical parameters only, i.e. hospital and sentinel physician returns, morbidity in armed forces, usual rises in absenteeism in schools, etc. However, for this reason the emergency response should be graded by increasing the tactical use of the control techniques according to an escalating strategic plan, and not on the all or nothing principle.

For example, one can envisage a graded alert, as follows:

**Condition Amber.** Epidemic in the region; local vector populations highly permissive. Response: mobilize equipment and manpower, alert physicians and make the threatening disease notifiable. Arrange for the initial release of emergency funds; purchase basic stocks of insecticides. Discuss material and manpower aid that might be needed with international organizations. Notify travellers coming from infected area to report any sickness immediately and treat “sick” houses and their environs with residual and space sprays.

Institute source reduction and other campaigns to reduce vector density in the most receptive areas. Advise the public through the media of the dangers and preventative counter measures.
**Condition Orange.** Introduced cases increasing, and too scattered to be treated as single foci. Initiate preventative area-wide treatment to cover the distribution of these foci and that of the most receptive urban areas, i.e. high density, low socio-economic levels or other risk parameters.

**Condition Red.** Indigenous transmission occurring as proved by history of patients' movements; earlier cases now proved by laboratory diagnosis.

Consider spraying the whole city or area on a cycle related to the life cycle and density of the vector until morbidity figures decline radically. In the latter, allow for latency in interpreting results.

**Lesson 2 - Summary**
Natural disasters frequently produce conflicts of interest, confusion and exaggerated reporting. To alleviate some of this, a clearly defined strategy and plan of action is needed. One of the most important steps in formulating such a plan is to have objectives that face the reality of the situation. These should include defining the population and area affected, identifying the needs associated with the disaster and identifying the potential vector and pest problems. Chapter 2 in the manual outlines the information that should be kept current.

In Lesson 1 it was noted that several factors are at work in determining the potential of vector-borne disease transmission. Although it was emphasized that there is little risk of a disease occurring when the causative organism is not present, many vector-borne diseases are not reportable and national health authorities may lack information on these disasters.

Two major factors may be at play following a natural disaster. One is the creation of ecological conditions conducive to increased arthropod breeding and the other is population displacement, frequently to places of substandard sanitary conditions and overcrowding. The first factor must be considered by the vector control specialist on establishing surveillance and control measures. Population displacement will be an intersectorial problem and will require close coordination with other health groups. These and other factors require a degree of flexibility that may be difficult to achieve within the framework of vector control services, and special training and planning will be necessary.

In developing a vector control contingency plan, three steps are necessary. The first is the state of readiness of the control service. A country or a geographical area is usually subjected to known types of disasters, for example the Caribbean area will have hurricanes with flood and wind damage whereas parts of Central and South America will be in an earthquake belt. Thus, the state of preparedness would consider those disasters in planning. Most vector control services function against only a few major vectors such as *Aedes aegypti* (dengue/yellow fever) or *Anopheles* sp. (malaria). Planning would be directed towards the potential risk from these vectors.

The second step would be evaluation of the situation at the time of the disaster. Vector control will not be a priority at that time but an assessment of the condition and availability of insecticides and equipment is essential at that time.

The third step is the surveillance of the consequences of the disaster on vector populations and taking measures to reduce these populations or reducing human-vector contact.
A contingency plan should be frequently revised especially in areas of high risk and as practical experience demonstrates the need. The plan should define who will be involved, the focal points and chain of command. It should provide guidelines on when to begin the activities of surveillance, prevention and control, what these activities will consist of and how they will be done with the resources available. The plan should not be complicated by details as this leads to inflexibility of operation. However, the various responses needed should be recognized and considered. Finally the plan should be circulated and discussed so the individual roles are understood. To meet this goal simulated exercises should be held to test the plan.

The coordinator should update the information constantly, including names, addresses, titles, and telephone numbers of key contacts in other units of the national emergency committee and within the vector control service. Supply inventories should be kept current as well as epidemiological statistics.

Lesson 2 - Self-assessment test
True/False
Indicate T or F:

_____ 1. Predisaster statistics are usually of little value since so many conditions will have changed because of the disaster.

_____ 2. Most existing vector control services function against a wide variety of vectors in their normal operations.

_____ 3. Inventories of insecticides should be listed for each vector that may become a problem following a disaster.

_____ 4. Vector control contingency plans are all quite similar since the risks involved are much the same worldwide.

_____ 5. A first step in vector control immediately following a disaster is to assess the condition and availability of insecticides and equipment.

_____ 6. Rehearsals of disaster contingency plans by vector control personnel are not practical since it is impossible to predict conditions following a disaster.

Answer Key
1. False
2. False
3. True
4. False
5. True
6. False
Lesson 3 - Postdisaster Action

Study Guide
While there are problems common to most disasters, there are specific steps to be taken after water-related disasters, and others after earthquakes and volcanic eruptions. There are also criteria for establishing priorities in implementing control efforts. Finally, the importance of early response to potential problems is stressed.

Learning Objectives
• Be aware of actions that should be taken following all disasters, and specific actions required after certain types of disasters.
• Be able to set priorities for implementing control efforts, using the established criteria.

Learning Activities
Read pages 11-15 in the manual. Read the summary in this lesson.

Evaluation
Complete the self-assessment test.

Notes
Summary
Following a natural disaster a contingency plan should be put into action. The vector control coordinator will rely on the health relief coordinator and the health relief committee for direction in mobilization. Aerial surveys will assist in estimating the extent of damage and delineating affected areas. If aerial photographs are taken they will provide guidance in planning the next steps.

Of major importance is restoring the normal vector control activities in the affected areas. The epidemiology service will be organizing and strengthening their disease-reporting system, and surveillance activities should be linked with the surveillance activities of vector control. In programs like malaria, epidemiology and vector control already have an established system of cooperation. However, in some of the vector-borne problems associated with overcrowding and unsanitary conditions such a system may not exist.

In many cases, especially in urban areas several different agencies may be involved in vector-pest-rodent control. Care should be taken to avoid duplication of efforts. Other agencies may be indirectly associated with vector control such as those that function in the re-establishment of a water supply and environmental sanitation, as well as those working to accommodate displaced persons.

Chapter 3 of the manual outlines the actions to be taken in vector surveillance and control. Emergency measures to control vectors should be enforced with environmental control activities, such as improved sanitation, when possible. This will include clean up and disposal of debris and solid waste, storage of foods to reduce contact with rodents and flies and storage of potable water in closed containers. In certain vector-borne diseases other health measures such as chemoprophylactic drugs for malaria control may be considered.

Where shelter has been destroyed and it is necessary to provide temporary public shelter, special precautions must be taken against many vectors and other insects that are normally not a public health problem (see Lessons 9-10). Whenever possible the deliberate creation of settlements should be avoided. When such camps are necessary, vector control personnel should be consulted on site selection and settlement design. It should be noted that regardless of all precautions taken in providing sanitary temporary housing, there is always the likelihood of an outbreak of a vector-borne disease among crowded populations. Thus continued surveillance by all the health authorities involved and a good sanitary education program are important.

It will not be possible to provide complete control against rodents, flies and other pest insects following a disaster. However, attempts should be made to hold the population to a level acceptable to the people.

The migration of people may affect the direction that emergency vector control measures take. When a susceptible population moves into a situation where the disease is endemic, for example a rural population into an urban area where dengue is endemic or an urban population into a rural area where malaria is endemic, it may be necessary to increase the vector control effort even though the vector population may remain almost at the predisaster level.

Basic vector control measures may include the following:
1. Maintain good public relations and inform the public about what individuals can do to protect themselves against vector-borne disease and to reduce breeding sites.

2. Maintain adequate surveillance including vector density and distribution surveys and monitor closely all high-risk areas.

3. Resume all routine control measures and where needed use residual spraying and emergency measures such as space spraying.

4. Eliminate or reduce breeding sites of mosquitoes and other Diptera through integrated control, especially source reduction.

5. In areas where there is crowding and temporary shelters, establish surveillance for lice, mites and fleas. Dust the population with appropriate insecticides in areas where typhus is known to exist.

Lesson 3 - Self-assessment test

True/False

Indicate T or F:

_______ 1. Rapid response to a potential vector control problem is likely to lead to mistakes and errors in judgment, so action should be delayed until the extent of the problem is known.

_______ 2. Accurate assessment of the vector control situation after a disaster depends greatly on unofficial sources of information.

_______ 3. Migration of people into an area is normally not a problem as long as the vector population is held at the predisaster level.

_______ 4. Geographical and topographical maps assist in reconnaissance after a disaster.

_______ 5. Population movement away from the disaster region reduces the risk of vector-borne disease.

_______ 6. In case of a vector-borne disease outbreak, larval control should have immediate priority over adult control

Answer Key

1. False
2. False
3. False
4. True
5. False
6. False
Lesson 4 - Vector- and Rodent-Related Diseases

Study Guide
It is difficult to assess vector control problems during the immediate period (one to seven days) after impact, with bites and annoyance more prevalent than health problems. However, delayed effects (during the next 30 days or more) can result in a variety of vector-borne diseases.

Learning Objective
Be aware of the variety of vector-borne diseases that may be the delayed effect of natural disasters.

Learning Activities
• Read page 17 in the manual. Study the table on page 18 in the manual.
• Read "Introduction to Arthropods of Public Health Importance" on page 20 of this study guide.
• Read the summary in this lesson.

Evaluation
Complete the self-assessment test.

Notes
Introduction to Arthropods of Public Health Importance

Excerpted from "Introduction to Arthropods of Public Health Importance", HEW Publication No. (CDC) 79-8139.

**Arthropods and Public Health**

**Introduction**

Arthropods are animals belonging to the major division, or phylum, of the animal kingdom called Arthropoda. All arthropods have jointed legs, the name being derived from the Greek words meaning "jointed feet". Insects make up the largest class of arthropods in number of species and are the arthropods of greatest public health significance. Insects are probably the most successful of all land animals. They are found in the air, in soil, and in fresh and brackish water. Not only do they consume and destroy plant tissues, but some insects live on or inside other animals and readily attack humans. Despite their small size, the combined bulk of insects may equal that of all other land animals and the number of species of true insects described to date numbers more than three quarters of a million.

For centuries humans have fought insects as pests, as carriers of disease, and as destroyers of his food. They cost farmers billions of dollars each year by destroying or decreasing the value of crops; but when the need to control insects is sufficiently urgent and humans have the will to do so, people can keep them under reasonable control. Flies, fleas, lice, and mosquitoes infect humans and domestic animals directly or indirectly with the organisms of many dangerous and debilitating diseases. Vector-borne diseases such as malaria, typhus, and plague have had profound effects upon humans throughout history.

![Diagram of effect of environmental factors on the three primary living elements and an incidental host in a vector-borne disease.](image)

**Figure 1**: Diagram of effect of environmental factors on the three primary living elements and an incidental host in a vector-borne disease.

The arthropods affect human health in many ways. One way of visualizing these health-related effects is to consider two large groups of diseases or conditions based on the number of living factors involved (Fig. 1).
Diseases Involving Two Primary Living Factors: Host and Parasite

**Arthropods with direct effect on humans**
These conditions, often called diseases, result from the direct effects of the arthropod on humans—not from a virus, bacteria, protozoan, helminth, or fungus normally associated with disease (see Table 1).

Examples are entomophobia, pediculosis, scabies, myiasis, arthropod bites and stings, allergy and anaphylactic shock.

<table>
<thead>
<tr>
<th>Type of Host</th>
<th>Malaria</th>
<th>Filariasis</th>
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<tr>
<td>Primary (definitive)</td>
<td>Mosquito</td>
<td>Human</td>
</tr>
<tr>
<td>Secondary (intermediate)</td>
<td>Human</td>
<td>Mosquito</td>
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</table>

Table 1: Host relationships in two mosquito-borne diseases.

**Entomophobia (fear of insects).** Although many arthropod pests do little actual harm except in arousing intense feelings of revulsion in certain people, crawling creatures such as earwigs and cockroaches bother some people so much that they may require medical attention. Intensely personal feeling aroused by real or imagined infestations of insects must be met with care by public health workers, with efforts to eliminate the specific problem or with referral for appropriate medical attention. A moderate feeling of revulsion to insects is of value for it assures the interest of the public in attaining higher standards of personal and premises sanitation.

**Infestation.** Living arthropods may be present on or in the human body: external, as in pediculosis (lousiness); subcutaneous, as in scabies, which is caused by itch mites burrowing under the skin; or internal, as in myiasis. Insects involved in myiasis include the screw-worm larvae of the New and Old World, sheep bot fly larvae and the larvae of the rat-tailed maggots which may accidentally be drunk in dirty water and produce intestinal infestations.

**Diseases Involving Three Primary Living Factors: Host, Parasite and Vector**

**Humans as the principal or only host**
These are typical human diseases in which humans are the normal, often only vertebrate host, and an arthropod is a common, often essential vector of the parasite from one human to another.

Examples are dengue, epidemic typhus, filariasis, malaria, relapsing fever, yellow fever (urban).

**Humans as incidental host**
These are the zoonoses, the diseases of animals transmissible to humans and where the infected animal serves as the reservoir host of the pathogens. While a person is often an accidental and dead-end secondary host of essential wild-animal diseases, some of these diseases, once they are established in humans, may be transmitted directly from person to person through the same or different vectors.
Examples are African sleeping sickness, Chagas' disease, encephalitis, haemorrhagic fever, leishmaniasis, murine typhus, plague, relapsing fever, scrub typhus, tularemia, yellow fever (jungle).

**Bites and Stings of Arthropods.** Almost everyone has been bitten or stung by insects, and in small numbers insect bites are of little significance. However, when a person is repeatedly bitten by mosquitoes, flies, fleas, bedbugs, ticks, chiggers, or punkies, his/her body may react to the foreign protein and severe illness may result.

Spiders related to the notorious black widow spider in the genus *Latrodectus* are found on every continent. Their bites, which in many instances have caused death, should always be considered serious. A number of other species of spiders inject a toxin that can cause tissue necrosis and may even cause death.

Scorpions have a stinger at the end of their body which they normally use to subdue their prey, such as cockroaches and spiders. The sting of some scorpions is comparatively harmless, while other species have a dangerous sting that can cause death.

When certain species of ticks remain attached and fed for prolonged periods of time (i.e. 5 days or more) a condition known as tick paralysis may result. This disease is caused by injection of a toxin and may be fatal, especially in children; rapid recovery usually follows removal of the tick.

Honeybees, hornets, and wasps inflict a sting that can be quite painful, but singly or in small numbers these stings have no serious consequences for most people. However, some people who have received 500 or more stings at one time (as when they have knocked over a beehive or stumbled into a hornet's nest) have died in a very short time.

Many insect venoms contain complex protein substances and formic or acetic acid which in most cases cause little reaction. However, a small number of people, perhaps 2%, may become hypersensitive some time after an initial sting or bite. If such people are bitten or stung again by the same species, they may rapidly experience generalized anaphylaxis with difficulty in breathing, swelling of the face and neck as well as at the site of the sting, and shock. Such persons require emergency medical attention as death may occur in minutes.

**Contact Poisons or Irritants.** Some insects, e.g. certain caterpillars and blister beetles, upon contact with human skin secrete or shed materials which cause painful skin irritation including local inflammation and blistering.

**Diseases with Three Living Factors: Host, Parasite and Vector**

In these diseases the arthropod serves as a living vector (Figure 4) carrying the parasite or other disease-causing organism from one host to another, as opposed to the nonliving vehicles (air, water, or food) involved in airborne, water-borne, or food-borne diseases. The vector-borne diseases vary in complexity, mode of transmission and range of vertebrate hosts involved. They are often separated into two large groups according to whether transmission is merely mechanical or whether it involves biological processes. These diseases can also be separated into those which primarily affect humans and those where humans serve as only an occasional or incidental host.
Mechanical Transmission of Disease. Mechanical or passive transmission of disease occurs when an insect transports microorganisms such as dysentery, typhoid, or cholera bacteria on its feet, body hairs, or other surfaces from filth to human food or directly to humans.

Biological Transmission of Disease. Biological transmission of disease occurs when the arthropod not only transmits the microorganisms from one host to another but is essential in the life history of the parasite.

Diseases with Humans as Principal Host
For several of the most widespread and important arthropod-borne diseases affecting humans, people apparently serve as the only natural vertebrate host. These include such diseases as malaria, Bancroftian filariasis, onchocerciasis, and dengue. In other diseases where human-vector-human transmission is characteristic of epidemics, such as epidemic typhus and urban yellow fever, there are additional enzootic cycles which do not normally affect humans. While it would seem likely that vector-borne diseases which involve only humans as a vertebrate host would be more easily controlled, such has not been the case. Some of the most tenacious and widespread diseases, such as malaria, dengue and filariasis, have been extremely difficult to control, despite the absence of significant non-human reservoir hosts.

Diseases with Humans as Incidental Host
In the last half century, studies throughout the world have shown that many cases of human sickness are really accidental and secondary cases of wild-animal diseases. These are the zoonoses, normally diseases of animals which are transmissible to people. Humans have contracted the illness through contact with arthropods that normally feed on wild animals. Frequently the person is a dead-end in the chain of infection, as with many types of mosquito-borne encephalitis. However, in some cases a person who has become infected with yellow fever in the jungle, or plague in a rural area, has travelled to the city for treatment and there has served as the source of infection for an urban epidemic of yellow fever or plague.

The classical studies on yellow fever have clearly demonstrated two epidemiologic types: urban yellow fever, in which a human is the vertebrate host and Aedes aegypti is the vector; and
jungle yellow fever, in which monkeys and other jungle mammals are the normal hosts and "wild" mosquitoes transmit the virus from monkey to monkey, and occasionally, accidentally to humans.

Control of the zoonotic vector-borne diseases has been extremely difficult, since they often affect humans who inhabit the fringes of or invade areas where the disease is common in wild animals and their associated vectors. Often prevention can be achieved by such measures as vaccination (e.g. yellow fever) or personal protection from vector attack with protective clothing or repellents.

Summary
Vector-related diseases usually involve three living entities, the host, the parasite and the vector. Certain of these diseases only involve humans as host (jungle yellow fever, murine typhus, plague other than pneumonic, arthropod-borne encephalitis). In these cases there is a reservoir host involved that allows the parasite to remain active in nature without benefit of humans. Another group of diseases transmitted from animals to humans may or may not involve a vector. In addition, some pathology such as pediculosis, scabies, myiasis, and envenomization may be produced directly by an arthropod. Each disease is controlled by a number of extrinsic and intrinsic conditions. An understanding of these conditions is important in considering the epidemiology of the disease.

The supplementary reading assignment (Introduction to Arthropods of Public Health Importance) provides a summary of many common vector-borne diseases and the vectors involved. It is important to identify correctly the vector species. An expert taxonomist should be consulted in doubtful cases.

Each vector-borne disease is influenced by a number of factors that affect the host-parasite-vector relationship. Natural disasters produce a drastic change in one or more physical factors that influence the population density and distribution of vectors. Some of the physical factors will produce more available breeding sites for the vector such as more pools for pool-breeding anophelines or more water containing artificial receptacles for *Aedes aegypti* or other culicine vectors. Physical factors may tend to congregate reservoir hosts in the same area as humans. The disaster also affects a number of social factors that will either influence the likelihood of the vector or produce epidemiological conditions conducive to the transmission of the vector- or rodent-related disease. Disasters frequently change human population distribution and density, which alters the normal immune-nonimmune ratio of the population. Furthermore, the population change along with the physical destruction of the disaster will alter the quality of life of the individuals. General sanitation, personal cleanliness, housing, diet, etc. will tend to deteriorate.

In *Epidemiologic Surveillance after Natural Disaster* (PAHO Sci. Publ. 420, 1982), the following vector-and rodent-borne diseases are listed for epidemiological considerations:

- Ebola-Marburg Viral Disease
- Haemorrhagic Fevers of Argentinian and Bolivian Types
- Leptospirosis
- Malaria
- Pediculosis
- Plague
- Relapsing Fever (Louse- and Flea-borne)
- Salmonellosis
The list in the manual is more extensive as a number of conditions related to contamination produced by arthropods and rodents are given. Also included are annoyance, arthropod and rodent bites and envenomization. It should be noted that annoyance, bites and envenomization can occur almost anytime and may not be considered as a priority in a vector-control operation. When included it may serve more to provide comfort to the population than to fulfill a medical need.

The most important vector-rodent problems are likely to be the delayed ones that occur in about 30 days or more after the disaster. Many natural disasters, especially those involved in changes of rainfall, initially destroy or flush the normal water breeding site. Time is required for the vector population to recover and expand into new sites produced directly by the disaster or human-made sites resulting in changes of human lifestyle.

Lesson 4 - Self-assessment test

True/False

Indicate T or F:

1. Flies usually transmit disease to humans by mechanical or passive transmission.  
2. Flies and rodent populations may increase due to disruption of sanitary services, increased human crowding and storage of potable water.  
3. Diseases for which humans are the only natural host are the easiest to control.  
4. The immediate effect of many natural disasters is to reduce larval habitats and even reduce adult vector populations.  
5. Diseases for which humans are an incidental host are usually not serious.  
6. Mosquito-borne diseases, especially malaria, dengue, and typhus, cause significant concern after disasters with which heavy rains and floods are associated.

Answer Key

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Module II - Control Measures for Specific Vectors

Lesson 5 - Aedes aegypti

Study Guide
Following a natural disaster, if dengue or yellow fever is endemic and the population density of Aedes aegypti is high, appropriate measures should be taken. This lesson deals with the surveillance, control, and evaluation of such measures.

Learning Objectives
• Know the various surveillance methods used to measure larval and adult populations, and the advantages and limitations involved.
• Know the control methods available, and the advantages and limitations involved.
• Understand the importance of evaluation of control methods.

Learning Activities
Read pages 21-36 in the manual. Read the summary on page 26 of this study guide.

Evaluation
Complete the self-assessment test.

Notes
Summary
The following outline is a suggestion of a plan of action for a dengue epidemic. A number of the points can be adapted for control operations following a natural disaster.

Emergency Control Measures
Emergency vector control may be considered following a natural disaster such as tropical storms and hurricanes or to prevent a possible epidemic of dengue or urban yellow fever in countries infested with *Aedes aegypti*.

For epidemics of *Ae. aegypti*-borne disease, it is advocated that emergency control measures be used in the immediate area, in areas nearby or in the path of a spreading epidemic, especially all points of entry into the country. Most emergency plans aim at producing a rapid reduction of the adult mosquito population and maintaining a low level until the virus disappears from the human population. In most arthropod-borne virus epidemics, there is usually a considerable delay until the virus is identified and an emergency declared. Consequently in the immediate area of the original cases, vector control activities might not be too effective, but nevertheless should be considered.

Although the literature refers to a House (Premises) Index of below 5% as a point in which urban yellow fever no longer is successfully transmitted (the same index has been proposed for dengue), little reliance should be placed upon the index. The index may be outdated, taken at a period of low mosquito density. It may be inaccurate due to inadequate field personnel. It may be an overall figure that does not take into account pockets of high infestation within the area. Vectoral competence may also vary. However, high index areas should be considered as potential risk areas.

Emergency Control Operations
Each country’s control operations for emergency may be unique, requiring a flexible administrative and technical approach to be successful. However, most countries now have some type of administrative structure to handle natural disasters and disease emergencies. Unfortunately, vector control staff frequently are not considered in the administrative structure. In some instances by the time they are consulted, their effectiveness to respond to the situation has been reduced.

The Disaster Committee
Countries with disaster committees should form a vector control and/or a dengue-yellow fever surveillance subcommittee (see Lesson 2). The duties of this subcommittee could be as follows:

1. Develop a general plan of action for emergency vector control.
2. Maintain an updated inventory of national resources for vector control. This information is available from government and private sectors.
3. Establish a system of sentinel physicians and hospitals to report suspect arboviral disease and have a list of national or international diagnostic laboratories with the capacity to make virus isolations and/or serological identification.
4. Maintain an updated registry of professional human resources and initiate training where necessary.
5. Maintain contact with the national vector control program and assure that the vector status is constantly monitored. Identify potential risk areas and assign them surveillance priorities.
6. Disseminate incoming epidemiological information to medical and vector control authorities. This service should include a system for providing accurate information to the public.
The Control Organization Plan of Action

"An ounce of prevention is worth a pound of cure" is very true in vector control. Minor environmental management including adequate sanitary services together with education can maintain a low source of breeding sites for Aedes aegypti. An informed public can assist in producing maximum results in control activity with a minimum of expenditure. Since the goal of each individual country should be to reduce risk of dengue and urban yellow fever, the public should be a vital component in any plan of action. This is well understood in horizontal health programs and should also be incorporated into vertical control activities.

Prevention of arboviral activity through vector control should strive to attain the following:

1. Have a well-trained organization.
2. Establish baseline data (mosquito population, elimarology, serology, morbidity, and mortality).
3. Anticipate requirements and resources.
4. Provide technical and administrative evaluation.
5. Review and replan constantly.
6. Assign responsibilities to an infrastructure adequate to assume them.
7. Provide an adequate procurement and supply mechanism.
8. Manage well.
9. Recognize the role of inflation.
10. Incorporate the general public into the program.

It is recognized that each country will have a different plan of action. The purpose of the following outline of strategies is to call attention to control procedures that have shown success during past epidemics and to provide a logical step approach.

The Strategies

Emergency control is aimed at preventing an arbovirus epidemic or reducing transmission of the virus during the epidemic. In either case the objective is to produce a rapid reduction in the adult mosquito population and maintain it until the virus activity disappears.

There are several levels of cooperation and coordination involved in preparing a strategy aimed at emergency control operations. PAHO on the regional basis functions in the following way:

1. To promote proper vector surveillance and control hopefully to fit local resources and priorities.
2. To provide technical collaboration in specific areas such as laboratory, epidemiology, entomology, and vector control and surveillance.
3. To disseminate information to member countries as it is received and analyzed.
4. To provide laboratory identification and release of information on incidence and virus types.
5. To act as a procurement agent for individual country need, especially insecticides, control supplies and materials.
6. As a liaison with different agencies to promote bilateral and international cooperation, especially for emergency standby.
7. To cooperate in training at a national and multinational level.

It is of prime importance to remember that in the case of dengue, vector control is the only preventive measure available. If cases of dengue are reported from nearby countries, a country should not wait for laboratory confirmation of suspect local cases to implement emergency control measures. There should be some linkage formed between vector control, epidemiology,
laboratory and hospital clinics, and other related disciplines to establish feasible contingency plans.

Vector control activities should begin as soon as possible. The key to effective emergency planning in vector control is prior information obtained through routine entomological surveillance. Any contingency plan must rely on accurate information. This should include the following:

1. Up-to-date street maps showing *Aedes aegypti* positive areas (distribution and density).
2. Grading of larval habitats, their frequency of positivity and adult output.
3. Identification of risk areas, e.g.
   a. *Aedes aegypti* House Index of 5% or above
   b. A low-income community heavily populated and without a domestic water supply
   c. An area with a poor road network and an inadequate solid waste disposal system
   d. All ports of entry where ovitraps or habitat inspections show moderate infestation
4. Record of amount of insecticide, vehicles, supplies, equipment and staff on hand.

**Pre-emergency Control**

Pre-emergency control refers to activities undertaken when epidemiological information from nearby cities or countries indicates that an outbreak of dengue or yellow fever may be imminent.

The following steps should be considered for pre-emergency control:

1. Spot entomological surveys, especially to locate and evaluate risk areas. Once risk areas are known, a more detailed survey should be taken to define the area and the principal breeding sources. One may use past epidemiological data and house indices as a guide.

2. A health education campaign using all available public health information systems should be started. To accomplish any goal the public must be informed properly to cooperate. Radio, television, newspapers, brochures and posters will help but individual contact through schools, churches and community organizations is essential. Status reports of all control activities, dates, and location of teams, home closures, legal measures and premises indices may be used to establish community pride and spirit of competition.

3. Source reduction campaigns. These should begin immediately through community participation and local solid waste disposal services. To be successful the following should be considered:
   a. Information should be available on the major types of breeding sources and whether source reduction would be effective.
   b. An estimation of the amount of solid waste per area of operation to determine the number of vehicles needed.
   c. A sectorial plan to relate vehicles available to amount of solid waste and maps of routes to use.
   d. A public information campaign alerting the population in each sector to the time of pick-up and the responsibilities of the community. It is best for collections to be made on nonwork days.
   e. In some cases legal measures may be necessary to insure adequate source reduction. If operations are to be initiated at the community level, measures should be enacted to insure acceptance of this responsibility.
f. Since garbage and debris accumulates rapidly, it is suggested that routine cleanups on a four- to six-week basis be established during the emergency.

g. Remember that not all breeding habitats are subject to source reduction and that the number of containers of a type do not always indicate importance.

4. Larviciding activity
   a. For domestic water storage containers, use 1% temephos (AbateR) sand granules following an eight- to ten-week treatment cycle.
   b. For nonpotable water treatment, other insecticides (malathion, fenitrothion, propoxur, pirimiphos-methyl, chlorpyrifos, monolayers, biocontrol agents (Bacillus thuringiensis) and proprietary oils) can be used according to directions.
   c. If larviciding activity is in progress, consideration should be given to speeding up operations and/or concentrating activities to cover first the risk areas and ports of entry.
   d. Provisions should be made to evaluate immediately the insecticide operations in risk areas and provide additional applications to missed or Aedes aegypti -infested containers.

5. Adulticiding measures will depend upon:
   a. Location of the epidemic in relation to area or country under potential risk
   b. Number of cases and severity of the disease in the epidemic area
   c. Immune status of population
   d. Availability of equipment and insecticide
   e. Political importance that government gives to the problem

It is suggested that available ground and portable equipment be mobilized to treat risk areas where deemed necessary. Although emphasis is placed upon droplet size and density, these determinations are usually forgotten in an emergency. However, an attempt should be made to check these aspects. Records should be kept on insecticide output per-machine-per-hour of operations for comparison with equipment specification. Entomological evaluations of applications should be made whenever possible. The simplest evaluation would be a comparison of the Ae. aegypti densities before and after application.

It should be emphasized that the public must be kept informed to insure cooperation. There is a need for constant coordination between the epidemiological and vector control services.

**Epidemic Control**

Where dengue or urban yellow fever is present, WHO and neighboring countries should be informed at once. There should be a strengthening of surveillance at ports of entry/exit including larviciding, source reduction, intensified emergency adulticiding and alerting people entering and leaving the endemic area.

One of the major problems associated with arbovirus epidemics has been the nonavailability of functioning equipment. Sufficient equipment is frequently either lacking or inoperable because of faulty maintenance, lack of vehicles, or lack of trained staff.

The current thinking regarding emergency adulticiding is to recommend holding aerial ULV applications as an optional decision for the individual country. If dengue, haemorrhagic fever, or urban yellow fever is present, aerial ULV should be recommended where equipment is available; all other space spray equipment should be utilized immediately.
The following suggestions have been made for space spray operations in an epidemic:

1. One vehicle mounted ULV or thermal fog apparatus can treat approximately 70 city blocks per working day (morning and early evening applications). Coverage will depend upon meteorological conditions, size of equipment and traffic.

2. Portable ULV or thermal fog equipment can be mounted on vehicles to extend street coverage.

3. Street coverage with ULV or thermal fog equipment may not reach all of the resting places of mosquitoes. Some health education will be necessary for the people to cooperate in opening doors and windows during applications (ULV). Because of the nature of the thermal fog, cooperation in allowing the fog to enter the house may be low.

4. Portable ULV equipment may be used to treat inside dwellings. One portable mistblower can treat from 80 to 120 houses per day. This approach, if done correctly, is an extremely effective method of reducing adult density, but it is labor intensive.

5. Space spray cycles are usually seven to ten days. In risk areas, cycles of two to five days would hasten adult mosquito reduction. Applications should continue on schedule until an average collection of one or less adult females per house per hour per person. (Ovitrap or Fay Light Traps may be used when available.)

6. A radius of 300 to 500 meters should be treated around known, introduced cases in the early phase of the epidemic. This is effective only where there is adequate epidemiological surveillance and would not be possible during an intensive epidemic. It should be noted that generally the lag time in reporting cases is such that there is more than ample time for other mosquitoes to become infested, transmit and thus spread the virus to other areas.

7. Special emphasis should be placed on treatment of schools, hospitals, and other community buildings housing high densities of people. These buildings should have screened doors and windows for mosquito proofing. In some cases residual insecticide applications may be used. Mosquito nets could be considered in hospitals. All breeding habitats within or near these institutions should be treated with an insecticide or disposed of as a source reduction measure. Individual protection such as small insecticide aerosol bombs and/or mosquito coils should be encouraged.

8. Measures employed in the pre-epidemic control phase should continue.
Lesson 5 - Self-assessment test

True/False
Indicate T or F:

_____ 1. Using residual sprays to control adult *Aedes aegypti* in dwellings might not be effective since as few as 10 percent of the adults rest on the walls.

_____ 2. Ovitraps can not reflect immediate changes in the adult female *Aedes aegypti* population.

_____ 3. For estimating adult populations of *Aedes aegypti*, landing counts are recommended over resting collections.

_____ 4. The speed and time of application are important when insecticide is applied by a space sprayer mounted on a vehicle.

_____ 5. The primary criterion for evaluation of emergency control measures is whether or not an epidemic is curtailed.

_____ 6. The storage of potable water may increase *Culex quinquefasciatus* breeding more than *Aedes aegypti*.

_____ 7. Ovitraps provide an indirect method of assessing the presence and size of the adult *Aedes aegypti* population after a natural emergency.

_____ 8. Larval *Aedes aegypti* development can be complete in three to four days.

_____ 9. Biting of *Aedes aegypti* usually occurs during, but is not limited to, the night.

_____ 10. All mosquito eggs found on a paddle in an ovitrap might not be *Aedes aegypti*.

_____ 11. The two insecticides that can be used for treating containers holding potable water are temephos and fenthion.

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<td>9. False</td>
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<tr>
<td>10. True</td>
</tr>
<tr>
<td>11. False</td>
</tr>
</tbody>
</table>
Lesson 6 - Anopheline Vectors

Study Guide
If malaria is endemic to an area where a disaster occurs, surveillance can be directed toward detection of human cases or changes in the mosquito population. This lesson describes principles and methods especially important in surveillance and control of anopheline vectors and malarial disease.

Learning Objectives
• Be aware of the special problems that may require upgrading of normal malaria surveillance following a disaster.
• Know the factors that affect the control approach to be taken following a disaster.
• List the three elements of a basic anopheline control program.
• Realize the importance of evaluating control measures.

Learning Activities
• Read pages 37-45 in the manual.
• Read "Malaria Epidemic in Haiti Following a Hurricane" on page 33 of this study guide.
• Read the summary in this lesson.

Evaluation
Complete the self-assessment test.

Notes
Supplementary reading

On the night of October 3-4, 1963, a hurricane (Flora) swept across the southern peninsula of Haiti with devastating effect. In addition to the immediate damage caused by the storm, the area affected suffered a severe malaria epidemic which started approximately two to three months after the hurricane had passed. Since the epidemic occurred during the course of a malaria eradication program in which an extensive surveillance program was being carried out, an opportunity was provided to study its development closely. The following is a description of the outbreak, which is estimated to have caused some 75,000 cases of malaria.

Malaria in Haiti
Malaria in Haiti is mesoendemic and moderately unstable, with seasonal epidemic exacerbations showing a fairly close correlation with alterations in rainfall. Comparatively high blood slide positivity rates (31 %) were seen in survey of school children carried out in 1940-1942 by Paul and Bellerive of the Rockefeller Foundation. At that time 88% of the infections were caused by *Plasmodium falciparum*, 10% by *P. malariae* and 2% by *P. vivax*.

The principal vector is *Anopheles albimanus*, which is the main vector in the Carribbean and Central American region. *A. albimanus* is primarily a coastal mosquito, although it is readily found inland if conditions are suitable. It is largely non-domestic and zoophilic, but bites humans and will enter houses. Reported sporozoite rates are low, below 0.6% according to MacDonald. On the basis of epidemiological surveys, malaria transmission in Haiti is considered to be found mainly in areas under 500 meters altitude.

The rainy season in the area usually starts in late March or early April. The rainfall rises to a peak in May, with a secondary peak in August or September, and then begins to drop in October, November and December (Fig. 1). Although there is considerable fluctuation in rainfall from month to month and from season to season, some mosquito breeding continues, even during the driest seasons.

A number of blood parasite surveys carried out in 1960 and 1961 in the area later affected by the hurricane showed parasite rates ranging from 17% to 32%. Annual parasitological surveys were started in January 1962 when the malaria eradication spraying program was initiated. Rates of 10% were seen in 1962 in index localities in the hurricane zone. By January 1963, the rate had dropped to 0.8% in the same area, but the rates in January 1964 had increased to 17%.
The Haiti Malaria Eradication Program
The malaria eradication program in Haiti was started in March 1961. The preparatory phase activities were carried out from May to December 1961 and the first cycle of spraying of houses with DDT at a dosage of two grams technical grade per square meter was started in January 1962. Spraying was limited to localities under 500 meter altitude and was carried out in six-month cycles. About 50% of the fourth cycle had been completed when the hurricane struck.

The surveillance program was started in June 1962, five months after initiation of the spraying operations. By October 1, 1963, some 100 voluntary collaborator posts were in operation in the area affected by the hurricane. These were being visited monthly by eight malaria service case finders, who also collected blood slides, primarily from fever cases, in localities along the route from one collaborator post to the next. Both collaborators and case finders in Haiti provide single doses of chloroquine to all fever cases from whom blood slides are obtained.

Area Affected by the Hurricane
The cyclone crossed the mid-section of the southern peninsula of Haiti, directly affecting an area of some 2,200 square kilometers. This area is made up of two coastal plains separated by a discontinuous chain of mountains in the interior, which reach an altitude of 1,200 meters. The main resources of the region are coffee and sisal cultivation. Small scale farming of bananas, corn millet, and red beans is carried on for family use. Some 520,000 persons live in the affected area. The region is densely populated, averaging some 250 persons per square kilometer. The highest densities are found on the coastal plains, where certain sections have more than 350 persons per square kilometer. The population is primarily rural. There are few urban centers and these contain only about 10% of the total population. Practically 100% of the population is of the Negro race.

The houses in the rural areas are of the type of construction commonly found in Haiti: walls made up of a base of woven wooden strips, covered with mud, and a thatch roof made of palm
leaves or straw. The houses are quite small, approximately 9 feet by 19 feet, with the sprayable wall surface averaging about 100 square meters. There is an average of 2.5 persons per house.

**Description of the Hurricane**
The hurricane was reported for the first time off the coast of Venezuela on September 30, 1963. The storm touched the southern peninsula of Haiti about 5:00 p.m. on October 3, and reached its maximum intensity in the interior about 8:00 p.m., with winds up to 250 kilometers per hour. It had completely passed over the peninsula by midnight that same night.

Flown over at a low altitude, the area presented a picture of total destruction and desolation. Almost all the houses were completely demolished. The first estimate of actual damage, which could never be completely verified, was that there had been some 4,000 to 5,000 deaths. Some 200,000 persons were without any shelter and crops not yet harvested had been destroyed.

In addition to the actual damage from winds, considerable damage was caused by floods following the storm. There were actually two distinct periods of heavy rainfall, one immediately related to the passage of the cyclone on October 3 and 4, and a second period on October 8, occasioned by the passage of the hurricane to the north of Haiti.

The second period of rainfall was less intense than the first, but because of the highly saturated condition of the soil from the first heavy rains, the second period of rains caused even heavier flooding. Many of the river courses had been blocked by fallen trees and impacted debris, mud and stones, causing diversion of the flood waters at many points. Although no observations were made on mosquito density by entomological personnel during October, it is assumed that the breeding subsequent to the hurricane must have reached an extremely high level. The temperature and humidity in the area for October and November were optimal for mosquito survival and reproduction (Table 1).

<table>
<thead>
<tr>
<th>Date</th>
<th>Temperature °C</th>
<th>Avg. relative humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg.</td>
<td>Max.</td>
</tr>
<tr>
<td>October 1963</td>
<td>27.6</td>
<td>31.8</td>
</tr>
<tr>
<td>November 1963</td>
<td>27.9</td>
<td>32.6</td>
</tr>
<tr>
<td>December 1963</td>
<td>27.8</td>
<td>32.5</td>
</tr>
</tbody>
</table>

**Table 1: Temperature and average relative humidity in Port-Au-Prince, Haiti, October-December 1963.**

**Development of the Malaria Epidemic**
The first indication of an unusual increase of malaria incidence in the affected area was a report by a voluntary collaborator post in mid-December of a sudden rise in the number of fever cases. By the end of December it was obvious that a full-blown epidemic was developing. From a total slide positivity rate of about 2% for the area in September 1963, the incidence rose to 12.1 % by the end of December, to 22.2% by the end of January and to 25.6% by the end of February (Table 2).

The sharp increase in malaria infections apparently occurred simultaneously in almost all parts of the area directly affected by the hurricane. Tabulation of the slide positivity rates by date of blood slide collection at voluntary collaborator posts indicated that the incidence already was
ranging sharply about six weeks after the hurricane, in the middle of November. The epidemic curve continued to maintain a high plateau, fluctuating between 21% and 31% during December, January and February.

The slide positivity dropped by the end of March to 9%. The affected zone was visited by entomological personnel at the end of November and in February and it was reported that many of the possible breeding areas already were quite dry and very few A albimanus larvae could be collected. This would seem to be consistent with the rainfall data for this period (Fig. 1). However, the incidence rose again in April to 12%, continued rising to 17% in May and was up to 19% in June and 27% by July (Figure 2).

Table 2: Malaria cases detected in area affected by hurricane by month of laboratory examination of blood slides.
The parasite density was determined for all positive slides collected in the affected zone. The proportion of cases with "high" parasite density (more than 1,000 parasites per cubic millimeter of blood) rose from 56% in October 1963 to 77% in November 1963, dropped to 64% in March 1964 and rose to 84% in June 1964.

The outbreak was caused by *Plasmodium falciparum* (Table 3). Males and females were equally affected. Although the highest slide positivity rates were seen in infants and young children, the older age groups were also heavily affected, with rates in adults reaching 21% in January 1964 at the peak of the outbreak (Table 4).

The most intensely affected area was along the northern coastal plain of the peninsula. The coastal sections showed higher rates than those in the interior and localities under 300 meters showed higher rates than localities at higher altitudes. At the height of the outbreak, malaria cases were detected in about 80% of the localities sampled. Slide positivity rates for slides collected by voluntary collaborators reached 40-50% in some localities.

![Figure 2: Percent of positive blood slides collected by voluntary collaborators. September 1963 to October 1964, by week of blood slide collection (zone affected by hurricane).](image)

About one half of the fourth spraying cycle had been completed in most of the zone when the hurricane struck. Spraying operations had to be completely suspended in part of the area, since there was little left to spray, and were not resumed until January 6, 1964, when the regular fifth spraying cycle was started in the rest of the country. In the intervening period, a quick reconnaissance to appraise the amount of house damage was carried out at the end of October, and a second more detailed geographic reconnaissance was accomplished in December. The first reconnaissance revealed that in the area affected by the hurricane about 68% of the houses had been destroyed, with the rest damaged to a greater or lesser degree. By the
December reconnaissance some 80% of these houses had been rebuilt and repaired, and most of the rest were under construction. By the end of the fifth spraying cycle in April 1964, practically all the houses had been rebuilt or repaired.

<table>
<thead>
<tr>
<th>Species</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Plasmodium falciparum</em></td>
<td>6,184</td>
<td>98.5</td>
</tr>
<tr>
<td><em>Plasmodium malariae</em></td>
<td>59</td>
<td>1.0</td>
</tr>
<tr>
<td><em>Plasmodium vivax</em></td>
<td>26</td>
<td>0.4</td>
</tr>
<tr>
<td>Mixed</td>
<td>7</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6,276</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Table 3: Distribution of *Plasmodium* species as based on positive blood slides, October 1963-May 1964

<table>
<thead>
<tr>
<th>Date</th>
<th>Blood slides collected</th>
<th>Positive Slides</th>
<th>Percent Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 1</td>
<td>204</td>
<td>72</td>
<td>35.3</td>
</tr>
<tr>
<td>1-4</td>
<td>955</td>
<td>326</td>
<td>34.1</td>
</tr>
<tr>
<td>5-9</td>
<td>1,297</td>
<td>391</td>
<td>30.1</td>
</tr>
<tr>
<td>10-20</td>
<td>3,031</td>
<td>841</td>
<td>27.7</td>
</tr>
<tr>
<td>21 &amp; over</td>
<td>6,247</td>
<td>1,094</td>
<td>17.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11,734</strong></td>
<td><strong>2,724</strong></td>
<td><strong>23.2</strong></td>
</tr>
</tbody>
</table>

Table 4: Blood slides collected by voluntary collaborators, by age group, October 1963-March 1964.

The area of high slide positivity rates and rapidly increasing malaria incidence matches almost perfectly the area affected by the hurricane. However, it should be noted that some sections in the middle of the hurricane area, with a high percentage of house destruction, showed rather low parasite rates during the course of the epidemic. These are inland, mountainous sections, and are largely non-malarious areas.

The number of fever cases reporting to voluntary collaborator posts began to rise sharply in early December, reaching peak in January and early February. At the height of the outbreak, the collaborators were collecting about 1,500 slides a week.

It is estimated that some 75,000 cases of malaria occurred in the hurricane zone between October 1963 and March 1964, based on an overall 25% slide positivity rate for fever cases, with an estimated 50% of the population affected with fever during the course of the epidemic.

Even though the epidemic developed rapidly, and probably affected most of the susceptible persons at risk in the area, there were no reports of undue or exceptional suffering or illness from the population or the civil authorities. A number of reports were received from the medical practitioners of an increase in malaria cases in the area, but there was nothing to indicate that the epidemic had produced any alarming increase in the number of deaths or even in the amount of disability in the population. Mortality reporting is practically nonexistent in Haiti and no reliable information could be obtained from official sources.
Discussion
The rapid, simultaneous development of the malaria epidemic over practically all the area affected by the hurricane can be attributed to the following factors:

1. Continuing malaria transmission in the area before the hurricane and the presence of a considerable reservoir of gametocyte carriers at the time of maximum mosquito activity after the hurricane.

2. The great majority of the population without shelter or living in temporary shelters, with maximum exposure to biting activity of the mosquito vector,

3. Almost complete removal of insecticide coverage in houses.

4. An explosive increase in mosquito breeding, brought about by the heavy rainfall and extensive flooding.

5. Increased population movement in search of food, construction material, medical care, etc.

There had been an increase in malaria incidence in the affected zone in June, July and August, 1963, before the hurricane. Although there was an apparent drop in incidence in September, it is very likely that the number of fresh clinical cases was on the increase by October, when the hurricane struck. With a considerable number of gametocyte carriers available after the rains and flooding had stopped, when mosquito density was reaching its peak, and with little or no protection from mosquitoes available, the first sharp rise in incidence could be expected about six to eight weeks after the hurricane. This rise was seen, in fact, in the middle of November (Fig. 2).

It is unlikely that the epidemic could have developed as rapidly, and as simultaneously over such an extensive area, if malaria transmission had been interrupted before the hurricane occurred, during 3.5 cycles of house spraying with DDT. The explosive nature of the outbreak can best be explained by assuming that all the factors necessary to produce a malaria epidemic were combined at a time when the malaria incidence was already increasing in the area.

As has been noted above, the great majority of the rural houses were destroyed by the storm. Most of those that remained standing were without roofs, and practically all the houses, with or without roofs, were thoroughly drenched by the heavy rains that followed the storm. It can be assumed that there was almost complete removal of any insecticidal coverage that had been present before the hurricane. No appreciable difference in malaria incidence was seen between localities sprayed during the first three months of the fourth cycle, before the hurricane, and those that had not yet been sprayed when the hurricane struck.

No direct correlation was seen in the different sections in the affected zone between the amount of house destruction and the level of total slide positivity parasite rates over the six-month period after the hurricane. It is assumed that the difference in rates is an expression of the differing "malariousness" of each area rather than a direct result of the amount of house destruction. Also, it was noted that the percentage of house destruction was not necessarily a reliable index of insecticide coverage, since practically all of the houses left standing were damaged to some degree, and most of the insecticide was later removed by rains, repairs or replastering.
The fifth cycle of spraying in the affected zone, which started in January 1964, was accelerated so that the area could be covered in four months, by the end of April 1964 when the next transmission season was due to start. In addition, mop-up brigades covered the area again in April, to spray any new or repaired houses missed by the regular brigades.

The rainfall in the area in April was particularly heavy, and totalled as much as was recorded during October 1963, when the hurricane had struck (Fig. 1). The malaria incidence in the area had dropped during February and March and it was hoped that the fresh insecticide coverage would provide the protection needed to prevent any further increase. However, the rates began to rise in May and June and by July had reached a slide positivity of 30% for slides collected by voluntary collaborators (Fig. 2).

In addition to an increase in percent of positivity for slides collected by both voluntary collaborators and case finders, the absolute number of cases also rose (Fig. 3). The proportion of positive slides with high parasite density began to rise again in April, after having dropped from a peak in December. Also, the percent of “positive” localities and the percent of collaborator posts detecting malaria cases began to show an increase in July. From all indications, there was a true increase in malaria in the area, evidently as a direct result of the heavy rains in April.

![Figure 3: Malaria cases detected (positive blood slides) in zone affected by the hurricane, from June 1963 through October 1964, by month of laboratory examination.](image)

It was assumed initially that one of the main factors in the development of the epidemic was the loss of insecticide coverage caused by the house damage and heavy rains during and after the hurricane. In view of the increase in malaria transmission after the spring rains, in spite of fairly adequate spray coverage, it would appear that this factor may have less importance than previously estimated.
Recent studies on the behavior of *A. albimanus* in Haiti indicate that most of the biting activity takes place in the early evening, when the great majority of rural population can be found outside their houses. Only a small proportion of the mosquitoes can come inside of the houses to bite or rest.

Even though the vector is susceptible to DDT and bioassays on sprayed wall surfaces indicate satisfactory mortality up to six months, it is likely that most of the malaria transmission in Haiti is extra-domiciliary and that DDT house spraying alone may not be sufficient to interrupt transmission in highly malarious areas. Additional studies are now being carried out to clarify these questions.

**Summary**

An epidemic of malaria following the passage of a hurricane over Haiti October 3-4, 1963, is described. The epidemic started about six to eight weeks after the hurricane and it is estimated to have produced some 75,000 cases of malaria in a three-to four-month period. It is assumed that the rapid, simultaneous development of the epidemic over practically the entire affected area was facilitated by the presence of a considerable reservoir of gametocyte carriers, and the massive increase in mosquito breeding brought about by the heavy rains and flooding. The effect of DDT insecticide spraying in houses on malaria transmission in Haiti is still under investigation.

Any gains made by two years of DDT spraying have been completely wiped out by the epidemic and the malaria eradication program can be assumed to be starting over again in the affected area.

**Summary**

A few references to malaria case increases resulting from natural disasters occur in the literature. One quoted often is that of Mason and Cavalie. The epidemic started about six to eight weeks after the hurricane. However, many publications relate malaria to increased rainfall (see Lesson 12). Any decisions in malaria control following a natural disaster should be based upon data obtained from closely monitoring all of the natural and human factors that comprise the malaria ecosystem. All three "environments" (physical, biological, and social) are apt to change following a disaster. The gathering of data should follow the general procedures routinely carried out by the malaria service.

Usually a malaria service maintains a history of malaria control in the area. All the facts of the history should be examined for risk areas and weak spots in the programs. An audit of program personnel, facilities, supplies and services will indicate corrective measures that should be taken. The following information should be readily available.

1. The boundaries of the area with malaria should be mapped.
2. All epidemiological data should be kept current and under review.
3. Species of *Plasmodium* in the area and their relative frequencies should be known.
4. Is there resistance to drugs? If so, which drugs and which species of *Plasmodium*?
5. Which *Anopheles* in the area are known vectors and what are their rank of importance?
6. Where and when do the larvae of the vector species occur?
7. Are the adults seasonal in occurrence?
8. What are the biting habits of the vectors?
   - time of day and where biting occurs (mostly indoors or outdoors)
9. What entomological surveillance methods are appropriate to observe mosquito population densities?
10. What is the status of insecticide resistance?
11. What are current control methods?

In addition to the above information the following should be collected:

1. Condition of housing in the area.
2. Changes in density and distribution of human population.
3. Changes in density and distribution of domestic animals, if they serve as hosts to the vector.
4. Status of impoundages, canals, ditches, irrigation systems, temporary pools, etc. which might effect mosquito breeding.
5. Current accessibility of area to vector control operations.
6. Outside assistance available to the program: financial and human resources, manpower, supplies and equipment.
8. Personnel available or obtainable from other sources and training required.

Entomologists have statistical methods of forecasting malaria epidemics. The entomological factors that they consider are:

- vector density in relation to humans
- daily survival rate of vector
- human-biting frequency
- length of the sporozonic cycle
- proportion of anophelines with sporozoite that are actually effective

Some of this information may not be possible to obtain, but simple entomological procedures are available to monitor population and changes in human-mosquito contact. Special attention should be given to: 1.) meteorological factors, and 2.) environmental factors, especially migration of non-immune people.

In recent years there has been emphasis on the role of the primary health care worker and community participation in all vector control, but especially malaria control. Many countries have a system of volunteer collaborators to take blood smears and administer treatment. In some cases the activities of the collaborator have been expanded to include vector control, or his/her duties have become part of the primary health care network. The role of the community may be particularly important following a natural disaster. They may work to destroy adult vectors by doing the indoor residual spraying of houses or even space spraying where required. In destruction of larvae, individuals can do larviciding, rearing and release of larvivorous fish, and flushing and cleaning of ditches and drains. They may also do source reduction near the human populations.
Lesson 6 - Self-assessment test

True/False

Indicate T or F:

1. Environmental management for malaria control is usually slow to initiate and too expensive at the start to play more than a superficial role in emergencies.

2. The location of a refugee camp may be important in reducing vector-human contact.

3. A hand compression sprayer with an appropriate nozzle is the method of choice for residual application of insecticides.

4. No increase in malaria infections following a disaster is a true sign that the control measures used were effective.

5. Not all of the species of anopheline mosquitoes are vectors of malaria.

6. Any vector control approach should consider housing conditions and human population movements but need not become involved with geographical reconnaissance.

7. If adult control measures are effective, there is little need to re-establish immediately the larval control measures.

8. Petroleum oil products, nonpetroleum monolayers and insect growth regulators can be used for adult mosquito control.

9. Even with a natural disaster, once the malaria eradication program is in the maintenance phase, there is little potential for re-establishment of transmission.

10. Hurricanes and floods seldom affect breeding sites of anopheline mosquitoes.

Answer Key

1. True
2. True
3. True
4. True
5. True
6. False
7. False
8. False
9. False
10. False
Lesson 7 - *Culex quinquefasciatus* and Other Pest Mosquitoes

**Study Guide**
Pest mosquitoes may also be vectors of disease and consequently are subject to surveillance and control. This lesson describes methods of estimating larval and adult populations and suggests ways in which pest mosquitoes can be controlled.

**Learning Objectives**
- Describe the various methods available to collect mosquitoes.
- Know the control measures appropriate for *Culex quinquefasciatus*.

**Learning Activities**
Read pages 47-51 in the manual. Read the summary in this lesson.

**Evaluation**
Complete the self-assessment test.

**Notes**
Lesson 7 Summary

*Culex quinquefasciatus* has been expanding its distribution range due to environmental changes caused by humans. This is especially true in crowded urban areas where inadequate maintenance or lack of sewage disposal systems, blocked drainage networks and inadequate water delivery systems have resulted in the creation of favorable larval breeding places. It develops mainly in habitats containing highly polluted water. The environmental changes produced by natural disasters frequently compound the problem.

*Culex*, *Culiseta*, and *Aedes* species have been incriminated in a number of arthropod virus diseases. Many of them such as St. Louis encephalitis, (SLE), western equine encephalitis (WEE), eastern equine encephalitis (EEE), and Venezuelan equine encephalitis (VEE) involve a reservoir host such as a bird, horse, or other animal. Thus for monitoring this type of virus activity, both the vector and the potential reservoir must be checked for virus activity. In addition to surveying the adult vector populations, real and potential breeding sites should be watched for increase in number of sites or adult output. Most vectors have seasonal population peaks that are influenced by the availability of breeding sites, latitude and temperature. In some cases there may be a vector species associated with animal transmission and another species with human. This is the case with EEE. In this type of situation both species should be monitored.

As mentioned in the manual, maps should be available and should be updated to indicate the location of breeding sites and changes in larval and adult population indices. Aerial photographs are extremely helpful. Unless the area has had previous arbovirus epidemics, there may be little baseline data available to compare population densities. However, where available these data should be utilized.

Any surveillance program should identify areas where simple source reduction procedures can be used. Furthermore, in some areas larvivorous fish may be introduced to keep densities in check. However, if larvivorous fish are used, it might be advisable to wait until the flood water has receded to a level where fish seeding would be practical.

Emergency measures will have to include gathering of virological, entomological and epidemiological information. The climatic factors following a natural disaster will also affect the potential course of the viral activity. In temperate areas, an epizootic might occur towards fall, but temperatures could curtail mosquito population levels before the virus affected humans.

In many arbovirus epidemics, control measures are employed after the epidemic has peaked and their effect is diminished. It is recognized that many of the laboratory tests needed to confirm the activity of a specific virus are time consuming. For this reason, every step of the surveillance program must be well organized. Where the possibility of arbovirus activity exists, surveillance of the vector, human, and reservoir host populations should be intensified. For some arbovirus surveillance, sentinel animals are used. This will have to be an individual program decision as they are costly and labor intensive. At the same time the vector control staff should have a plan of action available in case of an emergency as well as a routine control activity designed to prevent the occurrence of the emergency.

Control will depend upon the vector involved. For adults, space spraying (either ULV or thermal fogging) is recommended. When large areas are involved, consideration can be given to aerial ULV application. In the case of space spraying a single application may be sufficient but it is best to plan for several applications, especially in the areas of highest risk.
The results of the spraying should be evaluated; any upswing in the adult mosquito population after spraying can be used to determine the frequency of application. Should the original application produce poor results, even though all procedures for space spraying were followed, there may be resistance to the insecticide. In this case, the insecticide should be changed. Of course, it is recommended that resistance be determined before an insecticide is used. Unfortunately, in most cases this is not done.

Lesson 7 - Self-assessment test

True/False

Indicate T or F:

1. The interpretation of larval and adult mosquito surveys depends upon the baseline data that are available and the types of vector-borne diseases found in the disaster-stricken area.

2. One method of surveillance for pest mosquitoes, flies and rodents may be complaints from the refugee or resettlement sites.

3. To estimate the adult mosquito population by landing/biting collections, the time of day for collections should be varied to get average counts.

4. Many mosquitoes, especially some species of Anopheles and Culex, seek out light, cool, humid places to rest during the day.

5. Culex quinquefasciatus breeds mostly in clear unpolluted water.

6. Culex quinquefasciatus are known vectors of St. Louis encephalitis and Bancroftian filariasis.

Answer Key

1. True
2. True
3. False
4. False
5. False
6. True
Lesson 8 - Synanthropic Flies

Study Guide
Increases in synanthropic flies, and the health problems they cause, may be expected after natural disasters. This lesson describes simple surveillance methods and recommends control and evaluation measures.

Learning Objectives
• Identify problems related to increases in synanthropic flies following a natural disaster.
• Describe surveillance and survey methods for synanthropic flies.
• Specify principles for fly prevention and control and ways in which control measures can be evaluated.

Learning Activities
• Read pages 53-55 in the manual.
• Read the summary in this lesson.

Evaluation
Complete the self-assessment test.

Notes
Lesson 8 Summary
Houseflies frequently become a major nuisance after a disaster because basic environmental sanitation breaks down. In some cases solid and liquid waste disposal facilities are destroyed and even simple outdoor latrines are flooded or destroyed. The population may defecate at random or in specific defecation sites until latrines can be constructed. Many times the sites are also dumping areas for garbage and rubbish. The people should be encouraged to take preventative measures to reduce fly populations. These may include:

1. Disposal of household waste
   • burning of waste
   • bury waste (one- to two-foot cover)
   • bag waste in sealed plastic sacks
   • disposal of animal and human feces by spreading thinly (human if latrines are not available)

2. Location of animal housing and waste disposal, especially in rural areas.

3. Placement and construction of latrines; survey the human defecation habits as even with latrines available, they might not be used.

For either prevention or control, it is important to locate the breeding site. There are a number of designs that can be used in pit latrines, depending upon the water table and flood conditions. In addition, devices can be used to either limit access of flies to the pit latrine or to trap the emerging population. Oil can be used in pit latrines, but larviciding is usually not recommended unless absolutely necessary. Space spraying may be effective in control of adult flies from large areas, but baits and residual spraying are also used.

Space spraying may be done indoors or outdoors. Indoor spraying may be by ultra-low-volume or aerosol bomb. Frequently, either only pyrethroid or a combination of a pyrethroid with an organophosphate or carbamate insecticide is used. Outdoor spraying may also be done with a thermal fogger (see Lesson 14 for information on equipment and insecticides recommended). Outdoor space spraying should be done early in the morning and in the evening in places where the flies congregate. Treatment may be done daily for seven to ten days to kill the newly emerged adults.

Baits may be effective but a number of precautions should be followed. Baits should be kept away from foodstuffs and be clearly labeled. If possible a dye should be used as a warning marker. A container is needed for mixing the bait and a bucket and scoop may be used for broadcasting it. When not in use this equipment should be cleaned and stored out of reach of children.

If the resting sites are identified, a residual insecticide application can be done. Residuals may be used in permanent buildings and in and around garbage containers, etc. Resting counts or fly paper counts can be used to monitor all control procedures.

Flies are resistant to a number of insecticides and there is cross-resistance between DDT and synthetic pyrethroids. Therefore, although chemical control is an effective method for clearing an area of flies, an attempt should be made as soon as possible to control by source reduction.
Lesson 8 - Self-assessment test

True/False

Indicate T or F:

_____ 1. Education of the population is one of the most effective methods of fly control.

_____ 2. Flies usually transmit diseases to humans by coming in contact with food and drink.

_____ 3. Flies can migrate up to four miles to new sources of food or breeding areas.

_____ 4. Flies have been incriminated in the transmission of many of the enteric diseases of humans.

_____ 5. Fly traps in homes provide good surveillance information since all synanthropic flies enter houses.

_____ 6. For either prevention or control of synanthropic flies, the most important step is to locate the breeding sites.

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<th>Answer Key</th>
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<td>1. True</td>
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Lesson 9 - Other Vectors

Study Guide
Certain lice, fleas, ticks, and mites may cause serious health problems following natural disasters. Other arthropods may come into more frequent contact with people during flooding. This lesson gives specific information about the species involved and actions that can be taken.

Learning Objectives
• Identify the role of other arthropods in producing disease and related problems following natural disaster.
• Understand the importance of general sanitation and health education in prevention.
• List possible control measures for these arthropods.

Learning Activities
• Read pages 58-60 in the manual.
• Read, but do not memorize, the relevant sections in Annex III, pages 75-83 in the manual.
• Read the summary in this lesson.

Evaluation
Complete the self-assessment test.

Notes
Lesson 9 Summary
There are three species of human lice: 1) the human body louse, *Pediculus humanus*, 2) the head louse, *Pediculus capitis*, and 3) the crab or pubic louse *Pthirus pubis*. Of these only the body louse is a disease vector. It transmits louse-borne typhus (endemic typhus), relapsing fever, and trench fever. The first two diseases may occur in epidemic forms in the aftermath of natural disaster.

Body lice, if present, are likely to be widely dispersed under conditions where large groups of people have difficulty washing or obtaining changes of clothing. Consequently when a disaster produces any long-term temporary settlement situation, surveillance for body and head lice should be established.

Both nymphs and adults feed off of human blood and may obtain several blood meals a day. The bites tend to produce a local skin reaction with varying degrees of irritation. Secondary infections, especially with impetigo, may occur.

Since these lice can survive only on humans, treatment in emergency situations is usually an insecticide dust. Resistance to insecticides is common in lice; it is important to know susceptibility of lice to the insecticide before choosing an insecticidal powder. In emergencies the choice of insecticide is usually determined by availability. The entire population should receive a treatment. When no insecticide is available a large-scale boiling of clothing and bedding should be organized. Oil drums or other large containers can be used. Heat kills eggs and adults. Clothing washed in 60°C (140°F) water should kill both.

Cockroaches may be common in temporary housing. They are not vectors of any specific disease but like flies they can mechanically transfer infections. As they feed they often defecate and contaminate food products in that manner. Since disease transmission is generally mechanical, the period during which transmission could occur is relatively short. They are active at night and usually congregate in dark, damp, warm micro-environments, such as near cesspools and pit latrines.

Bedbugs are parasitic blood-sucking insects found both in temperate and tropical areas. The nymph and adult stages are blood feeders. Although they are blood feeders, it is generally accepted that the bedbug plays an insignificant role in the transmission of disease to humans. The bite produces a small, hard swelling or wheal that is whitish in color. It may produce edema and inflammation. During the daytime, bedbugs live in the beds, cracks in walls, furniture, mattresses, etc. Control of large bedbug infestations requires the use of residual insecticide.

Fleas transmit plague and murine typhus. They may be involved with some other rickettsial diseases, tularemia, and salmonellosis. They can also produce dermatitis. Only adult fleas bite humans. The Oriental rat flea, *Xenopsylla cheopis*, and other rodent fleas are involved with plague and murine typhus (endemic typhus).

It is extremely difficult to carry out a successful, large-scale flea control operation without expert help. It is important to know the distribution of flea-borne diseases (the endemic areas) and the seasonal preference of the disease. Plague, for example, is more virulent in warm weather. When disease transmission is involved, do not use rodenticides or other methods of destroying rodents until flea control measures have begun. A clue to plague activity may be a sudden die off of a local rodent population. Care must be taken in handling dead rodents. For nuisance fleas, source reduction inside and around buildings is important. The primary focus of the infestation should be found or the area will become reinfested.
Several species of ticks feed on humans. Besides an irritating bite they transmit a number of diseases such as some spotted fevers, Q fever, tularemia, and babesiasis. However, unless it is tick season or unless these diseases are endemic in the area, their prevalence should not be influenced by a natural disaster.

Severe flooding, by flushing out and concentrating the snake population, has produced epidemics of snake bite in Pakistan and India. It would be helpful to have a list of the poisonous snakes in the disaster area. Venom detection kits using the enzyme-linked immuno-sorben Assay (ELISA) technique may give results in time to guide clinical management.

Management starts with first aid, especially immobilization. The victim should lie on his/her side since vomiting may occur. The person should be moved to a medical facility and if possible hospitalized for at least 24 hours. The only specific treatment is antivenom, which is costly and may have side effects. The use of antivenom depends upon the snake involved.

Lesson 9 - Self-assessment test

True/False

Indicate T or F:

_____ 1. Granular formulations for pest mosquito larval control are frequently used because they can penetrate heavy vegetative cover.

_____ 2. To control fleas, mass rodent control is the first step.

_____ 3. In treating beds for bedbugs, control personnel should not apply any insecticide to children's cribs.

_____ 4. Mites may transmit such diseases as scrub typhus and Q fever.

_____ 5. Lindane shampoo can be used against head and body lice but not against crab lice.

_____ 6. Emulsion concentrates can be used for residual contact sprays.

Answer Key

1. True
2. False
3. True
4. True
5. False
6. True
Lesson 10 - Rodents

Study Guide
Following a natural disaster the risk of rodents transmitting infectious diseases to people and contaminating food supplies becomes a major concern. This lesson deals with identification of problems and methods of control.

Learning Objectives
• Identify the major species of commensal rodents.
• List the four most important infectious diseases that they may transmit to people.
• Outline simple methods of surveying rodent populations.
• List measures used for prevention and control of rodents.

Learning Activities
• Read pages 55-58 in the manual. Study the forms and figures in this lesson.
• Read, but do not memorize, the appropriate section of Annex III, pages 82-83 in the manual.
• Read the summary in this lesson.

Evaluation
Complete the self-assessment test.

Notes
**Lesson 10 Summary**

Commensal rodents include three important species, the Norway rat, the roof rat, and the house mouse. "Commensal" refers to those animals that live at human expense, eating our food, living in our houses, and sharing with us their diseases, without contributing anything beneficial to the relationship. One or more of the three are found almost everywhere that humans live.

Rats will bite humans, causing injury, illness, and even death. Thus rodents transmit diseases to humans through their parasites, urine and feces, and bite. Rodents damage, destroy, and contaminate vast amounts of grain before harvest and during storage.

Rodent-borne diseases are zoonoses or diseases of animals that may be transmitted to humans. Other animals besides rodents act as reservoirs for a number of diseases. Many of the zoonoses are of little concern in natural disasters but others have to be considered if the causative organism is in the area. These include plague, murine typhus, leptospirosis and salmonellosis.

In recent years plague has been reported from a number of countries. It is primarily a disease of rodents, transmitted from rodent to rodent and from rodent to humans by fleas. The principal flea vectors are several species of *Xenopsylla*, but a number of other rodent fleas may also be involved. A number of wild neotropical rodents are thought to harbor plague organisms, but in urban areas in the aftermath of a natural disaster the commensal rodents (*Rattus rattus* and *R. norvegicus*) are of major importance. Should the disaster be in rural areas where the causative organism, *Yersinia pestis*, has adapted to wild rodents, some surveillance should be considered. The pathogenicity of *Yersinia pestis* varies widely, but in many instances dead wild rodents may be noted. If an epizootic is occurring near a temporary shelter area, some of the fleas could leave the dying rats and seek other vector hosts including humans. Flea control should always precede rodent control.

Murine typhus, like plague, involves commensal rodents and the Oriental rat flea, *Xenopsylla cheopis*. However several other species of fleas are also believed capable of transmitting the causative organism, *Rickettsia mooseri*. The mode of transmission is by infected rat feces. The distribution of the disease is worldwide, mainly in areas of warm climates. Like plague, the ectoparasite should be controlled before rodent control.

Rat-borne leptospirosis is worldwide. Caused by a spirochete, *Leptospira icterohemorrhagieae*, it is spread either by contact with contaminated rodent urine or by handling a sick animal or infected animal tissues. Other animals such as cattle, swine, and dog are also involved in transmission and may be more important than rats.

Food products may be contaminated by rats and mice. The house mouse may be more important than rats in spreading an infectious food poisoning caused by organisms in the bacterial genus *Salmonella*. The disease is transmitted to humans by infected fecal droppings and urine.

Rodents, like other animals, may be concentrated in the vicinity of humans as a result of natural disaster. Rat infestation may be prevented by denying them food and harborage. In many disasters large quantities of food may arrive and be stored for distribution. Whenever possible the storage building should be made as rat-proof as possible. Food sacks should be stored at least 30 cm above ground level. Stacks should not be built into comers. All refuse and spillage should be disposed of in containers having tight-fitting covers. All burrows in the area should be filled with stones and concrete to prevent rats from nesting in such places. Grass around the
storage building should be cut and debris removed. Tree branches overhanging buildings should be trimmed to prevent rats from gaining access into buildings.

The same precautions should be taken in kitchen and sleeping areas. Food wastes, providing both food and water, can be a major cause of rodent infestation. Waste disposal areas should be constructed to keep rodent populations at a minimum.

Many kinds of rodent poisons are available. Mice readily drink water if it is available, so water baits may be effective when other water sources are restricted. In control, several methods may be used simultaneously to yield better results. When using bait, try to limit available food and water.

**Lesson 10 - Self-assessment test**

**True/False**

*Indicate T or F:*

1. Since rodent control is typically a national problem, predisaster information is usually available.  
2. Leptospirosis is maintained in reservoirs of commensal rodents, dogs, pigs, and cattle. 
3. Acute, quick-acting rodenticides are preferred over chronic, slow-acting compounds for rodent control following a disaster. 
4. Five main rodent species may transmit infectious diseases to humans. 
5. Anticoagulant rodenticides are diphacinone, difenacoum, brodifacoum and chlorophacinone. 
6. Rodent surveys based on sighting should always be conducted in full daylight to assure accurate counts.

**Answer Key**

1. False 
2. True 
3. False 
4. False 
5. True 
6. False
Module III - General Control Action

Lesson 11 - Program Management

Study Guide
This lesson departs from the manual and provides insights into the complex organization and decision-making process involved in management of a vector control program. While the reading assignment deals with a specific experience, the principles and procedures can be applied generally to the management of vector control programs.

Learning Objectives
• Understand the decision-making process involved in developing a control program.
• Chart the organizational structure of a control program.
• Chart the organizational structure of the survey and control functions of a field operations plan.
• Be aware of the choices available in techniques and insecticides when implementing a vector control program.

Learning Activities
• Read "Problems Hindering Aedes aegypti Eradication" on page 56 of this study guide.
• Read the summary in this lesson.

Evaluation
Complete the self-assessment test.

Notes
Supplementary reading
Excerpted from "Problems Hindering Aedes aegypti Eradication," M.E.C. Giglioli, Director, Mosquito Research & Control Unit, Grand Cayman, Cayman Islands, B.W.I.

Figure 1 gives a flow diagram of the "ideal" actions and decision-making processes that should be taken in planning, proclaiming, creating and/or reorganizing an Aedes aegypti program.

Organization at the Planning Level

![Figure 1: Costs of a routine control program compared to losses caused by a dengue epidemic.](image)

Pertinent to planning are the following salient points:

Having decided that Aedes aegypti is present, and that it constitutes a potential problem to the country, interested parties in the government and the private sector should convene as a multisectorial committee to advise government. The first decision required is which ministry should be entrusted with the program. Though, traditionally this responsibility has been given to the Ministry of Health, Singapore's highly successful example of placing vector control under the
Environmental Ministry is worth consideration; further, if the country has also a pest mosquito, blackfly or sandfly problem, Development and Tourism might provide a more suitable parent ministry, as long as the program remains in close liaison with the epidemiologist and the public health department.

The next decision required from the committee is whether the required expertise (epidemiologist, entomologist etc.) is available locally, or whether international consultants should be brought in; in either case the initial surveys and resulting draft plan should include budgets, cost/effect, and cost/benefit projections.

Finally the consultant team, advised by the national committee, should decide whether the local political-economic state mandates a labor-intensive program, or should a more efficient, small, mobile elitist staff execute the program? Once this information and the decisions are available, a realistic draft plan of the required staffing, strategy, plant, equipment costs (recurrent and capital) and cost effects can be drawn up for consideration by appropriate budgetary officials.

Finance will then decide whether the plan is economically feasible or whether aid will be required to finance it, or if modifications are needed to meet economic limitations.

Approval at the Political Level
Once the plan and its financial feasibility are found acceptable, it is essential that it should seek and receive the approval and endorsement of the highest body in government. Its direction, aid agreements and policy should be clearly stated and officially proclaimed by the government, as was done in the cases of the model programs in Brazil and Sardinia which were created by presidential and royal proclamations, and the more recent Cuban example which was mounted under a State Emergency.

The highest recognition of a newly created or reorganized program detailing its leadership, aid agreements and responsibilities is essential to ensure its acceptance by the populace and its continued support by the government until the program's proclaimed aims are achieved.

The Role of International Aid
When the program makes use of international aid, the agreements between the recipient country and the aid organization should be drawn up to cover periodic visits by specialist staff to collaborate in developing and evaluating appropriate technology as well as encouraging the application with vigor and determination and finally making recommendations for changes in the plan methodologies.

Organization at the Program Level
Figure 2 gives the basic organogram of a program emphasizing its extradepartmental relationships and intradepartmental organization into administrative and operational parts, with further geographic sub-organization depending on the size of the country.
Figure 2: Flow chart of the decision-making process to create or reorganize an Ae. aegypti program.
The relevant features of this diagram are the direct channels of communication between the program's headquarters and other government departments and bodies, in particular with the Treasury. Logistics and management within the program can be efficient and effective only if management is empowered on the basis of frequent audits of strict accounting, to deal speedily with orders and disbursements. Similarly the direct link with the epidemiologist and public health department is re-emphasized.

Within the program, apart from the more usual management training, logistics, and laboratory subgroups, is the statistical section, responsible for the evaluation and representation of field data. Field data is the basis of planning and its analysis should not stop with merely a summary sheet, as is so often the case.

During the early stages of the program, field operations should be split into control and survey subgroups, but by the end of the attack phase these should become interchangeable, with survey teams also treating isolated foci as they come across them. Throughout the attack and later phases, mobile inspection teams operating under the laboratory should run random or specific checks on field work.

The size of the organization will depend on the size of the country or its infested areas, but it is advisable to keep it small, highly trained and mobile as this will facilitate supervision, enhance management and insure continuity of employment when the program moves into the surveillance phase. In some cases this small core organization may function more as an advisory body with actual control operations being done at the community or other small, politically defined level.

**Organization of Methodologies**

Figure 3 gives the choice of methodologies of field operations, listing the various techniques of survey and control available to an *Aedes aegypti* eradication program. It stresses the never-ending cycle whereby all field data is returned through the laboratory to statistics and evaluation to provide a constant feedback for sound planning and management. The function of this often-overlooked section is to provide constant up-dated situation reports on which the success or failure of the program can be evaluated and plans modified to meet the changing conditions encountered in the field.
Figure 3: Organization and functions of an Ae. aegypti program.

All too often this cycle is broken or incomplete, resulting in partial feedback and analysis with unrelated blind adherence to the original plan, right or wrong. In addition, all survey collections should be identified by a qualified technician.

While the diagram shows various combinations of survey and treatment it is not suggested that all should be used; for example, in most cases routine and frequent surveys consisting of ovitraps and larval premise indices suffice. Mosquito activity and biting along with their seasonal variations should be studied if space sprays are considered as this is directly relevant to the time of day that they should be applied. Applications of space sprays should also coincide with suitable meteorological conditions, to allow transient fogs or aerosols to be effective.

Organization of Techniques for Integrated Pest Management (IPM) and Insecticide Management to Minimize the Loss of Susceptibility

Figure 4 summarizes three principles of insecticidal management to prevent or at least minimize the loss of susceptibility to an insecticide. Obviously the principle of use "by moderation" requiring unsprayed genetic "refugia" cannot be adopted in any eradication program; thus the planner is left the choice of using insecticides by either the "saturation" or the "multiple attack" principles. Final selection will depend in part on the status of the vector's resistance in any one country, and in part on logistics and funds. Multiple attack requires the rotation or the use of
mixtures of insecticides and thus is likely to be more expensive. Furthermore, both principles are theoretical and may not work under some field conditions.

Figure 4: Organization of field operations in an Ae. aegypti program giving choice of survey and control methodologies and the correct flow of field data for evaluation and planning.

On the other hand the "multiple attack" principle is best suited to an Aedes aegypti eradication program as total treatment of both larvae and adult populations is practiced and thus the selective pressure will be at its strongest if only one insecticide is used. For this reason it is best to try to use a non-neurotoxic insecticide as the larvicide (e.g. insect growth regulation, monolayers) biocontrol agents wherever possible and reserve the more common insecticides for adulticidal measures.

Figure 4 also gives the major choices of insecticides available, drawing attention to those of reasonable stability and those that are rapidly broken down by temperature, light and hydrolysis and that are thus more suitable for use as transient aerosols and fogs as they satisfy both environmental and genetic selection requirements.

The original planning of the program must select the basic strategy of control, aiming at either residual or transient treatments; in either case the total treatment of habitations and peridomestic areas is the ultimate aim of the campaign.
Summary

Vector control will seldom be a priority in the immediate aftermath of a natural disaster. Environmental sanitation, basic health services, disease surveillance, housing, etc. are more important. Yet vector- and rodent-borne disease can occur in epidemic proportions as a result of changes produced by a disaster.

A disaster may require the same operational procedures as should be followed in an epidemic of the vector-borne disease. Many of the problems discussed in the paper of Giglioli will be encountered in the aftermath of a disaster. Of course, occasionally the vector-related disease is not one handled by the vector control service and confusion will arise.

Vector control is traditionally a vertically structured operation. In the past the operations were quasi-military. Today many of the control activities are being transferred to the community or to the primary health care workers. As stated earlier, there should be a disaster committee or civil defense organization that could assume coordination of disaster relief.

Vector control should be a part of any medical component. If there is a vector control agency, the superior officer should have the responsibility of being the central coordinator of the vector activity. Figure 3 in the assigned reading provides a good diagram of vector control operation. Regardless of the administrative structure most of the activities listed would be or should be routinely done. The activities would change somewhat with the target organism involved.

Good administration includes knowing the priorities of the activity, being able to provide for optimal use of available resources, and continually improving the standard and performance of the service provided. Communication must include those affected directly by the disaster so they understand the actions taken and their cooperation will be forthcoming. Cooperation with the public as well as within and outside of the operation will be a key to its success.

As a result of a natural disaster, a number of factors will have to be assessed. Since many different agencies are involved, preplanning and the development of a strategy will be necessary. The best way to deal with a disaster is to learn the appropriate responses before the disaster happens. One way is through simulation training exercises. These should include persons within disaster committee agencies, individual agencies, and, if possible, community agencies.

Another aid to preparedness is to study the past. Many geographical areas are subject to the occurrence of various disasters. There are areas with earthquakes, others with floods, etc. Studying what was done in the aftermath of a previous disaster and what went wrong should help to reduce the occurrence of many problems.

Almost any disaster will produce some movement of the human population. In many disasters there will be extensive destruction of housing. The section on malaria vectors indicated that where house damage occurs, especially where water is involved, residual action of insecticide will be less effective. The crowding of humans and the potential of vectors and reservoir hosts being congregated with humans must be considered.

One recommendation in disaster planning is the production of hazard zone maps. In many instances where a vector control service exists, this will have been done as normal operating procedure and be available to other agencies. Malaria and anti-Aedes aegypti control agencies, as well as similar agencies, have sectional maps usually large enough to show individual houses. Furthermore, especially those houses in rural areas will have a malaria number, and
many vital statistics on the occupants will be available. These maps will greatly facilitate assessment of the disaster impact and assessment of shelter, sanitation, roads or other ground or water transportation networks.

Where traditional vector control operations exist, the disaster staff may find available such basic transport needs as bicycles, mules, canoes, and motor vehicles. In addition the operational staff will know the people and the terrain better than staff of most other agencies. This type of expertise should be utilized where needed, but not to a point where it jeopardizes their own activities to a level where increases in the vector-borne disease could be expected.

Two basic problems may plague the vector control specialist following an emergency. One is the lack of jurisdiction and not knowing who does what; the other may be the absence of the technology to accomplish the goals. The latter can be solved in part through planning within routine vector control programs. If these are well organized and equipped, the technology will most likely be available to solve the problem.

Planning should include the selection of the type(s) of control measures to use, control cycles needed, and an idea of the duration of the measures. It should also include evaluation and assessment of all activities as they progress. Since a disaster will cause a strain on a control budget, a program manager should have a costing of each type of routine exercise (including manpower, insecticides, equipment maintenance, transportation, and indirect administrative and technical costs).

Planning should also consider:
1. Geographical distribution of the vector.
2. Most effective control measures under prevailing climatic conditions.
3. Crucial vector population density level to begin control measures.
4. Logistics of the operation.
5. Environment and ecosystems involved.

Most of the information given above is related to the common sense and experience of the vector control manager rather than to special aspects dealing with a natural disaster. The control manager, through his/her day-to-day operations, should have gained the information required to handle disaster-related vector problems. The basic requirement is to be flexible to adapt to the different situations.
Lesson 11 - Self-assessment test

Multiple Choice
Circle the correct answer(s):

1. Which ministry or governmental unit should have responsibility for administering a vector control program?
   a. health
   b. environment
   c. either a or b
   d. tourism
   e. any of the above

True/False
Indicate T or F:

_____ 2. Final selection of control technique for an Integrated Pest Management (IPM) program may depend on the logistics involved or funds available.

_____ 3. As many survey methods as possible should be used in vector control field operations since this will provide a greater amount of data upon which to base decisions.

_____ 4. Selection of techniques and insecticides for an Integrated Pest Management (IPM) program must be based on status of the vector’s resistance and the risk of loss of susceptibility during the program.

_____ 5. In organizing a vector control program, a small, mobile staff is usually preferred over a labor-intensive program.

_____ 6. The operational procedures required of a vector control program during an epidemic are quite often the same as those followed in an on-going program.

_____ 7. One of the most important communication links in a vector control organization is between the program headquarters and the treasury.

_____ 8. Immediately after a disaster, assignment of vector control field staff to other duties may be justified since they know the people and terrain better than the staffs of other agencies.

Answer Key

1. e
2. True
3. False
4. True
5. True
6. True
7. True
8. True
Lesson 12 - Epidemiology and vector control

Study Guide
Epidemiological principles and information are helpful in planning for and responding to vector-borne disease problems following a sudden natural disaster. Knowledge of past or present geographic distribution of diseases in a region; interaction of the host, parasite and vector; environmental factors that are favorable or unfavorable to disease control; and the cyclic nature of many vector-borne diseases are all important to setting priorities and making decisions in disaster management.

Learning Objectives
• Recognize the importance of epidemiology of vector-borne diseases in vector control.
• List three living factors that must be present to create the possibility of an epidemic.
• Understand the unified view of epidemiology and its application to control of vector-borne diseases.

Learning Activities
• Read excerpts from "Epidemiology and Control of Vector-Borne Diseases" in this study guide.
• Read the summary in this lesson.

Evaluation
Complete the self-assessment test.

Notes
Supplementary reading

Approach
An attempt is made by the authors to present the important principles of the epidemiology of vector-borne diseases in general. Although a specific disease may be used repeatedly to illustrate a series of principles, no attempt is made to give in detail the epidemiology of any disease. Control is presented essentially as an outline of methods only.

When a disease smolders at a low level in an area, an epidemic may develop when the quality of nutrition declines, environmental sanitation breaks down, or there is increased crowding and stress. Under such conditions subclinical or mild cases of disease become moderate to severe, and severe cases end in death.

Environmental Relationships
Interplay between the three living elements, host, parasite, and vector, mentioned previously as primary living factors in a vector-borne disease, and with other factors, physical, biological, and social, determine whether or not infection and disease will result. A diagram of these relationships is shown in Figure 1.

![Figure 1: Diagram of effect of environmental factors on the three primary living elements and an incidental host in a vector-borne disease.](image)

The Parasite
Parasite - A small organism or virus living in or on, and at the expense of, a large one.

When used in the context of the epidemiology of disease, the term "parasite" is usually synonymous with causative agent. However, clarity is often sacrificed in using the terms "parasite" and "agent". An infected Oriental rat flea may be a true ectoparasite on a rat. At the same time, it is a vector of true internal parasites, known as endoparasites, such as plague.
bacteria or the rickettsia that cause murine typhus. A similar dual meaning attaches to the term "agent", which usually refers to the causative or parasitic agent of disease-causing organisms.

Kinds
There are six groups of parasitic agents that cause vector-borne diseases in humans. These are shown in Figure 2.

| 1. Viruses—yellow fever, dengue, encephalitis, rabies |
| 2. Rickettsiae—spotted fever, typhus, rickettsialpox, "Q" fever |
| 3. Bacteria—plague, tularemia, relapsing fever, leptospirosis |
| 4. Protozoa—malaria, Chagas' disease, amebic dysentery |
| 5. Helminths—filariasis, broad fish tapeworm disease, Asiatic lung fluke disease, trichinosis |
| 6. Arthropods—scabies, pediculosis, myiasis, chigoe flea infestations |

Figure 2: Kinds of parasites which cause vectorborne diseases of humans.

Specificity
Parasitism Versus Clinical Manifestations
Often, one species of parasite causes a specific disease condition; however, there are frequent exceptions. Malaria mimics many diseases, dengue can be caused by very different viruses, and the uninformed would consider bubonic and pneumonic plague, both caused by *Yersinia (=Pasteurella) pestis*, as separate diseases. Hence, the physician and public health worker must rely on laboratories to accurately identify a parasite to provide the basis for an effective control program.

Host Range
The following quotation from "Epidemiology" (Fox et al., 1970, p. 51) points out the significance of the breadth of range of host and vectors a parasitic agent can infect, as this affects its success.

Host range is the spectrum of animals and arthropods an agent can successfully parasitize or infect. The broader the range, the greater are the possibilities for successful links in the transmission and reservoir mechanisms. Among agents utilizing arthropod vectors we may compare St. Louis encephalitis virus with *Rickettsia prowazekii*, the cause of epidemic typhus. St. Louis virus infects many avian and mammalian species and also parasitizes a wide range of mosquitoes. The typhus agent, in contrast, has but one mammalian host, the human, and but one arthropod vector, the human body louse.

The Vector
Vector - The living transporter and transmitter of the causative agent of disease.

Arthropod Vectors
Taxonomic Groups

The arthropod vectors of human diseases are mainly in these six orders: Diptera, Siphonaptera, Orthoptera, Anoplura, Hemiptera, and Acarina. These are illustrated in Figure 3.
While conducting initial studies of a vector-borne disease to establish vector and host relationships and, subsequently, while investigating epidemics that may occur, services of an expert taxonomist may be needed. Control measures often hinge on the habits of precise species that must be coped with.

**Characteristics of the Arthropod Element In the Transmission Cycle**

A number of factors influence the vector capability of an arthropod. The more important ones are characterized below:

**Ability to become Infected** - Mosquito species of only the genus *Anopheles* can become infected with human malarial parasites. On the other hand, several species in the general *Aedes, Culex, Anopheles,* and *Manosonia* can become infected with Bancroftian filarial parasites.

**Ability to transmit the parasite to a susceptible host** - Some species of *Anopheles* are for various reasons better transmitters of malaria than others. For example, entomologists working at the National Institute of Health, Laboratory of Parasite Chemotherapy, Chamblee, Georgia, have documented striking differences in ability to transmit on the part of several anophelines maintained in laboratory colonies (Coatney et al., 1971). Flea species such as *Xenopsylla cheopis,* whose digestive tract commonly becomes blocked with plague bacilli, are much more dangerous vectors than are species not so susceptible to blocking.

**Willingness to bite humans repeatedly** - Other factors being equal, the most dangerous vectors of malaria are those anophelines that prefer human blood (are anthropophilic). At least one species (provisionally designated as species "C" of the *Anopheles gambiae* complex) has such a preference for animal blood (is zoophilic) that it is not an important vector of human
malaria in Africa (Davidson in Wright and Pal. 1967, pp. 211-250). The Oriental rat flea, *Xenopsylla cheopis*, readily bites humans and is an efficient vector of plague, but certain fleas of wild rodents, although important in the plague transmission cycle among rodents, seldom feed on humans and are unimportant as human vectors.

**Survival rate** - Arthropods that transmit biologically must live long enough to become infective (must survive the extrinsic incubation period). The relatively long life of *Anopheles gambiae* contributes to its efficiency in maintaining "stable malaria," a type difficult to control. By contrast, the shorter life of *An. culicifacies* helps make it a less efficient vector in areas of "unstable malaria," a type more easily controlled (see Macdonald, 1958, Chap. 4).

**Domesticity** - Close association of an arthropod vector with humans contributes to its efficiency. The important vectors of Chagas' disease in humans are those triatomine bugs that live in houses. The fact that *Aedes aegypti* breeds primarily in or near human dwellings is an important factor in making this species a vector of explosive epidemics of dengue and urban yellow fever.

**Effects of Environment on Vectors and Transmission**

![Figure 4: Time-temperature relationships in the lengths of incubation periods of the yellow fever virus in Aedes aegypti.](image)

A comprehensive discussion on the effects of various environmental factors on vectors goes beyond the scope of this publication. However, two climatic factors will be treated briefly, as examples.
**Temperature** - Yellow fever and dengue outbreaks in the United States have usually occurred in summer and extended into fall until cold weather has killed infected yellow fever mosquitoes.

**Water** - Seasonal outbreaks of mosquito-borne diseases are often synchronized with rainfall or are related to irrigation practices.

*Coastal flatland malaria of the Caribbean.* Very few cases of malaria occur in the dry season during the winter months. New cases begin appearing in May, shortly after the beginning of the rainy season, preceded by significant rises in populations of the major vector, Anopheles albimanus.

*Mountain malaria of the Andes.* Populations of Anopheles pseudopunctipennis increase as the rainy season ends and brook-pool breeding places stabilize. The malaria season correlates with the dry season.

**The Host**

Host - Any living animal or plant affording subsistence and, often, lodging to a parasite.

**Types of Hosts**
The parasites that cause many vector-borne diseases have a life cycle that takes place in two or more hosts of different species. One of these hosts may perform the function of vector in transmitting the disease agent to the other host.

An animal in which a parasite either attains maturity or carries out its sexual cycle is called a primary host or definitive host; an animal in which the parasite is in the larval stage or carries on asexual development is a secondary host or intermediate host (see Table 1).

<table>
<thead>
<tr>
<th>Type of Host</th>
<th>Malaria</th>
<th>Filariasis</th>
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<tbody>
<tr>
<td>Primary (definitive)</td>
<td>Mosquito</td>
<td>Human</td>
</tr>
<tr>
<td>Secondary (intermediate)</td>
<td>Human</td>
<td>Mosquito</td>
</tr>
</tbody>
</table>

Table 1: Host relationships in two mosquito-borne diseases.

Since it is not possible to apply "asexual" and "sexual" to viruses, rickettsiae, bacteria, or leishmaniae which have no sexual forms, a modified terminology is proposed by Chandler and Read (1961, p. 17). They prefer to use the terms "definitive" for the vertebrate host and "intermediate" for the invertebrate host, or even more simply "vertebrate" and "invertebrate" hosts.

**Intrinsic and Extrinsic Incubation Periods of Parasites in Hosts**
In many vector-borne diseases caused by parasites that develop in two hosts, there is an intrinsic incubation period - the time interval between the entrance of the parasite into the vertebrate host (usually humans) and the appearance of clinical signs and symptoms of the
disease. There is also an extrinsic incubation period - the time interval between the acquisition of the parasite by the invertebrate host (the vector) and the point in time when it can pass on the parasite to a new host (thus becomes infective). This development of the parasite is dependent upon the production of infective stages (malaria plasmodia, for example) or infective concentrations (encephalitis viruses, for example) and their transfer to a location in the body of the vector (often the salivary glands) from which they can be transmitted.

A knowledge of the incubation periods of pathogenic organisms in humans (or other vertebrate hosts) and in arthropod vectors is essential in investigating epidemics of, or in controlling, vector-borne diseases.

Immunology

**Susceptibility Versus Resistance**

A host is susceptible if, after infection by a specific parasite, disease is the result. Full resistance is defined as failure of the parasite to develop after infection, and partial resistance when only subclinical infection or mild disease results.

The quality of resistance is determined by the effect of the sum total of body mechanisms that interpose barriers to the progress of invasion, growth, and multiplication of parasitic agents. Resistance is of two types: nonspecific and specific.

**Kinds of Immunity Against Infectious Diseases**

Classically, immunity has been classified as natural or innate (immunity that is inherited) and acquired (immunity a person develops after embryonic life commences). We will not deal with typical natural immunity, which includes individual or racial immunity, but will elaborate briefly on acquired immunity as applied to vector-borne diseases. Such immunity may be acquired naturally or artificially.

**Naturally acquired immunity** - When a newborn child is protected from a disease by antibodies received during gestation from the mother who has recovered from this disease, this naturally acquired immunity is of the passive type. An example is the immunity to malaria seen in infants born in areas of high malarial endemicity. This immunity lasts only a few months.

The active type of immunity results from antibodies produced after disease or subclinical infection. Examples include yellow fever, plague, typhus, and encephalitis. This immunity is usually long lasting. However, with some diseases, malaria for instance, active immunity is short lived.

**Artificially acquired Immunity** - As the name implies, this type of immunity results from an artificial procedure. The passive type results from the use of serum or gamma globulin to lessen the severity of reaction to parasites while the body builds its own protective antibodies. An example in the area of vector-borne diseases is found in the experimental treatment of typhus with hyperimmune serum. The active type comes from protective antibodies resulting from vaccines to give initial protection and periodic "booster shots" to maintain high-level immunity. Examples are vaccines for yellow fever and epidemic typhus.

**Endemic versus epidemic areas** - A large proportion of the population in an endemic area (where disease exists continuously but often at a low level) may have had a particular disease and have recovered or have had subclinical cases, either of which would give immunity. Outsiders, however, lacking immunity, fall easy victim to the disease. There are well-known
areas of endemic disease - sandfly fever in the Mediterranean region, for instance, and malaria in much of the tropics, as well as scrub typhus in the Southwest Pacific. Epidemics frequently occur among groups of visitors in these areas.

Epidemics tend to die out from diminution of the reservoir of susceptibles, e.g., yellow fever in stable island populations. Those previously exposed who survived are unaffected when re-exposed to parasites because of long-lasting immunity due to persisting antibodies.

Effects of Habits of Human Host on Disease
A wide variety of human habits affect the occurrence of vector-borne diseases. One example involves dwellings.

Location and Types of Dwellings
Humans can increase or decrease the risk of exposure to certain vector-borne diseases by their choice of dwelling locations. The effective flight range of many mosquito vectors is from one to two miles. Consequently, the location of military camps at a distance in excess of two miles from Anopheles breeding sites and from native villages, where human reservoirs are found, has been used effectively by the United States military services in keeping down the incidence of malaria.

The amount of protection from arthropod and/or vertebrate vectors of disease provided by human dwellings bears directly on the incidence levels of various diseases. Rodent-proof dwellings with well-fitted screens that exclude most flying insects contribute to the control of certain vector-borne diseases. By contrast, simple dwellings often found in rural regions of developing countries, such as Bolivia, offer no protection from mosquito-borne diseases. On the other hand, they provide excellent harborage for the triatomid kissing bugs that carry Chagas' disease and allow rodent vectors of Bolivian haemorrhagic fever to enter and transmit this disease indirectly to humans by contaminating food and cooking and eating utensils.

Exposure due to inadequate or nonexistent housing, often accompanied by crowding and poor sanitation such as prevails among combatants, prisoners of war, and refugees, encourages epidemics of certain vector-borne diseases. For example, typhus was a prevalent and much feared disease during every war until the latter years of World War II. Early in this war, during the North African and Southern European campaigns, body lice - typhus vectors - which multiply enormously under the crowded, unsanitary conditions prevalent in war operation areas, were effectively controlled. This was the first major use of DDT, the then new "wonder insecticide," in solving a public health problem.

Epidemiologic Classification of Disease In Humans
Diseases are classified mainly as epidemic or endemic.

Epidemic Disease
An epidemic or outbreak is the occurrence, in a community or region, of illnesses of similar nature, that clearly exceed normal expectancy and derive from a common or a propagated source. There is no general agreement to distinguish between the terms "epidemic" and "outbreak"; however, the latter term is frequently used when only a small number of cases is involved. Thirty years ago, a dozen cases of malaria in southern United States would not have been considered an epidemic; today, two or more cases would be so classified. In the United States today, one case of plague, yellow fever, or epidemic typhus is considered either an epidemic or a potential epidemic, meeting the requirements in respect to reporting of an epidemic (Beneson, 1970, pp. 289-290). How much above "the average number" the incidence must be before it is regarded as epidemic disease is a matter of judgment based on experience.
The greater the fear of the disease, as of encephalitis, the smaller the number of cases needed to justify the term "epidemic."

Epidemics may be classified as pandemics, long-term epidemics, short-term epidemics, or irregular epidemics.

**Pandemics** - Epidemics occurring over a wide geographical area (plague is a classic example) are called pandemics.

**Long-term epidemics** - Records of some vector-borne diseases indicate that they appear in cycles. Malaria and tularemia are examples. The rises and falls may be due to a combination of factors, such as immune status of host and reservoir, numbers of vectors, and environmental influences.

**Short-term epidemics** - Disease prevalence undergoes seasonal fluctuations. These are observed in diseases such as malaria, arthropod-borne encephalitis, spotted fever, murine typhus, and epidemic typhus. Some diseases are prevalent during the spring, others during summer, fall, or winter.

**Irregular epidemics** - Epidemics occurring at irregular intervals may be due to any factor or combination of factors that facilitate transmission above the normal level. The extent of the epidemic varies considerably, depending on previous history of the disease in the area, disturbance of communal immunity, introduction afresh of the parasite, introduction afresh of a vector, change in vector density, or change in weather (Macdonald, 1957, pp. 49-55).

Examples of irregular epidemics of diseases absent from a community for a long time or previously unreported are the outbreak of yellow fever in Trinidad in 1954 after the absence of the disease since 1914, and the outbreak of Eastern encephalitis in Massachusetts in 1938 (Feemster, 1938), the first recognized occurrence of this disease in the state. In 1971, the first recognized epidemic of Venezuelan encephalitis in the United States occurred in Texas.

An irregular epidemic that followed the introduction of a vector is illustrated by the huge outbreak of very severe malaria in Brazil in 1938. This epidemic was attributed primarily to importation of a very efficient, long-lived African malaria vector, *Anopheles gambiae* (Macdonald, 1957, p. 51).

**Endemic Disease**

When a disease is constantly present to a greater or lesser degree in a district or particular locality, it is called endemic. In malaria eradication campaigns, particularly in the tropics, four types of malaria endemicity have been described (Macdonald, 1957, p. 80) as follows:

**Holoendemic malaria** - Spleen rate (percent of people with enlarged spleens) in children (2-10 year age group) constantly over 75 percent, and adult spleen rate low.

**Hyperendemic malaria** - Child spleen rate constantly over 50 percent, adult spleen rate also high.

**Mesoendemic malaria** - Child spleen rate 11 to 50 percent.

**Hypoendemic malaria** - Child spleen rate 0 to 10 percent.
Yellow fever, first introduced into Havana, Cuba, in 1649, was endemic until 1901 except for its absence during the period 1655 to 1761 (Carter, 1931, pp. 188-194). This occurred because the city provided a number of nonimmunes, sizable enough to maintain the disease at a low level. These were of two classes: 1) newborn babies, and 2) immigrants and soldiers from Spain who had never had the disease.

For one and one-half centuries, Havana was one of the focal points from which epidemics of yellow fever originated, the virus being carried by boat to other areas in the Western Hemisphere either in infected people or in infected mosquitoes. In other cities farther north, as Philadelphia, Pennsylvania, the epidemics of yellow fever tended to burn themselves out or were terminated when cold weather killed the infected *Aedes aegypti* mosquitoes. Hence, these urban areas did not continue as endemic foci of yellow fever.

**Host Age Patterns of Disease**

Age is a definite factor in susceptibility of the human host to a number of vector-borne diseases. In some, the very young are more susceptible (see Figure 5), while in others, high susceptibility is seen in the middle aged (see Figure 6) or the very old. In still other diseases, age is not a factor of susceptibility.

![Figure 5: Malaria in a highly endemic area.](image)

The Reservoir

Reservoir - A single or a few vertebrate and/or arthropod hosts in which a parasite is maintained for a lengthy period (James and Harwood, 1969, p. 62).

Elements in the reservoir, as just defined, are either vertebrate hosts (sometimes also vectors) or invertebrate hosts (usually also vectors). However, not all hosts are important reservoirs. Although this definition is adequate for most vector-borne diseases, nonliving reservoirs (such as soil and water) are important in some. "Lengthy period" as used in the definition of reservoir may need to be loosely applied when studying some arboviral diseases and certain other diseases in which no long-term reservoirs have as yet been clearly identified. In certain of these,
short-term reservoirs, in which the parasites amplify, are very important in the disease cycles. A better understanding of the epidemiology of a disease and how it can be controlled should result from discussion of the concept of the reservoir.

Humans
Humans are the reservoir in certain arthropod-borne diseases, including malaria, urban yellow fever, dengue, and epidemic typhus. These vector-borne diseases, whose cycles include only humans as the reservoir, and whose main vector is only - or primarily - one species of arthropod, are often vulnerable to simple control procedures that are highly successful. Decline in their incidence in many areas has been dramatic.

Human mobility often makes people unknowing, but often effective, contributors to the spread of certain vector-borne diseases. This is particularly true while a human is filling the role of reservoir in the disease cycle. Yellow fever and dengue have been repeatedly introduced into areas by human carriers in whom the disease was in the process of incubation, before clinical symptoms appeared. Similarly, malaria has been introduced many times into uninfected areas by carriers who entered during the incubation period or the chronic or convalescent stages of the disease, or by people in whom malarial attacks were abortive, atypical, mild, moderate, or relapsing.

The human's role as a reservoir of a specific disease-producing parasite may be of short duration (a few days in the case of urban yellow fever), of moderate duration (up to two or three years in vivax and falciparum malarias), or prolonged (40 years or more with epidemic typhus - Wilcocks, 1959).

Humans are abnormal dead-end hosts of certain diseases and hence are not a reservoir. Audy (1958, p. 314) has written that a particular host may harbor a parasite without maintaining it (perpetuating it); hence, he distinguishes between "maintaining hosts" (reservoirs) and "incidental hosts." Examples of the latter are the parasite *Rickettsia tsutsugamushi*, causing
scrub typhus, and the viruses that cause some of the arthropod-borne encephalitides in humans. This nonmaintenance in such diseases is because the rickettsia or virus does not normally develop to a high enough level in the human host for him/her to become a reservoir and serve as a source of pathogens for reinfection of arthropods.

Nonhuman Vertebrates
A disease that has a nonhuman vertebrate as its principal host and reservoir is called a zoonosis. Mammals may act as reservoirs of a number of such diseases including plague, tularemia, murine typhus, relapsing fever, and Chagas' disease.

Birds, either resident or migratory, are short-time reservoirs of the viruses of eastern, western, and St. Louis encephalitis. The size of the small-bird nestling population and the level of virus amplification that occurs therein may be important factors in determining the degree of hazard to humans. Nestlings are much easier for mosquitoes to feed on than are adult birds because of the absence or scantiness of feathers.

Arthropods
Ticks, often with long life cycles, and mites may serve as reservoirs of infection. Examples include ticks that harbor the relapsing fever spirochete, the rickettsia that causes spotted fever, and the virus that causes Colorado tick fever; and mites that are reservoirs of the rickettsia that causes scrub typhus. Transovarial transmission in which the parasite is transmitted from parents to offspring through infected eggs often occurs; hence, the vector often starts active life already infected and does not have to acquire the parasite from a host. This transovarial transmission, however, is not true of ticks that are reservoirs of Colorado tick fever.

Reservoirs are often genus- or species-specific. Well-known examples are *Boophilus* ticks serving as reservoirs of *Babesia* protozoans, which cause Texas cattle fever, and *Ornithodoros* ticks, reservoirs of *Borrelia* spirochetes, which cause endemic relapsing fever. Species specificity is shown in the latter. For example, *B. hermsii* is found only in *O. hermsi* and *B. turicatae* only in *O. turicata*.

Encephalitis viruses disappear within a few days after their appearance in birds, but mosquitoes, once infective, remain so for life. Some virologists thus consider mosquitoes as the more important reservoirs of eastern, western and St. Louis encephalitis.

Stability of Reservoirs
Although some reservoirs are transient or seasonal, others are quite stable and permanent. Locations of these stable reservoirs (along with the presence of suitable vectors and hosts) are called the foci of a vector-borne disease. Russian investigators, under the leadership of E.N. Pavlovskii, use the word "nidus" instead of "focus" and have emphasized and developed to a high level the study of "nidality" of disease.

Unified View of Epidemiology
In the foregoing discussion, the three living factors that may be present in a vector-borne disease cycle and the reservoir concept have been discussed individually. Passing reference has been made to other environmental factors that influence the presence or absence of disease. Although some relationships between the factors have been pointed out, the general approach has been to take a disease apart to get a good look at some of its components. Now it will be put back together by discussing the concept of nidality of disease and by presenting some life cycles of arboviral diseases.
**Nidus**
A vector-borne disease is not broadly and evenly distributed geographically, but occurs in nidi (singular, nidus), nests, or foci in which the pathogenic agent circulates freely, by means of vectors, among animal hosts, independent of humans. A human becomes a victim when he/she becomes exposed to the vectors by entering a nidus of the disease.

**Biogeocenose**
An association of animals and plants (a biocenose), together with physical environmental characteristics of climate, microclimate, geologic structure, soil, and water supply, constitutes a biogeocenose. (A synonymous term used by U.S. workers is ecosystem.) A nidus of a vector-borne disease has its own characteristic biogeocenose or biogeocenoses. By learning to recognize these living and physical characteristics of a nidus, persons can pick out nidi in new and unsurveyed areas by applying what might be called "landscape epidemiology." This consists of recognizing characteristics of the locality under survey that suggest the likelihood of a disease being present or absent.

**Nidal Centers**
The term "nidus" is sometimes used to indicate a more expanded territory, sometimes called a nidal center, where a disease is prevalent due to one or more transmission patterns. This expanded territory may contain many nidi (used in the narrow sense) that may be discontinuous (see Figure 7). Within a nidal center may be an epicenter where the disease is especially prevalent.

![Figure 7: Known and probable foci and areas of plague, 1959-1979.](image)
**Comprehensive Definition**
The following definition of natural locality (nidality) of diseases is proposed by Cerny (1965, p. 481).

...the natural focality can therefore be defined as a phenomenon in which a given pathogen circulates within biocenoses formed during the evolutionary process independently of man or of animals and plants cultivated by man, which can be drawn into circulation of this pathogen as a new link in the chain.

This definition would seem to exclude mabria, dengue, or other diseases in which humans are the principal or only host. However, Russian workers definitely include these among diseases that display nidality.

**Plotting Disease Cycles**
As workers gather information on vector-borne disease, they have found the practice of plotting cycles helpful in understanding their various epidemiologies. This provides a coordinated view of what is known and is not yet known. As an example of the utilization of this procedure, workers in the Arbovirus Ecology Laboratory of the Center for Disease Control have composed and made available some unpublished charts of the disease cycles of selected arboviruses, as understood in 1971. These are reproduced as Figures 8 through 11.

![Figure 8: Dengue virus cycle in tropics.](image1)

An examination of these will show they vary greatly in complexity. The most direct and simple are dengue and yellow fever. Increasing complexity is seen in cycles of the various encephalitides; for example, Venezuelan encephalitis, with distinct endemic and epidemic cycles, is very complex. It may also be noted that the ways in which the encephalitis viruses overwinter in a temperate area are still unknown.

![Figure 9: Yellow fever virus cycles in tropical America.](image2)

![Figure 10: EE virus cycle in U.S.](image3)

![Figure 11: Endemic cycle of VE*.](image4)
Summary
Humans, their pathogens and insect vectors, are all members of a community of associated organisms having a common physical environment at least part of the time. If the physical environment changes there may be either a harmful or beneficial effect on any one or all three of these organisms. Natural disasters may destroy breeding sites for certain vectors or increase the sites; for example, when a vector depends on temporary pools for development of immature instars, there may be a good correlation between a vector-borne disease and precipitation. The disaster may alter human living conditions, such as producing crowding and unsanitary situations that will enhance the vector-pathogen-human linkage. Or, the human migration associated with the disaster may introduce a new pathogen into a susceptible population.

Each disease has certain characteristics that will help an epidemiologist assess its potential risk following a natural disaster. One aspect is whether or not a seasonal pattern of the disease exists and if it is correlated with any factors related to the disasters. In this case the factors producing the disease pattern must be known as well as how the factors are changed. The disaster may decrease the change in an immediate problem, for example, by slowing vector development and prolonging emergence. On the other hand, it may favor an epidemic by increasing the survival of the vector, increasing its dispersal, or congregating the vector or reservoir in close proximity to humans.

Mosquitoes are closely associated with the water environment of immature instars. Rainfall increases most mosquito breeding sites. The population density of many artificial container breeding mosquitoes, such as *Aedes aegypti*, may first be reduced by flushing the larvae from the containers, but by producing more water-holding containers, many of which may have had *Ae. aegypti* EGGS, the population soon increases. The same situation exists for those *Ae. aegypti* and other yellow fever and dengue transmitting mosquitoes living in natural containers, i.e. rock holes, banana and pineapple leaf axials, tree holes, etc.

Eastern equine encephalitis along the East Coast of the United States has been correlated with swampland flooding conditions following above-normal rainfall. The 1969 Venezuelan equine encephalitis epidemic in Ecuador was correlated with an increase of flooding.

Droughts can concentrate water and accumulate stagnant water, which can change the mosquito species composition. This would increase breeding of *Culex quinquefasciatus* and related species.

Epidemic malaria cannot always be explained by increased breeding sites of *Anopheles* arising from excessive rainfall. In some cases there will be extensive collection of temporary water as the water level following flooding declines. But production will depend largely upon the stability of these temporary breeding places. Any fluctuation of seasonal rainfall following the disaster may cause oscillation in the adult mosquito production. Flooding in association with high temperatures not only increases breeding sites but, by maintaining a high atmospheric humidity, extends the survival of infected mosquitoes. A temperature of 20° to 25° C and a relative humidity of 60% may greatly increase the chances of an epidemic.

Inundations have had a questionable role in malaria epidemics in Central and Northern South America, but in southern Brazil a drought followed by inundations may have been a factor in an 1829 epidemic in Macacu, Province of Rio de Janeiro, Brazil. Inundations have also been mentioned as having a role in malaria epidemics in Bolivia.
Scrub typhus is basically an occupational disease and has a well known geographical distribution. It is generally a rural disease, but there are urban examples. If placement of a temporary settlement in the endemic area was associated with a "typhus island" or a "mite island," an epidemic could conceivably occur. These "islands" may be produced by patching grassland that could congregate the mites. Colonies of mites might flourish where the soil is moist. Cutting the grass and packing the soil might limit the population densities of these mites.

There appears to be a defined temperature range for scrub typhus activity. In Japan scrub typhus occurs only after the mean temperature is above 15° C. The important factors with scrub typhus are to study the disease distribution maps and to know the disaster area in relation to the disease.

Plague may be associated with natural disasters. Pollitzer mentions the movement of free living animals (sylvan reservoirs) due to disasters such as floods. The population of commensal rodents may become higher in a changing environment such as would occur after a natural disaster. In some areas, historically, the annual period of maximum rat infestation corresponds with the annual plague season. This time period should be checked against the time of the disaster.

Plague is apt to be seasonal in temperate climates; as mentioned above, it is associated with the breeding cycle of the reservoir host. Therefore surveillance of the noncommensal rodents for an epizootic is important. At the same time surveillance of the degree of flea infestation in commensal and noncommensal rodents should be done.

Epidemics of pneumonic plague occur in the tropics but epidemics of bubonic plague seem to be rarer when the temperature is above 80° F (26.6° C). However, high humidity and moderately high temperature (68°-76° F) seem to be favorable to the metabolism of the flea and its transmission of the plague bacillus. On the other hand, some studies show that the mean life span of fleas may be reduced by high temperatures.

Unless the causative agent is present or there is a chance it will be transported into the area of a natural disaster, little concern should be placed on the possibility of excessive disease occurrence. The epidemiologist and the vector control specialist should be familiar with the causative agent, the vector or reservoir host, the mode of transmission, the incubation period in vector and humans, and the life history/population density of the vector. Preventive measures are ideally the best way to handle vector problems. These would include environmental sanitation by providing insect-proof latrines and adequate methods of waste-water disposal, and source reduction measures such as elimination of insect breeding sights. However, other priorities in light of the disaster may make this difficult. Consequently more reliance may be given to the use of chemicals against the adult and immature stages of the vector or pest. In this case, routine control should begin early. Although generally it is best to have a specific identification of the vectors and pests, experts might not be readily available to do this. In most cases it is best to begin control measures first with whatever resources are on hand and then to do the identification later. It should be stressed that species identification is necessary; once done, it might be necessary to change the control procedure.
Lesson 12 - Self-assessment test

Multiple Choice
Circle the correct answer(s):

1. If a disease is present at low levels in an area, which of the following may cause an epidemic to develop?
   a. decline in the quality of nutrition
   b. break down of environmental sanitation
   c. increased crowding and stress
   d. b and c
   e. a, b, and c

2. Interplay among which of the following three elements determines whether or not infection or disease will result?
   a. host, arthropod, vector
   b. host, parasite, vector
   c. host, vector, immunity
   d. host, environment, vector
   e. host, reservoir, vector

3. A vector’s capability to transmit disease may vary due to which of the following factors?
   a. ability to become infected
   b. survival rate
   c. domesticity
   d. a and c
   e. a, b, and c

True/False
Indicate T or F:

4. The population in an endemic area, where a specific disease exists continuously at a low level, requires a very active immunization program against that disease.

5. Age is a definite factor in susceptibility of a human host to a number of vector-borne diseases.

6. A disease endemic in an area with certain environmental characteristics (climate, ecologic structure, soil, water supply) is also likely to be found in another area with those same characteristics.

7. The disease cycle of dengue virus in the tropics is very complex.

8. Humans are a host, but not a reservoir, for arthropod-borne diseases.

9. Stable reservoirs, along with suitable vectors and hosts, create foci of a vector-borne disease.

10. Short-term epidemics are often related to seasonal fluctuations in the environment.

11. The disease cycle of Venezuelan encephalitis is very complex, with many unknown factors.

12. Humans are often a primary host to a parasite but never a secondary host.

Answer Key

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Lesson 13 - Pesticides and application equipment

Study Guide
This lesson deals with the complexity of the chemical approach to vector control. It presents the variety of options in selecting the correct pesticide, formulation, equipment and application to deal with an emergency. It also deals with precautions that must be taken to protect the safety of personnel, the population and the environment. The student will not be held accountable for all of the detailed information presented, but rather should gain an appreciation for the difficult role of vector control personnel in carrying out their duties following a sudden natural disaster.

Learning Objectives
• Recognize the complex factors a vector control officer must consider in chemical control of anthropods.
• Be familiar with the types of pesticides available, their formulations, and various methods of application.
• Know the hazards that storage and application of pesticides and disposal of containers pose for personnel, the population, and the environment.

Learning Activities
• Read excerpts from "Chemical Methods for the Control of Arthropod Vectors and Pests of Public Health Importance" on page 78 of this study guide.
• Read excerpts from "Insecticides for the Control of Insects of Public Health Importance" on page 81 of this study guide.
• Read "Methods of Disposal of Surplus Pesticides and Pesticide Containers in Developing Countries" on page 87 of this study guide.
• Read the summary in this lesson.

Evaluation
Complete the self-assessment test.

Notes
Supplementary reading
Excerpted from A. Smith, "Chemical Methods for the Control of Arthropod Vectors and Pests of Public Health Importance," WHO/VBC/82.841, Rev. 1

Brief review of methods of control of principal Insect vectors and pests
Effective application of any control measure must be based on a fundamental understanding of the ecology, bionomics and behavior of the target species and its relation to its host and environment. Effective vector control also requires careful training and supervision of post control operations and periodical evaluation of the impact of the control measures. Where possible environmental sanitation methods must be applied for each situation in conjunction with chemical pesticides. The following is a general review of chemical control methods of principal insect vectors and pests. It provides ready reference for health officers responsible for vector control, with further details given in the different sections for each group of insects. It is emphasized, however, that some methods outlined in this guide have had to be based on experience acquired in one country only or in a single field trial and are therefore to be considered with caution before using them as the basis for large-scale operations elsewhere. Chemical control methods also require due regard to be given to the impact of the compounds used on the environment including fish, birds and beneficial invertebrates.

Mosquito control
(a) Malaria vectors - Before resorting to extensive chemical control measures, environmental management should be undertaken at a community level as far as is practicable. The principal sources of breeding should be reduced, e.g. by draining permanent pond, leveling small depressions, preventing seepage from irrigation and drainage canals, filling up small road excavations, etc. For reducing larval densities in their breeding places, village drains should be kept clear of rubbish, and ditches, streams and irrigation canals should be kept free of vegetation to allow free passage of water. Grass, weeds, and dense vegetation around houses should also be cleared.

Residual insecticide spraying is still the most widely used method of vector control in antimalaria programs, and is one of the measures employed to prevent, halt or retard the spread of drug-resistant malaria. Indoor residual spraying is generally more appropriate for rural than highly urban situations and can be effective where epidemiological findings reveal good prospects for its successful use. Key determinants of the effectiveness of an insecticide as an indoor residual spray are (1) the basic resting behavior of the mosquito vector; (2) the toxicity and period of effectiveness of the residual insecticide deposit to the vector mosquito; (3) the effects of the insecticide on the resting behavior of the mosquito (irritability, excito-repellency); and (4) the behavior of people in relation to their night shelters - which may or may not have sprayable surfaces. Where there is none, or only limited resistance to it, DDT is still the insecticide of choice, because it is comparatively inexpensive, has a long residual effect, and an unparalleled record of safety to humans. For DDT resistant vectors, organophosphorus compounds like malathion, fenitrothion and pirimiphos-methyl and carbamates such as propoxur and bendiocarb can be used. Other alternative insecticides, which proved satisfactory in village or larger-scale trials, are permethrin and deltamethrin in the pyrethroid group.

(b) Yellow fever and dengue/dengue haemorrhagic fever vectors - Basic sanitation and health education are the fundamental control measures. All unusable containers, tires, coconut shells, etc. in and around houses should be disposed of properly. Water-storage containers should be mosquito proofed and water in flower vases and ant traps, inside houses and offices, should be regularly emptied. Tree holes and bamboo stumps should be rendered incapable of holding water by being filled with gravel or punctured.
When environmental sanitation is not feasible, chemical methods of control should be considered. Application of temephos 1% sand granules to domestic stored water is effective for more than 8-12 weeks depending on usage of the water. Pirimiphos-methyl emulsion concentrate has given effective control for 11 weeks in water jars. Chlorpyrifos and fenithion emulsion concentrates or granules have given larval control in ant traps for 12 and 14 weeks respectively. A ULV formulation of fenitrothion sprayed into water jars and anttraps was found effective for seven months. Jodfenphos granules applied to water jars gave effective larval control for 16 weeks, and pirimiphos-methyl granules gave effective control for nine weeks.

While, in general, larvicides are mainly used for chemical control of the vectors, adulticides can be a most useful tool in certain situations, particularly for dealing with outbreaks of epidemic disease. ULV applications with malathion or fenitrothion from the ground or the air, or by fogging with 4% malathion or 1.6% pirimiphos-methyl in oil solution, are effective methods. ULV application of malathion outdoors has given significant reductions in adults and also in larval breeding. ULV applications of fenitrothion applied by a small portable nonthermal fog applicator to the exterior and interior of houses has given good immediate control of the wild population with continuing effectiveness for two months attributable to residual action. ULV applications of bioresmethrin or permethrin have been successfully used in many countries.

(c) Encephalitis vectors - Effective larviciding has been achieved by several insecticides applied from the air or from the ground. Chlorpyrifos and temephos have given good control. Aerial or ground ULV application of chlorpyrifos involved careful safety measures in view of its relatively high mammalian toxicity. Fenitrothion 1% dust was effective when applied once a week. Carbaryl dust has been found effective for a month. Nevertheless, unless a detailed epidemiological study pinpoints the risk area, larvicidal treatments may be particularly uneconomical compared with use of adulticides.

Aerial or ground ULV applications or thermal fogging are the principal means of combating disease outbreaks. Malathion, fenitrothion, propoxur, naled, chlorpyrifos, bioresmethrin, permethrin, and deltamethrin have given good control. Although indoor residual spraying is least used as most vectors rest mainly outdoors, animal shelters are sometimes sprayed.

Synanthropic fly control
Burying of garbage and any other accumulated organic matter, removal of animal excreta, proper management of privies, and other basic sanitation measures are the fundamental means for reducing or eliminating fly breeding sources. Sticky fly papers or dichlorvos dispensers may be hung in dwellings and animal shelters.

Controlled tipping should be practiced wherever possible when there is a supply of suitable covering material. The top and sides of the refuse dump should be covered each day, after tipping has ceased, with a 30 cm. deep layer of soil or sand, and then compacted. The heat generated by fermentation will kill many of the fly larvae. Very few of those larvae that are not killed by the heat will be able to emerge through the surface covering as adult flies. Those that do emerge can be killed by spraying or dusting the covered refuse with a suitable insecticide. The working face should not be treated with insecticides, unless flies become a serious problem, as there is then a greater risk that the flies will become resistant to the insecticides used, because the larvae will be developing in a medium contaminated by insecticide. Burning refuse in incinerators, or otherwise, is an effective method of preventing fly breeding provided that unburnt moist residues, in which flies develop, will not remain. When flies become a serious problem, organophosphates such as Diazinon or fenchlorphos may be applied to dumping sites.
as indicated above, but insecticides should be reserved, if possible, for outdoor space treatment during epidemics of cholera, dysentery and typhoid, in order to reduce the possibility of resistance developing to these chemicals. Treatment of resting places of adult flies or use of toxic baits may be employed for local fly control.

**Flea control**
Assiduous attention should be given to cleanliness of dwellings, pets and their sleeping quarters in order to reduce flea infestations. Under the supervision of the health authorities, the community should also participate in trapping rodents inhabiting its houses. Insecticide dusts maybe applied to rodent burrows and runways for control of flea larvae and adults, especially during plague outbreaks prior to implementing rodent control.

**Louse control**
Body louse infestations are usually associated with persons who do not regularly change and wash their clothes, particularly in conditions of over-crowding. Insecticide dusts are used to control heavy infestations, and especially for controlling or preventing louse-borne disease epidemics. Frequent washing and combing hair can reduce the possibility of head louse infestations. Pubic lice are generally transmitted venerally. Since heavy infestations of head lice generally occur among school children 6-15 years old, insecticidal lotion, shampoo or dust could be applied to infested children at school. A small amount of the lotion, shampoo or dust may be distributed to the students to bring home for the treatment of other members of the family.

**Insecticides used in public health**
As this guide cannot review all the pesticides known to be effective for the control of insect vectors and pests, and is not intended to reflect the extent to which any particular pesticide should be used in a vector control program, the decision to apply any compound rests with national health authorities or individual vector control personnel.

In selecting a pesticide and formulation, consideration should be given to its biological effectiveness against the pest concerned, susceptibility status to the target organism and hazard to humans and to their environment as posed by the proposed use. If possible, small trials on the efficacy of a formulation and application method should be carried out under local conditions before large quantities are acquired. Consideration should also be given to cost of the pesticide, transportation requirements and availability of equipment for applying it. The hazard of a compound is directly related to its method of use. The determination of cost should be based on the expense of the material as applied and not on the purchase price of the chemical. To save transportation expenses and because they are generally more acceptable to the population, emulsifiable concentrates are preferable to oils. However, in some cases larvicidal oil solutions may serve better than emulsions. The technical grade of a compound may be ordered for preparation of the formulated product if local facilities and skills are available.

**ULV applications**
During the last decade there has been a great increase in the use of ultra low volume (ULV) methods of insecticide application for control of vectors and pests of public health importance. The ULV technique involves the application of a volume of liquid from the air or ground which by definition is less than 51/ha. This type of operation has resulted in substantial savings in vector control programs through speed of operating, reduced labor requirements and associated handling costs. The size of the insecticide droplets is not defined by the term ULV. However, when ULV space treatments are applied, droplets in the aerosol-to-mist range are used.
Space sprays can be controlled reasonably well to give an effective compromise between the biologically optimum droplet size spectrum to achieve maximum kill and that which allows maximum insecticide dispersal within the target area. Greater utilization of ULV concentrates and of other ULV formulations in recent years has resulted in the control of outbreaks of arboviral diseases such as dengue haemorrhagic fever in Southeast Asia, Japanese encephalitis in Korea, western encephalitis in Canada, Venezuelan encephalitis and Murray Valley and Ross River encephalitis in the Pacific.

ULV applications, when used as space treatments, should be made in the evening or early morning to coincide with peak mosquito activity and stable weather conditions.

ULV cold aerosols and thermal fogs are equally effective against adult mosquitoes, although the latter use a higher volume of diluted spray per hectare. An advantage of cold aerosol application is that it does not produce a dense fog that may constitute a traffic hazard.

In cold aerosol generators, the insecticide is broken down into an aerosol by mechanical forces alone, without the aid of heat. With thermal fog generators, the insecticide is dissolved in an oil or water that is vaporized by injection into a high-velocity stream of hot gas. When discharged into the air, the oil carrying the insecticide condenses in the form of a fog.

**Supplementary reading**

Excerpted from "Insecticides for the Control of Insects of Public Health Importance," Center for Disease Control, U.S. Department of Health and Human Services, Revised 1981.

**Public Health Pesticides**

**Introduction**

Effective control of insects of public health importance requires the judicious use of both chemical and non-chemical measures. These two approaches to vector control supplement but do not supplant each other. Non-chemical methods, such as source reduction and biological control, can contribute significantly to vector control efforts but are seldom effective by themselves. Thus, pesticides remain essential to the control of disease vectors.

Patterns of pesticide development and usage have changed through the years. In the 1930s, vector control was in its infancy. Few synthetic pesticide compounds existed, and research was restricted to solving practical formulation and application problems. An era of intensive pesticide development led to the introduction of DDT and other chlorinated hydrocarbons followed by organophosphorus (OP) and carbamate pesticides. Advances in the design of application equipment also occurred.

Several problems have arisen affecting the usefulness of some pesticides. In particular, the development of resistance by some arthropods has brought about the need for alternative chemical or nonchemical methods of control. In addition, some highly effective pesticides, particularly the chlorinated hydrocarbons, have been found to remain in the environment for years and to accumulate in nontarget organisms, thus affecting food chains of fish, birds, and mammals. As a result, regulations have been imposed restricting or abolishing the use of these pesticides and more tightly controlling the use of others. As new regulations appear, economic considerations in the pesticide industry are affected: pesticide development becomes more expensive in money and time, and fewer pesticides are introduced. Nevertheless, a number of
effective and safe pesticides remain available for use in control of disease vectors. Their proper use will assure the continued value of these chemicals to public health for years to come.

Clearly, chemicals will continue to represent a major means of vector control in the foreseeable future; therefore the search for new compounds continues. The advent of problems associated with pesticide use means that in order to discover and develop the pesticides of the future, a much greater degree of sophistication will be required than before. As a result, insect control with chemicals has come a long way from its beginning as a branch of applied entomology and now delves into the biological and physical sciences and into engineering as well. Disciplines involved in development of pesticides and application equipment now include physiology, biochemistry, pharmacology, toxicology, organic and physical chemistry, engineering, and environmental studies as well as economic and medical entomology. The level of sophistication in the pesticides field now reflects that of the individual disciplines of which it is composed.

Types of Pesticides
Perhaps the most practical classification of pesticides is according to use - that is, by the formulation and target of the pesticide. For example, malathion may appear as an ultra-low volume (ULV) adulticide, a larvicidal wettable powder, a larvicidal emulsifiable concentrate, or dust. Most importantly, insecticide regulations are based on use, and the specific use of a given pesticide formulation is the basis for the pesticide label, which is the practical expression of the law. (Legal aspects do not apply in all countries.)

Other systems of insecticide classification are based upon the stage of insect life cycle acted upon (adulticides, larvicides, or oxicides); taxonomy of the target arthropod (acaricides for ticks and mites, pediculicides for lice); biochemical activity (cholinesterase inhibitor, microsomal oxidase inhibitor); or by the mode of entry into insects. Stomach poisons must be swallowed to cause death. Baits such as sugarwater containing dichlorvos for fly control are an example. Contact poisons, such as malathion applied by ULV for mosquito control, are volatile chemicals whose vapors enter insect bodies through spiracles and body surfaces. Some insecticides act, not as a result of penetration of the poison into the insect, but as a result of purely physical causes such as obstruction of the respiratory passages, causing the insect to die of asphyxiation. Mineral or petroleum oils used in larval control of mosquitoes serve as an example.

Finally, insecticides may be grouped by the chemical class to which they belong (chlorinated hydrocarbon, organophosphate, carbamate, etc.).

Insecticide Formulations
Insecticides are produced from natural or synthetic chemicals that kill insects readily but will not cause undue hazard to humans, animals, and plants when formulated and applied correctly. Some, such as malathion or naled in ULV applications, are applied as technical grade insecticides; others are made before application.

Technical grade insecticide is the basic toxic agent in its purest commercial form. It may be a solid, liquid, or gas. Its technical ingredients are rarely chemically pure due to unavoidable impurities remaining from the manufacturing process; however, they should be as pure as possible to avoid problems with solubility, formulating, grinding, stability, mammalian toxicity, odor or explosive hazards due to impurities.

Technical grade insecticide chemicals usually require further processing before use in vector control. "Formulation" is the process by which technical grade ingredients are made ready to be
used by mixing them with liquid or dry diluents, grinding, and/or by the addition of emulsifiers, synergists, stabilizers, and other formulation adjuvants. This may be done at the manufacturing plant, or the chemicals may be packaged and shipped in large containers to a formulation plant for formulation and repackaging into ready-to-use pesticide products.

**Liquid Formulations**

**Emulsifiable concentrates (EC)** or "spray concentrates" are liquid formulations obtained by dissolving technical grade chemical in a liquid solvent. One or more emulsifiers are added, so that the formulated pesticide can be further diluted with water for spray application. Several technical ingredients may be formulated into one emulsifiable concentrate formulation.

When the emulsifiable concentrate is added to water and agitated, an emulsion is formed and the concentration of insecticide is reduced to the desired strength for use in the field. Insecticidal solutions and emulsifiable concentrates usually are clear, whereas emulsions have an appearance similar to milk, which is a natural emulsion. Unlike solutions, most insecticidal emulsions require periodic agitation to prevent the concentrate from separating out from the solvent. Emulsions or solutions, diluted to field strength, are called "finished sprays."

Emulsifiable concentrates have the same advantages as solution concentrates, that is, low packaging and transportation costs plus the advantage that the diluent, water, is readily available.

Emulsifiable concentrate formulations are usually packaged in small (up to one gallon) metal cans or glass bottles or in tight-head steel pails or steel drums ranging from 2- to 55-gallon capacity. Many emulsifiable concentrates tend to attack or corrode steel and other metals as well as seaming and gasket materials and, therefore, require properly lined containers and special care in the selection of seaming compounds, gaskets, caps, bungs, and spouts.

Emulsions may injure varnished and painted surfaces due to the action of solvents such as xylene. Emulsions are often corrosive to metal sprayers and their fittings; sprayers used to dispense emulsions should be made of stainless steel, aluminum, fiberglass, or other noncorrosive materials. After use, the sprayers are easily cleaned by a water rinse.

Emulsions are widely used for the residual treatment of solid surfaces. Insects resting on these treated surfaces are killed by the insecticide residue. Some emulsions remain effective for a longer time on masonite or on bare or painted wood than on glazed tile or shiny metal. This is an important consideration in determining the time interval between applications.

**Solutions (S)** may be in the form of high concentrates or low concentrates. High concentrates are special formulations usually containing eight or more pounds of active ingredient per gallon. They may contain only the active ingredient itself. Most are designed to be used "as is" or diluted with petroleum solvents. They contain chemicals that allow them to spread and stick well. Ultra-low volume (ULV) concentrate materials should be used without further dilution. Low concentrates usually contain less than two pounds of active ingredient. Most of them are solutions in highly refined oils and need no further dilution.

**Flowables (F or L).** Some active ingredients can be made only as a solid, or at best, a semisolid. These are finely ground and put into a liquid along with other substances that make up the mixture and form a suspension. They are flowable solids. Flowables may be mixed with water. Unlike wettable powders, they seldom clog spray nozzles and need only moderate agitation. Most of them handle as well as emulsifiable concentrate formulations.
**Aerosols (A)** are liquids that contain the active ingredient(s) in solution in a solvent. Most aerosol formulations have a low percentage of active ingredient. They are made for use only in fog- or mist-generating machines and in aerosol cans.

**Liquified gases (LG) or fumigants (FM).**
Fumigants are volatile chemicals discharged into confined spaces to produce a gas that will destroy insects. There are two basic types of fumigants. The first group is made up of chemicals of low molecular weight and high vapor pressure, such as methyl bromide, ethylene oxide, hydrogen cyanide, hydrogen phosphide, and sulfuryl fluoride. These products penetrate quickly into cracks and crevices in enclosed spaces that can be completely sealed. The second group consists of compounds of higher molecular weight and somewhat lower vapor pressure that tend to volatilize and diffuse slowly. Examples are ethylene dibromide and ethylene dichloride. These products are more persistent and are used for fumigation in areas that cannot be made completely gas-tight.

Fumigants that develop pressure at ambient temperatures must be packaged in special, pressure-resistant containers.

All modern fumigants that produce effective control of pests are also extremely toxic to humans. Therefore, every fumigator must receive thorough training, must be provided with proper equipment, and must understand the hazards associated with the fumigants used.

**Dry Formulations**

**Wettable powders (WP) or "dispersible powders"** are finely ground, dry powders intended for dispersion or suspension in water for application in spray equipment. In producing wettable powders, dry technical active ingredients are finely ground and diluted with a suitable dry inert carrier material, usually clay. Liquid technical active ingredients are spray-impregnated on the dry inert carrier. In both instances wetting and dispersing agents are added for proper wetting in the spray tank and on treated surfaces. Sometimes stabilizers, anti-foaming agents, and/or further adjuvants are added. To be effective, wettable powder particles should remain suspended in water for a reasonable time. During use, suspensions should be agitated continuously or frequently to prevent settling of the solid insecticide particles or clogging of the strainer or spray nozzle. Wet-table powder suspensions tend to clog strainers and nozzles of sprayers when stored for long periods in humid areas or applied in high concentration. Trouble with suspensions may be experienced when using some municipal water supplies; soft waters may produce foaming while hard waters may require the addition of more wetting agent.

Wettable powders are packaged in sturdy paper or plastic bags; often a number of these bags are then packed in larger "baler bags," boxes, open-head fiber or steel drums, or on pallets under a suitable cover. Fiber drums may have steel or fiber tops or bottoms. Larger quantities of wettable powders may be packaged directly into drums.

Wettable powders need to be protected against moisture. Therefore, paper bags are usually constructed of several plies including a polyethylene or aluminum foil liner. Larger kraft bags or drums should contain an inner liner of polyethylene or equivalent material as a moisture barrier. The inner liner must be carefully sealed after filling.

Wettable powders have advantages over other concentrates. They do not have a tendency to irritate or be absorbed through the skin of the spray persons. Another advantage is the tendency of the insecticide to remain on the surface of the structure sprayed. When porous materials such
as concrete, plaster, adobe, or unpainted wood are sprayed with a suspension, the water penetrates, leaving the carrier and the maximum amount of insecticide on the surface available to kill insects. By contrast, solutions or emulsions penetrate porous materials leaving less insecticide on the surface. Wettable powders are abrasive to sprayer pumps and nozzles.

**Soluble powders (SP)** or "solution concentrates" are similar to wettable powders except that the technical active ingredient as well as the diluent(s) and formulating adjuvants used will completely dissolve in the liquid for which the soluble powder is formulated, usually water. The packaging requirements for soluble powders are basically the same as those for wettable powders. Protection from moisture is even more important for soluble powders.

Solution concentrates have the advantage of low volume, which reduces bulk, weight, and shipping costs. They are diluted at the destination, often in the field, making their portability a real advantage. The diluted mixture is termed a "field strength" solution. Oil solutions are used extensively in fog applicators, but are unsatisfactory for most dilute spray applications because of their toxicity to plants.

**Dusts (D)** consist of dry, finely ground carrier material containing an insecticide active ingredient. Dusts are intended for direct application, without further dilution, by suitable dust dispensing equipment such as simple dust guns, large power dusters, or aircraft.

Dusts usually contain low concentrations of active ingredient(s); and consequently, transportation costs in terms of active ingredient are high. For this reason, dilute dusts are often formulated from technical active ingredients or dust concentrates close to the point of use, rather than being transported over great distances. The packaging requirements for pesticide dusts are, in principle, similar to those for wettable powders. When dusts are formulated close to the time and location of use, somewhat less durable packaging may suffice.

Dusts are usually low in cost, easy to apply, nonstaining, and nontoxic to vegetation. Insecticides in dust form are generally not absorbed through the skin, but may be dangerous if inhaled. Dusts adhere poorly to vertical surfaces and are easily removed by rain and wind.

**Granular (G)** formulations have the technical ingredient mixed with or coated on inert carrier materials of the approximate particle size of granulated sugar. Clays, sand, ground corn cobs, and carbon are among the materials used as carriers for granulars. This type of formulation is intended for direct application equipment. Uniformity of particle size is necessary to assure proper application and distribution of granular pesticides. Packaging requirements for granulars are similar to those for other dry insecticides.

Insecticide granules do not adhere to leaves and, therefore, will penetrate dense foliage, a real advantage where it is desirable for the insecticide to reach the water surface for mosquito control in vegetated swamps. There is no drift problem with granules. The granular insecticide particles tend to remain where they are deposited and are not as prone as other formulations to be transported away from target areas.

**Bait (B)** formulations have the technical active ingredients mixed with edible or attractive substances. The bait attracts the target pests and the insecticide kills them when they ingest the formulation. The amount of active ingredient in most bait formulations is quite low, usually less than 5%.
Selection and Safe Use of Pesticides

Integrated Control
Selection of the proper pesticide should begin with a thoughtful analysis of the objectives of the control program and of the possible ways to achieve that objective. What pest is causing the problem? What is its current breeding potential? At what threshold will the pest become a public health threat? Are there other control means available (source reduction, biocontrol, etc.) and if so, will they control the vector sufficiently to alleviate a public health threat? Answers to such basic questions should be based on sound surveillance techniques and thorough knowledge of vector biology.

Although many insect control programs have relied almost exclusively on the use of chemicals, the most successful vector control programs have depended ultimately on the use of all available control methods in order to reduce vector populations and maintain them at levels that constitute a minimal threat to the public health. This judicious use of insecticides to supplement, not supplant, other methods of control is termed "integrated control."

Use of Insecticides
If it does seem advisable to use a pesticide, the exact placement of the pesticide in the control system should be plotted out and the following factors analyzed:

- **Legality** What pesticide formulations are registered for the task at hand? What special precautions are needed for their use?

- **Effectiveness** Which registered pesticides are best able to do the job? How rapidly do the compounds produce results and how often will repeat applications be required?

- **Insect resistance** How much resistance can be expected in the pests? Susceptibility testing is essential in some areas to avoid waste of time and money.

- **Storage and disposal** Are storage and disposal facilities for unused pesticides and empty containers available?

- **Competence and personnel** Are properly trained personnel available for handling and applying the pesticides to be used?

Application Equipment
Hundreds of different kinds of sprayers, dusters, aerosol generators, and other devices have been designed, manufactured, and marketed. The selection of the best equipment for a vector control program is of great importance since insecticide application problems may seriously affect such a program. The safe and efficient dispersal of insecticides to control insects and other arthropods affecting public health requires a knowledge of insecticide application equipment and training in the methods of applying these pesticides.

Insecticide application equipment must be utilized in a manner that will produce the maximum effect at minimum cost and avoid hazards to humans, plants, and/or nontarget organisms. Four key factors should be considered when selecting insecticide application equipment:
**Will it do the job?** Each piece of equipment should be large enough to do the job but not so big that it is difficult to operate. Simplicity of operation and ease of maintenance should be key factors in making a selection.

**Is it safe?** Safety should be a prime consideration in all insect control operations. Hazard to the equipment operator, the general public, and the environment should be considered.

**Is it of good quality?** In general, it is more economical to buy the best equipment available. Durable construction and efficient design are essential.

**Is it expensive?** Cost is a primary factor; however, in the selection of equipment, a carefully thought out, overall analysis should be made. Purchase of low quality items may save initially, but the long-range expense should be weighed against such factors as durability of equipment, availability of spare parts and repair facilities, and degree of care that can be expected from workers who use it.

Types of equipment currently used in vector control include hand sprayers and dusters, mist and dust blowers, fog generators, and both aerial and ground ultra-low volume application equipment.

**Safety**

All pesticides are toxic to some forms of life and to some biological systems. Many pesticides are highly toxic not only to the target pests, but also to many other organisms including humans and other higher animals. Pesticides can be used safely if the persons using them have full knowledge of the hazards involved and of the procedures required to avoid these hazards. The most available, up-to-date, and complete source of this information is the pesticide label; pesticides may be legally used only as the labeling directs.

The safe use of pesticides always requires employing these three basic steps:

**Plan ahead.** This includes having a thorough knowledge of the pesticide to be used, especially being completely familiar with all information, use directions, and safety precautions given on the product label; having all necessary application, protective, and other equipment and supplies available in clean, operating condition; and careful planning of all steps involved from the receipt of the pesticide product all the way to the safe disposal of empty containers, the cleanup of all equipment, spills, etc., after use, and the protection of personnel.

**Protect against avoidable exposure.** In handling pesticides, exposure to the pesticide must be avoided to the greatest possible extent. Persons involved must remember at all times that pesticides are toxic chemicals. Inhalation of pesticide sprays or dusts, skin contact with pesticides or their residues, ingestion by mouth through eating or smoking while working with pesticides or in pesticide-treated areas, and all other unnecessary exposure must be avoided.

**Protect against unavoidable exposure.** Persons directly engaged in mixing, loading and applying pesticides cannot completely avoid skin contamination or breathing spray mist, dusts or vapors. Depending upon the toxicity of the pesticide handled, operators must wear protective clothing and use protective equipment. In the case of highly toxic pesticides, operators must wear rubber gloves, rubber boots, hat, goggles, mask or respirator, and an impervious suit or coat covering the entire body. Leather items including shoes, belts, etc., cannot be effectively decontaminated and should not be worn during handling of toxic pesticides.
Close attention to personal hygiene is essential in working with or around pesticides. Glean clothes should be worn daily. If clothing becomes heavily contaminated, it must be changed immediately. Pesticide-contaminated clothing should be handled in such a manner that the worker's family, especially small children, or persons laundering the clothing will not be endangered. All exposed workers should shower or wash thoroughly at the end of the day or of the pesticide operation using plenty of warm water and a mild soap. In case of severe exposure or contamination, this should be done immediately.

Planning and training must include preparation for unexpected mishaps such as the need to service equipment in the field because of nozzle clogging or other malfunction, rupture or leakage of lines, hoses, gaskets, etc.

**Insect Resistance to Pesticides**
Considerations of the use of chemical control of insect pests must include the concept of insecticide resistance. Since most normal populations of insects represent a large gene pool, they contain individuals that vary widely in their susceptibility to insecticides.

As a result, putting selective pressure on a population with a toxic chemical leads to survival of those individuals tolerant to the chemical. Continued selective pressure causes a shift of the gene pool with the result that resistance develops in most of a population. Generally, genes conferring resistance to pesticides are disadvantageous in the absence of pesticide pressure and will be selected out of the population with time. However, complete elimination of resistance genes does not occur due to immigration of resistant insects and to production of new resistance genes through mutation. As pesticide resistance becomes more widespread, whether through heavy agricultural spraying of the same compounds as used in vector control or related compounds or by improper use of vector control pesticides, an understanding of resistance and its problems becomes essential to effective vector control. It is important to remember that not every pesticide failure is caused by pest resistance; the proper pesticide must be applied correctly using the proper dosage.

Resistance of insects to insecticides is defined as the ability of an insect population to withstand a poison that was generally lethal to earlier populations. In general, two types of resistance occur in insects:

**Physiological resistance:** The ability through physiological processes to withstand a toxicant by differences in (1) the permeability of the insect exoskeleton to insecticides, (2) the detoxification of insecticides into less harmful compounds, (3) the storage of insecticides in less metabolically accessible body tissues such as fat, or (4) the excretion of insecticides. Some biochemical mechanisms for the development of resistance are so general in scope that cross-resistance develops between similar or virtually unrelated pesticides. It has recently been demonstrated in the laboratory that resistance can develop to insect growth regulators and biological control agents. In theory, resistance based on the genetic enhancement of fundamental enzyme systems, such as the microsomal oxidases or esterases, will be directed toward any pesticide chemicals sensitive to degradation by these enhanced enzyme systems.

**Behavioral resistance:** This type of resistance is reflected in the ability to avoid lethal contact with the insecticide through protective habits or behavior, such as anopheline mosquitoes resting outdoors rather than on treated interior wall surfaces. Such resistance is also believed to be genetic with the resistance-conferring behavioral traits being selected in the same way.
Public health workers should periodically test the susceptibility of insect species to the insecticides used in control programs. It is particularly important to have a baseline level of susceptibility of a species to a new insecticide before changing chemicals. In many parts of the world, the widespread use of a particular insecticide in agriculture may have led to resistance in species of public health importance. For example, in Central America, the widespread use of DDT to control insects on farmlands has exposed malaria mosquitoes in and near these fields to this insecticide, killed off the susceptible individuals, and gradually developed a strain of Anopheles resistant to this chemical.

Supplementary reading

In many cases, the use of pesticides in developing countries is an example of the application of high-level technology without a complete infrastructure required to support such technology. Improvements in the mode of pesticide transport, container size and type, and storage facilities would significantly reduce the amount of damaged unusable pesticide. The amount of waste pesticides can then be disposed of by open or closed systems of burning or by burial in secured landfills with or without pretreatment by chemical hydrolysis. Countries using large quantities of pesticides should establish at least one incineration site for disposal of industrial chemicals as well as one hazardous waste disposal facility. Empty metal pesticide containers, in addition to their economic value, present a hazard to public health. Public health and agricultural authorities should develop a combined program to ensure the safe disposal, cleaning, and recycling of these containers. A national and regional emergency facility should be established to prevent accidents from occurring during transport and storage of large amounts of hazardous chemicals.

Introduction
Large-scale use of pesticides creates problems: safe disposal of surplus pesticides, damaged pesticides and "empty" pesticide containers. These problems are experienced by developing countries that have begun extensive use of agricultural chemicals to increase their output of agricultural products. It seemed therefore desirable to review pesticide disposal practices and to develop suggestions to solve hazardous waste disposal problems.

Definition of Pesticide Disposal Problems and Proposed Solutions for Developing Countries
Probably less than 0.2% of all manufactured pesticides used in industrialized countries end up as waste that goes unused in agriculture. The situation in developing countries can be dramatically different: the amount of pesticide that is not applied for its intended use tends to be considerably higher. In some cases, probably 5-10 percent of the purchased agricultural chemicals are never applied in agriculture. This represents a 25- to 50 fold increase in the amount of undesirable and uncontrollable pesticide entering the environment. In developing countries, pesticide release from manufacturing or formulating plants does not, generally, present a major problem. Instead, it is rather during transport, storage and application of pesticides that difficulties arise. The need for improvement in transport and storage of pesticides to and in developing countries cannot be stressed too strongly. Poor transport and storage facilities are the major causes of damaged and surplus chemicals.

The cleaning, disposal, or recycling of pesticide containers is another major problem in developing countries. The amount of chemicals entering the environment via "empty" containers is minor compared to the amount of damaged, or surplus chemicals left unused. However,
because these containers are in high demand by the local people, the risk to public health is very high and represents a major health hazard.

It is very important to realize that in many developing countries the techniques and procedures developed in the United States of America and Europe for the safe handling and disposal of pesticides may be quite useless. The technology and administrative system required to observe these guidelines and regulations may simply not be available or obtainable in the near future for most countries currently using agricultural chemicals. It appears, therefore, that improvements in the use of pesticides must be made stepwise, beginning with relatively simple and economical processes, with the awareness that countries should, however, strive for the same standards and procedures used in developed countries.

**Damaged and surplus pesticides**

*Transportation of pesticide containers*

Since most of the developing countries purchase their pesticides from foreign sources, the effect of transport on these chemicals and their containers is a major factor to consider. Most of the chemicals destined for developing countries will be transported by rail, ships and trucks. It is therefore essential that the package containing pesticides is capable of withstanding often extreme conditions of a lengthy transportation process. There are two major points to consider when attempting to determine the capacity of a package to protect the pesticide until its eventual use: (1) once unloaded, containers will generally be manually handled and will thus experience much more abuse than in mechanical processes, and (2) storage facilities may be lacking or inadequate. One can expect that the containers will be exposed to adverse conditions for significant time periods before the chemicals are used. The shipment of pesticides in 250 liter metal drums is the standard in most industrialized countries and is economical if transported by mechanical means. However, these containers weigh 250-280 kg. and it takes six to eight persons to lift them. Thus, in loading and unloading, the drums will be frequently exposed to abuse due to their weight. In some countries, flatbed trucks, supporting three pesticide drums on top of each other, will be unloaded by simply rolling the drums off the truck (2-4 m. high) onto old tires that act as shock absorbers: many drums will be dented or stressed and in some cases leakage will start.

Similarly, shipments of pesticides in "oversized" cardboard boxes, with individual packages in paper bags, are highly susceptible to damage. Thus, it is very important that an appropriate package system be used for the developing countries.

*The main reason for the occurrence of damaged or unusable pesticides appears to be improper container selection.* Minimizing the amount of deteriorated pesticide and damaged pesticide containers will be an important step towards solving disposal problems.

The following recommendations should prove useful in improving the delivery of pesticides to developing countries.

*No container larger than that which can be easily lifted by one person should be employed.* Field observations have shown that 20 liter and 40 liter containers arrive with little or no apparent damage, whereas 250 liter drums arrive frequently severely dented, with expanded lids or bottoms, or with signs of leakage.

*Metal containers should always be used for emulsifiable concentrates and other liquid formulations.*
Powdered or granulated formulations should be shipped in waterproof packages. Strong boxes, with formulations wrapped in plastic, will endure transport with less damage than those that are not waterproof.

Barrels with tops sealed with ring clamps should not be used. These tops can be easily loosened during loading and unloading and when it rains the contents may get damaged.

**Surplus**

Pesticides remaining as surplus after the spraying season may eventually become unusable and require disposal. For several reasons developing countries have to order pesticides many months before the actual need for these chemicals occurs. Thus there is a good chance for excess chemicals to accumulate at the end of a spraying season. If these chemicals are not used in the beginning of the next spray season, most likely they will become unusable. There are several reasons for this. First, in tropical countries, storage of pesticides in the open exposes them to extremely high temperatures for most of the year. After several years, either the active ingredient has undergone significant degradation, or the formulation mixture has deteriorated and the active ingredient is no longer able to suspend properly. In some cases involving only loss of active ingredient, spray solutions can be made stronger to compensate for this deterioration. However, there is an inherent danger in applying these partially degraded chemicals in that the breakdown products may drastically alter the toxicity and efficacy of the spray solution.

The second reason why pesticides should not be stored over many seasons is the strong possibility that containers will deteriorate during the alternating wet and dry seasons. Therefore no pesticide should be allowed to be stored more than three years.

Guidelines should be established, including a clause requiring an inventory of currently surplus chemicals so that these could be used, subject to quality control, in the next spraying season. If chemicals are found to be older than three years, their quality must be checked and if good, immediately used. If they are not usable, they should be sent for disposal before the container has degenerated too much for safe transport to a disposal site.

**Storage facilities**

In developing countries, facilities for secure and proper storage of pesticides are frequently lacking. If storage facilities are available, they tend to be used for other purposes. Yet pesticides are very valuable commodities as well as hazardous compounds; storage facilities, when present, should be made available for their safe and secure storage. Therefore if chemicals are lost due to damage during storage or transport or by theft, a significant economical loss will be experienced. In addition, the crop damage that might result from lack of spraying may be even more financially significant. It is therefore essential that proper facilities be built for central as well as regional storage of full pesticide containers and "empty" containers awaiting proper disposal.

Guidelines have been established in the industrialized countries for optimum storage facilities. All countries should strive to meet these guidelines. However, in many countries it may not always be feasible to do so. The minimum requirements that one should fulfill are:

- *All pesticide containers should be stored on high ground so as not to be flooded during a rain.*
• Each storage facility should be constructed so that containers are not in direct contact with the ground.

• Protection from sun and rain should be ensured by a roof or covering.

The storage area should be kept off limits to the general population by means of a locked fence or by guard personnel.

Equipment for the control and clean-up of leaks from containers should be immediately available. It may consist of pumps to transfer solutions from leaking containers to those that are undamaged, suitable shallow containers to accommodate the leaking drum or absorbents that can be spread on liquids so they can be removed and properly discarded.

Container labeling
One of the problems that occurs with long-term storage of pesticide containers in open areas is that the labeling can soon become destroyed by sun or water. Once the contents of the container can no longer be read, the containers should be considered as surplus or damaged pesticide. In some cases, samples can be sent for analysis to pesticide laboratories within the country or abroad so that the container ingredients can be verified and, if they conform to specifications, used effectively. However, it is not expected that this will occur in the majority of cases involving unlabeled containers. There have been many suggestions made concerning the proper labeling of pesticide containers and it is not within the scope of this report to be comprehensive in suggestions concerning container labeling. However, several specific recommendations can be made to help alleviate the build-up of damaged pesticides and the resulting pesticide disposal problems:

The date of manufacture should be printed with indelible ink in large, bold letters on the top of the container as well as on the side. In most storage systems, the top of the container is more visible than the sides. Legible dates on the containers would help ensure that surplus chemicals from the previous season would be applied before newly arrived chemicals. If storage personnel have to move numerous 250 kg. containers to check for date of manufacture, they will seldom do so and will use the more easily retrievable containers.

Containers should be labeled as to active ingredient and concentration on the paper label and by stencil on the drum itself, on the top as well as on the sides. This procedure would prevent the occurrence of unlabeled containers as a result of paper label damage from water and sun or from physical tearing or scraping. In no case should the label be applied solely to the outer packing material.

Although in many developed countries instructions regarding container disposal are printed on the label, these are generally meaningless in developing countries.

The above suggestions regarding damaged and surplus pesticides, storage facilities and container labeling are outlined in an attempt to prevent the year-to-year accumulation of pesticides that could render them useless. This is a major problem faced by developing countries. The estimate that more than 5 percent of all pesticides purchased from industrial countries will eventually become damaged, unusable chemicals is not at all unrealistic.
Disposal of surplus pesticides
Wherever and whenever pesticides are used, no matter how effectively, there will be a need for safe disposal practices. For most developing countries, the best available technology recommended by various national and international agencies is lacking, or only partially available. Thus, the purpose of this paper is to suggest safe and feasible methods that can be used in developing countries with the minimum adverse impact on public health and the environment. These methods are not always entirely without risk, but they are preferable to indiscriminate discarding of pesticides. Some of the methods should be used only as long as better technology is not available, while other methods are currently the best. Each country using pesticides should be strongly supported in its efforts to upgrade waste disposal and handling facilities to the highest possible standards.

There are a variety of chemical, physical and biological methods that have been suggested for the disposal of pesticides. In developing countries, however, the available methods are less diverse and the most feasible are chemical detoxification by hydrolysis, incineration, open burning, ground burial, and disposal in hazardous waste landfills. Basically, there are two alternatives: burial with or without chemical pretreatment or burning either in open or closed systems.

The idea of returning surplus or damaged chemicals to the manufacturer is good but in many cases impractical due to cost, liabilities, deterioration of containers, and unwillingness of shipping agents and manufacturers to accept these toxic chemicals. If a chemical is still effective and could be used for a different purpose than that for which it was originally intended, attempts should be made to use it for that purpose, though it might require permission from different authorities. If other use is not possible, or if the chemical has deteriorated, then it must be disposed of properly.

Chemical processes such as oxidation, reduction, fixation or chlorinolysis require too much technology to be considered feasible in most developing countries. Activated sludge treatment systems are generally not available or not of the correct size or technical design to handle industrial chemicals. Soil incorporation is a possible method, but incorporation requires large amounts of restricted land. The accessibility of land to wandering animals as well as to people generally precludes this procedure as a safe method. Thus, only two real alternatives exist: burning or burial.

**Burning**
For most developing countries, probably the most ideal as well as practical system would be mobile incinerators, capable of safely destroying pesticide wastes. Although the incinerator may not be designed to give the optimal effluent temperatures needed for complete combustion of the toxic chemical and any hazardous gases emanating from it, it should be capable of almost completely destroying the pesticide. If incinerators are not available, open burning of pesticides in remote areas and under controlled supervision is the second best solution. While incineration or burning of toxic chemicals may present a short-term acute toxicity problem for the immediate area of the burning site, once destruction of the chemical waste is completed, environmental and public health problems are minimal or have been solved. If open burning of large amounts of surplus pesticides is to be recommended, consultation with experts on each individual case is necessary. For instance, DDT, malathion, dalapon, diazinon, carbaryl, aldrin and PCNB burned at temperatures between 500-600 degrees C (temperatures achieved by open burning of wood and paper) are reported to be destroyed at 99.9 percent efficiency. Lower temperatures however, lead to incomplete combustion and sublimation.
Burial
A safer method, but one that may create a potential long-term hazard to the environment, is land burial. Compounds subject to chemical hydrolysis, such as carbamates, organophosphates, and dithiocarbamates, should be treated during or before burial by acid or base hydrolysis in order to destroy the technical product. It has to be understood, however, that in literature and disposal guidelines it is erroneously indicated that chemical hydrolysis proceeds relatively quickly, with half-lives reported in minutes or hours. One must be aware that these calculations were made with low, water-soluble concentration of pesticides (i.e. 1-100 mg/l). When one is concerned with detoxification of bulk amounts, then the half-life of the same pesticide under the same conditions will be measured in days, weeks and months, not in minutes. Base hydrolysis is, however, a very viable method for destruction of the active ingredient and is practical in developing countries. It should be stressed, however, that sufficient time be allowed for the hydrolysis to occur and that the "detoxified" solution after hydrolysis not be poured into water systems, but rather spread on dry ground or buried. The phenols and other hydrolytic breakdown products from these pesticides generally have LD50s in the range of 300-1000 mg/kg and thus should be classified as moderately hazardous solutions.

Thus, with or without chemical pretreatment, if pesticides are to be buried they should be buried at sites that will not be leached or periodically flooded. These sites should be carefully selected, designed and operated to ensure minimum damage to the environment and to the people in the vicinity. The decision to use burning or burial procedures is dependent on the area in question. In tropical zones with abundant rainfall, burning is advisable to avoid the possibility of uncontrolled movement of buried chemicals as a result of leaching and seasonal flooding. In arid climates, burial appears to be the safest method as long as there is no contact with groundwater. The following recommendations can be suggested for the disposal of large amounts of unusable hazardous pesticides. Countries should develop national systems for the disposal of toxic wastes. Such systems should include:

- an incinerator capable of destroying various toxic chemicals (not just pesticides), constructed and operated by adequately trained personnel;
- at least one hazardous waste disposal site.

These requirements should be considered as minimum standards for each country in order to safely dispose of pesticides.

Container cleaning, disposal and recycling
The cleaning and disposal or recycling of pesticide containers is a serious problem in developing countries. Guidelines have been proposed for container disposal; some of this advice is very practical. However, in some countries, certain unique conditions strongly affect the ability to follow the guidelines. First, in many developing countries, metal containers are extremely useful for a variety of applications and therefore are in high demand by the population. In most cases, people do not recognize the dangers they face in reusing these containers, even if they are labeled in the local language and describe the potential for poisoning. The second major point is that facilities for the proper cleaning and recycling of containers are rather uncommon; the necessary solvents may not be available, nor the equipment to clean and recondition metal containers.

It should be noted that most of the pesticides used in developing countries are packaged in metal, glass or paper/plastic containers. The use of glass containers should be discouraged because of the danger of breakage. The three types of containers should be disposed of by
means of different procedures. As a first step, metal containers should be rinsed at least three times. Whenever possible, the rinsate should be used as a diluent for the spray solution. This simple step will reduce the residue in a 250 liter drum to usually less than a few grams of active ingredient. *The effectiveness of this simple practical procedure cannot be stressed too much.* In most cases this will render the container sufficiently clean so that it no longer presents an acute toxic hazard. (However, this will have to be accurately checked by chemical analysis of pesticide residues in various types and sizes of containers.) Paper or plastic containers holding solid formulations should be shaken to ensure complete emptying into the spray solution. Water-soluble containers, if they can be protected from damage by water during storage, are ideal to reduce the quantities of waste pesticide and pesticide containers. The total package is simply added to the spray solution; it dissolves and is then mixed.

The rinsed containers should be resealed, collected, and brought to a secure storage site at the end of each day. If this is not done, containers will certainly disappear at this point and reappear serving a multitude of functions ranging from stoves, grills, dinner plates, suitcases, tables, water and food containers, building material, etc.

Paper or plastic containers, if in small quantities, should be burnt on site or collected and brought to a central storage facility for subsequent burning or burial. Glass or plastic containers should be crushed and punctured and then buried or disposed of in conventional landfill sites or dumps. It is difficult to decide whether to destroy them or not. Since metalpesticide containers represent a significant economical value in developing countries, there are basically three possibilities: (1) puncturing of container so that it cannot hold food or water and then discarding it in a landfill (this does not preclude scavengers from picking up these still-contaminated containers and using them for other purposes that may include direct contact with humans); (2) thorough cleaning of containers so that they can be released for public use (the containers will be used for water and food storage even if these uses are clearly prohibited); and (3) recycling of containers whenever possible.

In situations where pesticides are applied by large commercial firms or through governmental agencies, all of the above options are valid to some degree. However, control over individuals who use pesticides is generally minimal and thus these people should be well-instructed and urged to destroy the container immediately after it has been rinsed.

If one assumes that used pesticide containers are under the control of government or large commercial firms, the three previously discussed options need detailed elucidation. One economical and fairly safe way to clean pesticide containers before they are discarded would be to add inflammmable material to each drum and burn the residual pesticide in the container. After this step they could be discarded in landfill sites. It must be noted that the burning of containers can, in some cases, cause toxic fumes and therefore must be carefully conducted in secluded areas with the workers standing upwind from the fire. The burnt, punctured container should then not present any significant hazard to the environment or public health and the metal can be used for various purposes.

If it is planned to re-introduce the containers for public use, special care must be taken to clean them: cleaning with solvents and detergents and sandblasting. This type of treatment requires the construction of a central facility, operated in collaboration with agricultural and public health authorities, to ensure that containers can be certified as decontaminated and that hazardous wastes generated from the cleaning process have been properly disposed of. Afterwards containers can be released for sale for multipurpose use and should be safe even for water and food storage.
If solvents and sandblasting equipment are not available and containers are to be sold at public auction, one should ensure that the level of pesticide contamination of containers (triple-rinsed followed by washing with detergents) is sufficiently low and that they do not present a significant acute hazard if they are to hold water or food. It should be noted that the cost of cleaning containers could very likely be covered by the money obtained from the sale of decontaminated containers, especially if the cleaning is carried out in centralized facilities.

If it is not possible to use detergents or solvents, then igniting the inside of the container could serve as a minimum cleaning measure. In many instances, containers are cut open and used as a source of metal. Burning of opened containers is a good means by which residual pesticide can be removed but, as in any burning of pesticides, care should be taken concerning hazardous gases. If a country has manufacturing or formulation facilities for pesticides, it is highly advisable that the containers be recycled. These facilities usually have trained personnel, familiar with hazards of pesticide, and are equipped with solvents and machines needed for drum recycling. It would even be a wise choice to try to persuade these companies to be the drum cleaning center for all drums before they are recycled or distributed at public auctions by the health departments.

The following recommendations can be made regarding the disposal and recycling of "empty" pesticide containers.

- Immediately after a pesticide container is emptied, it should be rinsed three times and the rinse solution used as diluent for the spray solution.

- Immediately after the above rinsing, the container should be tightly closed.

- All containers should be disposed of immediately after the above procedures or collected at a secure storage facility for further treatment.

- If containers are to be sold, public health agencies should ensure and certify that the containers had been cleaned again and rendered safe for human use.

- Authorities concerned should support as much as possible programs involved with industrial re-use of metal drums, in order to minimize the potential of release of contaminated containers.

**Spill clean-up**

As previously mentioned, the transport of pesticides in developing countries can lead to greater damage to containers than in the industrialized world. It is also probable that due to difficult road conditions in some developing countries, accidents involving pesticide transport occur more frequently. Emergency procedures should be established to deal with large-scale, accidental spillage of hazardous chemicals as well as for the clean-up of spills or leakage from individual containers. These require national coordination and quick response by qualified people. For example, establishment of a control center could result in information on the design and best approach for immediate control of spills that present a hazard to the environment or public health. Such a center could initiate procedures for the clean-up of the spill and disposal of waste. Countries using pesticides may seek advice from the emergency spill control networks existing in developed countries when establishing their networks. In addition, these national centers should be able to mobilize quickly the equipment and manpower required at the place of accident. However in many countries, communication between control centers and accident...
sites may be difficult to establish. Another possible method to control chemical spills could be for a government or commercial representative to accompany the chemical shipment. These individuals have the required expertise and can coordinate evacuation programs, spill containment, clean-up, etc., as needed for each individual case. Responsibility for transportation accidents after the supplies have arrived and are being moved to where they will be applied should reside with the agricultural or other authorities supervising the application of these chemicals.

It is therefore recommended that **developing countries which import significant amounts of agricultural chemicals establish an emergency response system to deal with transportation accidents.** This could be solely a national program, or associated with other national programs, or coordinated by commercial firms supplying pesticides to the particular country.

The control and clean-up of minor spills presents a different type of problem. In well-designed storage systems, spills are contained due to hard floor surfaces and the drainage design of the facility. However, spill control and clean-up in systems where containers are simply stored in the open and on the ground present more serious problems. The minimum equipment needed at such a storage site should be the following:

- protective clothing, especially boots for clean-up workers;
- leaking containers into another empty, undamaged container;
- large size saucers into which leaking containers with their contents can be placed;
- shovels and containers for disposal of contaminated soil or absorbent clean-up materials.

Routine inspections of the stored drums should be made. When a container is found to be leaking, action should be taken immediately. The waste material should be disposed of by burial or by burning as previously discussed.

**General Comments**
Developing countries often lack an adequate infrastructure for the safe application of pesticides. It is therefore essential that potential risks be greatly reduced. In developing countries, hazards to the environment and public health are created primarily by the transport and storage systems and secondly by the need to order chemicals far in advance. Thus an accurate prediction of actual pesticide needs is often lacking. The managers of pesticide application systems should be responsible for ensuring that the required amount of chemicals arrives intact and on time, that the chemicals are used in the appropriate spray season, and that surplus pesticides do not accumulate. This is clearly a very difficult task.

**Recommendations**
Throughout this paper, specific comments have been made in an attempt to improve certain aspects of transport, use, and disposal of pesticides. The following recommendations are broader in scope but also aim to reduce the adverse impact of pesticides on humans and their environment.

Special consideration should be given to appropriate container size and material when sending and ordering chemicals. It should be recognized that increased costs of proper packaging may be compensated by decreases in the amount of damaged or lost pesticides.

Pesticide containers should be labelled on both the top and sides and the labels should be able to withstand storage conditions in open storage systems.
Appropriate storage facilities should be built in those areas serving as central and regional depositories for pesticides.

Close cooperation between national agricultural and public health authorities should be established in order to ensure that all aspects of safe use of pesticides are implemented.

Pesticide analytical laboratories should be established to analyze residues, assay pesticides for concentration of active ingredient, and determine if surplus or unmarked quantities of pesticides are still usable for their intended function.

National and international facilities providing advice on pesticide disposal should be established to handle specific questions on disposal of individual pesticides under a variety of situations, ranging from truck spills to individual pesticide containers or to large amounts of damaged pesticides. This information data bank should be available by the time the country receives the first shipment of a new chemical.

Public health programs that use pesticides should keep contact with agricultural programs to inform them on the safe use of such pesticides.

People from developing countries should be sent for training in developed countries in order to learn the proper methods for storage, transport, application, and disposal of agricultural chemicals. This is currently insufficiently stressed in agricultural or public health training programs.

Although specific questions concerning disposal of pesticides may best be answered by the industrial firms manufacturing the product, individuals or programs in developing countries should not solely rely on information obtained from industry. Agencies such as FAO and WHO should maintain a system whereby they can supply new information or verify given data by consulting with the nonagricultural chemical industry.

The long-term problems associated with improper disposal of hazardous chemicals can be well illustrated by a number of cases coming to the surface in industrial nations only recently. The main lesson learned was to destroy wastes as they are produced and not to leave them in some seemingly remote disposal site from which they will return to haunt society.

Summary
Although there are many methods of vector control, in an emergency situation the use of chemicals is usually the choice. The selection of the chemical, formulation, and application equipment depends upon the vector and the situation. The document prepared by Dr. Smith provides a summary of information.

Space spray equipment is used against adult mosquitoes, especially culicines, in times of an arbovirus epidemic. It provides rapid knockdown of the adults and if used in cycles the length of the developmental cycle of the mosquito is effective in stopping virus transmission. It is a method more practical for urban situations than rural, but the portable space spraying equipment can be used in both situations. Some vector control specialists recommend ultra-low volume (ULV) equipment while others recommend thermal equipment. In reality they both are good control methods when used properly. In an emergency it is best to use what is available and to use it correctly.
Space spraying equipment has been used in urban malaria control and as a means to set up barriers around dwellings of isolated cases of malaria. ULV aerial applications have been used against malaria vectors in rural areas, but usually the area to control is too extensive to be practical. Since increases of malaria cases usually lag behind the natural disaster by a few months, there should be sufficient time to handle malaria by conventional methods.

Space spraying can be used for control of pest insects around temporary camps. The spraying will have to be frequent, perhaps even daily, depending on the pest, its habitat and density.

Residual spraying also is directed against the adult stages of those insects in which the adults are the vectors or pests. However, in a number of insect species both the immature and the adult stages serve as vector or pests to humans. The WHO publication should be consulted for insecticides and equipment to use. As noted earlier, where wind or another cause of damage to dwellings allow rain to saturate inside walls, the efficiency of pest residual spraying is usually lost. Consequently, those houses that were damaged should be re-sprayed as soon as repairs are made. New houses, especially mud thatch ones constructed in malarious zones, should be sprayed immediately.

Residual spraying in temporary housing may be recommended in malarious zones or in areas where pests are associated with resting on the walls or living in the cracks and crevices. Some care will have to be taken in the selection of the insecticides as the insecticide and formulation selected for one group of insects might not be recommended for another.

In cases where temporary shelter is open, some control of mosquitos and flies may be obtained by using strips of cloth or plastic that hang from the edges of the roof. These strips can be sprayed with a residual insecticide. Insecticide-impregnated bed nets may be used.

At the present time there are a number of types of aerosol, mist blower, and ULV hand equipment on the market. These have been developed largely for agriculture, greenhouse and stored product insect control but can be used for space spraying. If the equipment is on loan from agriculture, care must be taken that the correct nozzle is available. The smaller equipment of this type can be used inside of dwellings whereas the portable thermal sprayers are recommended for outside use only.

The previous sections have stated that there are specific insecticides recommended against specific insects and/or insect habitats, but in emergencies one might have to use a different insecticide because of availability. This is one reason why some urge stockpiling of some insecticides or a system of obtaining amounts on loan from neighboring countries until a supply can be obtained. In emergencies many insecticide companies will make special arrangements to have insecticides airlifted to the disaster areas.

It should be noted that even when insecticides are recommended, they might not be the choice for the specific situation because of insecticide resistance. If there is a malaria service in the country, they usually have the professional expertise to do the tests. They probably have the information on resistance available for the malaria vectors and other mosquitoes. Large amounts of an insecticide should not be ordered until some assurance is obtained that the insecticide and its formulation will kill the target insects.

Care must be taken that the formulation of the insecticide ordered matches the equipment available. If orders are placed through international organizations or directly to an insecticide supplier, mention should be made of the equipment available and the intended use.
The CDC publication for insecticides is more for the United States of America than for other countries and this should be considered in studying it. If other countries are involved, the environmental protection regulations and insecticide codes of the specific country should be consulted. There are a number of general aspects of insecticide safety that should be considered. These are outlined below:

**Storage**
- Insecticides should be stored in their original containers.
- Storage areas should be locked and windows barred to prevent break-in.
- The storage areas should be well lit.
- Insecticides should be stored on elevated racks.
- If any insecticide or solvent is a fire or explosion hazard, suitable safety arrangements should be made (check with the fire department).
- Post names, addresses and telephone numbers of persons to contact for rescue and/or first aid procedures (and poison center if one is available).
- Provide directions on handling spillage for the types of insecticides in storage.

**Packaging**
- It is better to pre-package insecticides in a central location than to take bulk into the field.
- Packaging usually consists of weighing out one charge of insecticide and placing it in a plastic bag.
- Packagers should have protective clothing such as gloves, goggles, hoods, hard hats, aprons, overalls, boots, respiratory equipment and face shields.
- Clothing should be changed daily and contaminated clothing washed separately from other clothes.
- The packaging operation should be well supervised.
- Eating, drinking and smoking should not be permitted in areas where insecticides are handled.

**Safe use of Insecticides**
- Special training should be given to anyone handling insecticides. Safe handling and application procedures should form an integral part of the control operation.
- It should be noted that each type of insecticide, formulation and equipment will require special training.
- All control operations should be supervised. Part of the supervisor's responsibility will be to prevent insecticide-related accidents and to ensure that safety regulations are followed.
• The workers should be familiar with the label instructions of the insecticides, the use of all safety devices, the importance of clean clothing and following of safety and health instructions.

• All individuals handling insecticides or supervising their use should know the signs and symptoms of insecticide poisoning and general first aid measures.
Lesson 13 - Self-assessment test

Multiple Choice

Circle the correct answer(s):

1. The most practical classification of pesticides is by:
   a. stage of insect life cycle acted upon
   b. chemical class
   c. formulation and target
   d. biochemical activity
   e. taxonomy of target arthropod

True/False

Indicate T or F:

______ 2. Residual insecticide spraying is the most widely used method of vector control in antimalarial programs.

______ 3. Pesticides should be shipped in glass containers since they are easier to clean after the pesticide is used.

______ 4. Although there are many methods of vector control, use of chemicals is usually the first choice in an emergency situation.

______ 5. In shipping pesticides to developing countries, large containers should be used since this reduces transportation and handling costs.

______ 6. Ultra-low volume (ULV) cold aerosols are more effective than thermal fogs against adult mosquitoes.

Answer Key

1. c
2. True
3. False
4. False
5. False
6. False
Lesson 14 - Surveillance and evaluation

Study Guide
Since vector control problems may not arise for weeks or months following a sudden natural disaster, surveillance systems must function efficiently and effectively to provide decision makers with accurate information during the post-disaster period. Equally, once control measures have been selected and implemented, evaluation is necessary to determine if they have been effective, and if not, what alternate methods should be attempted. While the surveillance procedures, control methods, and evaluation measures will vary according to what diseases are endemic to the area and what vectors are present, the assigned reading related to Aedes aegypti provides specific information that can be generally applied in surveillance and evaluation programs.

Learning Objectives
• Know the purposes of surveillance, and methods and procedures available.
• Know the factors involved in organization and management of surveillance systems.
• List the various components of a control operation that should be evaluated.
• Appreciate the community's potential role in surveillance and evaluation operations.

Learning Activities
• Read the introduction in this lesson.
• Read the excerpt from "Surveillance, Prevention, and Control: Vector and Rodent Control" on page 101 of this study guide.
• Read excerpts from "Vector Topics No. 4, Biology and Control of Aedes aegypti" on page 102 of this study guide.
• Read the summary in this lesson.

Evaluation
Complete the self-assessment test.

Notes
Introduction

**Surveillance**

All vector control activities should depend upon a proper analysis of the situation. This will involve an accurate appraisal of the situation before the natural disaster, an identification of the factors attributed to the disaster that might have affected the vector population, and a careful surveillance system established to follow the population of their vectors as well as reporting cases of vector-borne diseases.

Surveillance is the systematic collection of information and its analysis for action. Any surveillance system should have the following steps:

**Determining what information is needed** This includes knowing the distribution of both disease and responsible vector as well as estimated population densities (preferably based upon past information) of the vectors involved in disease transmission.

**Collecting information** In cases where a disease vector surveillance system is already in operation, for example in malaria, dengue, yellow fever, and plague programs, it may be possible to use that system. When this source is not available, it will be necessary to obtain staff, train them and supervise their activities. Frequently special surveys may be needed or a sentinel system developed. In all cases, maps are an important tool. Maps can be used to understand an area (its demography and geography), to locate and illustrate vector distribution and breeding, to identify risk areas, and to locate human cases of the disease as they occur.

**Analyzing the information** Any information gathered will be worthless unless compiled and studied as soon as possible. A system of communication between field, laboratory and office must be established. Many vector diseases have normal seasonal patterns, and in certain seasons an excess of human cases is usual. Therefore incidence must be compared to what is expected for the particular time. One must analyze vector population changes with disease trends and be familiar with the transmission histories of the vector-borne diseases in question. Comparisons may be made of past with present and between different locations. In analysis of the information, special care must be taken to follow developments within risk areas. Many vector surveillance systems have established indices as a standard for comparisons. These include flea indices for plague; house, container and Breteau indices for *Aedes aegypti*, adult mosquito landing rates, window traps, animal bait counts for *Anopheles spp*; and dipper counts, light trap, and other adult traps for *Culex spp*. Maps, graphs and charts help to visualize what is happening.

**Taking the appropriate action** To take the appropriate action the above three steps must be followed and a system of feedback established. This feedback should be directed to the collectors of the information, to the teams that will be required to take the action, and in most cases to the public so the people know what is happening and what to expect. In most cases vector control staff in cooperation with the laboratory staff and the epidemiologist will be involved in decision making. However, in cases where the vector-borne disease is already active in nearby areas, one might not wish to wait for laboratory confirmation of cases. As mentioned above, the selection of sampling methods is important in the interpretation of results. One of the essential aspects is to know the target vector species, its habitats and behavior, and ecological conditions responsible for population changes. This requires a knowledge of environmental factors that have been altered directly and indirectly by the disaster. The following basic information should be available:
• Vector species of the vector-borne diseases transmitted in the area.

• Season of vector breeding and conditions causing changes in breeding or population levels.

• Time and season of optimal disease transmission.

• Density of vector at the present time, density required for transmission (if known) and whether population is stable, increasing or decreasing.

• Amount of human-vector contact occurring and factors influencing this contact.

• Methods acceptable for control of vector under existing conditions.

• Susceptibility to insecticide should insecticide treatment be the method of choice.

• In some cases attempts are made to determine the proportion of infected and/or transmitting vectors in the population.

There is no one perfect sampling method. One should know something about the efficacy and limitations of any method selected as well as how frequently it should be used. In most cases, especially for mosquitoes, it is wise to use more than one sampling method. Some sampling methods may attract special information such as age of insect, type of blood meal taken, and whether infected or not.

It will be impossible to collect insects over large areas and it may be necessary to select indicator villages or camps. These are usually selected because they are at greatest risk, with topography conducive to vectors, typical vector breeding sites, or a situation common among the villages or camps. Within the indicator village, a set collection station is usually established. However, some vector control specialists prefer making random collections.

Evaluation
The management of any action taken following a natural disaster will require careful monitoring. Monitoring may be defined as observing or checking what is being done in order to assess the effectiveness of the work. Monitoring of activities is a method of evaluation in which one looks for progress or reasons why goals have not been achieved.

In a vector control operation, there are a number of activities that require close monitoring. Among them are budget, personnel, supplies and equipment. Two types of information should always be available. One is what is needed and the other is what is available. In an emergency following a natural disaster it may be necessary to make adjustments in all of these activities. This is the reason why a contingency plan was stressed earlier in the course.

The contingency plan should have estimates of what may be required under various emergency situations and an inventory of what is available at the moment. The latter must be updated at regular intervals. In this discussion it is assumed that either an organized vector control program or a natural disaster committee is in operation and a contingency plan is available. In either case one of the first objectives will be to assess the potential problems created by the disaster and to implement a plan of action. This usually requires some type of disease vector surveillance. Once the methods of surveillance are selected, it may be necessary to recruit and
train or retrain and to monitor the work of staff at every level, thereby determining the degree of
proficiency and assuring efficiency and accuracy in the performance of their duties. Collection
and analysis of data are of little value when not done correctly and according to schedule.

Effective monitoring may be accomplished through adequate supervision and by the use of well-
designed forms. Supervision is a weak point in many vector control operations and will tend to
be even weaker in emergencies. Supervision must be planned into any operation and should be
part of any plan of action. Through using mock disaster drills it is often possible to identify weak
areas and remedy them. One important factor in supervision is proper human relations with staff
and the general public. The supervisor should be motivated by his/her superior and in turn
should be able to motivate his/her staff. This often requires training and practice. Supervision
tends to break down when staff members are not recognized for work well done and when
chains of command are broken.

Good recording forms are an essential tool for any vector control operation and should not be
forgotten during an emergency. Forms are the vehicle used for information flow. Since they are
the backbone for planning and program evaluation, staff must be taught to use them properly.
Furthermore, forms should be checked by the immediate supervisor before being forwarded.
Accuracy is the keyword. To be effective, the information should be processed rapidly and used.

As in surveillance it will be important to analyze each step of the monitoring process. The
analysis should provide information on any increase or decrease of usage of staff, supplies and
equipment. It should provide information on progress made towards achievement of goals or
targets as established by the disaster committee or stated within the contingency plan.
Monitoring should provide clues needed to investigate reasons for failure, should it occur.

Any monitoring system should have automatic feedback to keep staff informed and to serve as
a guide to supervisory personnel. Feedback helps to motivate staff. The disaster committee or
vector control operation should establish a list where various reports should be sent and keep
the list current with names, addresses and telephone numbers.

Monitoring is of special importance for control of equipment and supplies. Stocks of insecticide,
spraying equipment and spare parts should be kept up-to-date and replacements ordered well
in advance. Insecticides and application equipment used for emergencies may differ from those
used routinely, and this must be taken into account.

Vehicle and other equipment maintenance records should be kept whether in an emergency or
routine operation. It is essential that equipment be properly maintained, with spare parts on
hand during an emergency. If a monitoring system is to work, there must be clearly defined
channels of authority and responsibility. If either the delegation of authority or responsibility is
unclear it could unduly complicate the operation. Therefore, it is essential that all lines of
communication be maintained and orders be given according to prescribed procedure.

Supplementary reading
Excerpted from "Surveillance, Prevention and Control: Vector and Rodent Control," by Dr. A.
Smith, Ecology and Control of Vectors Unit, WHO, Geneva.

Surveillance
Outbreaks of vector-borne diseases are usually associated with recent or concurrent presence
of vectors in high numbers. Early detection and monitoring of vectors through efficient
surveillance measures are therefore important requisites in prevention and control of arboviral and rodent-borne diseases. These measures include:

· Identification of local vectors. Appropriate keys and a reference collection of specimens should be available.

· Longitudinal assessments of the densities of vectors in their principal habitats, using established sampling methods.

· Collection and pooling of arthropod material for determination and identification of arboviruses and their prevalence.

· Use of sentinel animals, e.g. chickens, pigs, for detection of circulating viruses and collection of infected mosquito arboviral vectors.

· Determination at intervals (normally about six months) of the susceptibility of possible arthropod vectors to principal insecticides, and of rodent vectors to rodenticides.

· Since outbreaks of arboviral diseases are often linked with unusual weather conditions, longitudinal meteorological observations on temperature, humidity, rainfall and wind (speed and direction) should be maintained.

· Application of the International Health Regulations in respect to surveillance measures to be applied for control of vectors in international transport, e.g. vector surveillance at airports and seaports, and in aircraft and vessels. In some areas surveillance is also required for international land transport.

Effective surveillance requires adequate staff and basic infrastructural components, e.g. appropriate laboratory equipment, reliable electricity and water supplies and sufficient transport.

Excerpted from "Vector Topics No. 4, Biology and Control of *Aedes aegypti.*" HEW, Vector Biology and Control Division, Atlanta, GA, 1979.

**Surveillance of *Aedes Aegypti* Populations and Evaluation of Control Measures**

**Purposes of Surveillance**

Before considering methods of control for use against *Aedes aegypti* and *Ae. aegypti*-borne diseases, one needs to know whether or not the species is present in a particular area and, if so, its relative abundance in that area as compared to other areas. Also needed are methods that will allow evaluation of the relative effectiveness of control measures and the influence of climatic conditions on populations.

A single survey, made during the portion of the year when rainfall is frequent and abundant and when temperatures are adequate for development of larvae, can demonstrate the presence of *Ae. aegypti* and provide some idea of its relative abundance in the areas surveyed. However, if disease transmission is likely to occur and/or control of *Ae. aegypti* is planned, a great deal more information is needed. Providing sampling measures for *Ae. aegypti* and an effective surveillance system will involve several different methods, the results of which complement each other. Whatever methods are employed, it is important to apply them consistently from place to place and throughout the period in which surveillance is used. Accumulation of
surveillance records for several years for a given area greatly simplifies planning of control efforts by making it possible to project probable mosquito abundance throughout the season.

Described below are sampling methods for *Ae. aegypti* that have been proven successful in field use for each of the life stages.

**Sampling Methods**

**Egg sampling:** *Aedes aegypti* is one of relatively few mosquitoes whose habits make sampling of the egg stage easy and practical. Sampling is done by collecting the eggs in oviposition traps or "ovitraps" as they are usually called. An ovitrap is a wide-mouth, pint-sized, black jar containing a narrow paddle (3/4 in. x 5 in.). A number of absorbent materials such as wood and heavy paper will serve for paddles, but a nontempered, dark colored hard board is recommended. It is clipped vertically to the inside of the jar with its back (rough) side facing the center and its lower end standing in at least an inch of water. As it absorbs water, the paddle becomes an attractive surface on which the mosquitoes deposit their eggs. The trap works by taking advantage of the natural responses of the gravid mosquito, which include attraction to dark objects, a preference for water that appears dark, and a rough substrate for egg laying.

Proper placement of the ovitrap in the field is crucial to its success and requires that certain other aspects of the mosquito's oviposition behavior be kept in mind. Adherence to the guidelines listed below will help realize the ovitrap's full potential as a sampling tool.

- The female normally flies near the ground, so the trap must be placed at or near ground level.
- The mosquito's responses are in part visual, so the trap must be visible to a female flying over it.
- The trap should not receive excess water from such sources as garden sprinklers or runoff from eaves or broadleaf plants.
- Adult mosquito resting places such as shrubbery and junk piles are good trap locations.
- Ovitraps should be placed in partial or total shade. Avoid direct afternoon sunlight and fully exposed paved areas.
- Ovitraps should not be located in tire yards or near piles of tires. Tires are highly attractive to female *Ae. aegypti* seeking oviposition sites, and their presence will reduce the effectiveness of the ovitraps.

All mosquito eggs found on ovitrap paddles are not necessarily those of *Ae. aegypti*. Other mosquitoes which breed in water-holding receptacles may also deposit their eggs in ovitraps. Eggs that appear to be different can be hatched and the larvae identified to be certain they are not *Ae. aegypti*.

Ovitraps provide an efficient and economical method for monitoring changes in the *Ae. aegypti* population of an area. They are particularly effective during dry periods when the lack of rain minimizes competition from other containers. Though their primary use relates to long-term population changes, they can serve in situations where assessment of short-term changes is
required, for example, evaluation of adulticide applications, *provided* that the traps are serviced daily and enough are available to compensate for short-term trap-to-trap variation.

Ordinarily, ovitraps are serviced on a weekly schedule. They are cleaned of debris, the water level is adjusted, and the paddles are replaced with new ones. Clean jars should be used to replace those that cannot be easily cleaned in the field. After paddles are removed from the traps, they should be kept in contact with each other, thus preventing the accidental transfer of eggs. Accurate interpretation of ovitrap data requires that all eggs on the paddles be counted under a dissecting microscope and that all records show, in addition, the location of all ovitraps and their condition (flooded, dry, broken, upset, moved, missing, etc.) each time the paddles are collected.

**Larval sampling**: Sampling for *Ae. aegypti* in the larval stage requires a thorough inspection of premises to locate all water-holding containers. It is essential to proceed carefully in searching for larvae because disturbing the water, jarring the container, or even casting a shadow will cause them to dive to the bottom where they may escape detection. When the inspector finds a container with water, he/she observes the surface of the water carefully, looking for mosquito larvae that may be either resting quietly or moving in their characteristic fashion. If no larvae or pupae are seen at the surface, he/she taps the container gently and watches for motion.

When larvae and/or pupae are found, a sample is collected and placed in a vial of water or alcohol for species identification with a microscope in the laboratory; a label specifying date, location, and type of container sampled should be placed in or on the sample vial. If the larvae can be examined on the day of collection, water is normally used; but if a delay is anticipated, they should be preserved in alcohol. For best results 95% alcohol should be used; lower concentrations may be used but are less desirable.

Since larvae occur in a wide variety of receptacles ranging in size from wading pools and boats to tin cans and fence pipes, a variety of collecting devices is necessary for taking samples. A dipper, preferably the white enamel type, is frequently used in sampling although strainers or nets of cloth or wire mesh fabric are more efficient for sampling large containers. Since larvae are most easily seen against a white background, it is often worthwhile to pour the contents of small containers such as cans and jars into the dipper or a white plastic or enamel pan for examination.

An ordinary squeeze-bulb syringe of the type used for servicing auto batteries or for basting food is well suited for removal of water from narrow-mouth receptacles or those too small for a dipper. It is particularly useful for taking samples from treeholes. For especially deep holes, a length of rubber or plastic tubing may be added to the syringe. Other items of equipment that will prove valuable in the course of larval collecting include a flashlight, a tea strainer (used for transferring specimens from debris-laden or dark-colored water to clean water), a white plastic or enamel tray for examining material from the dipper, a syringe or a medicine dropper for moving individual larvae into collection vials. The larvae of several other *Aedes* species and of certain other genera frequently inhabit the same containers as *Ae. aegypti*.

Larval sampling is most effective during periods of high rainfall and intensive mosquito breeding when sampling can provide a quick answer to the question of whether or not a particular urban or suburban area is infested. Generally, four indices have been used to determine incidence of *Ae. aegypti*. The indices are based on whether larvae are present or absent. The *House (Premise) Index* has been used for many years and is probably the most widely employed index; it is calculated by the percent of houses examined that have *Ae. aegypti*. Another index
widely employed is the Container Index, which one derives from the percentage of water-holding containers that have larvae of Ae. aegypti. The Breteau Index, which is calculated from the total number of containers with larvae of Ae. aegypti per 100 houses, has also been widely employed.

**Adult sampling:** Sampling the adult population of Ae. aegypti is far more difficult than sampling the larval stages, since the adults are not restricted to a small area as are the larval stages, and the sampling techniques for adult populations are less efficient.

One method of collecting is to search for resting adult mosquitoes in houses, garages, outbuildings, sheds, and similar adult resting places. Since Ae. aegypti is, in general, active throughout the day, resting specimens found during the day will usually be those that have recently fed and are quiescent during the period of blood meal digestion and egg development. Resting individuals will be found most often in dark corners, under tables and desks, and in similar places where light intensities are low, so a flashlight, in addition to an aspirator, will be required for their capture.

Another method widely employed for adult surveys is a landing-biting count. Both male and female Ae. aegypti are attracted to humans and frequently they may be collected on or near the collector before resting mosquitoes are seen. The mosquitoes may be captured individually as they approach or land on the person making the collection. In practice it may be desirable to combine resting collections with landing-biting collections and express the results as a house index (the percentage of positive houses).

Numbers of adults collected in the same location will vary with the time of day and with changes in climatic conditions. Because these variables not only occur but change quickly with time, it is essential that sampling methods and time of day used remain as consistent as possible. Standard light traps are not effective for sampling adult Ae. aegypti populations. In areas with low-level infestations, collection of adults may be the most efficient and economic procedure. On occasion, well-hidden containers may be the source of considerable numbers of resting adult mosquitoes. The presence of adults reveals breeding in the immediate vicinity and may help in location of the source.

**Organization and Management of Surveillance Systems**

The development of an Aedes aegypti surveillance system requires much planning and research. Factors to be considered include (1) the presence or likelihood of introduction of dengue or yellow fever viruses; (2) methods of control that may be considered; (3) availability of sampling equipment and personnel to collect samples and identify specimens collected; (4) variation in habitats and climate within the areas to be sampled; and (5) the number of sites needed to represent distinct geographic or political subdivisions.

Personnel for collection of samples in the field need little formal education, but they must be reliable in following explicit instructions and in reporting unusual problems encountered. Sampling schedules and methods, once established, should be rigidly followed so that population trends are detected as they occur. Supervision should be close enough to insure that samples are taken as scheduled and that sampling methodology does not vary. Forms and sample labels should provide all essential information and should be filled out at the sampling site when the sample is taken. Samples should be delivered to the laboratory for processing without delay and appropriate forms and labels should accompany or be attached to the samples.
Laboratory personnel should have sufficient training and competence to process and identify the sample submitted. This usually requires some formal training beyond completion of high school. One or two years of college with special training in mosquito taxonomy would be ideal. The competence of laboratory personnel will dictate the amount of supervision and quality control required but regardless of their competence, periodic independent checks should be made to ensure accuracy of identification and counting of specimens. Storage of samples for a period of time after they are identified by laboratory personnel will facilitate such independent checks.

Included in an effective surveillance system will be provisions for organization and appropriate presentation of data collected into tables, charts, or graphs that clearly summarize the data in such a way that data can be used for planning mosquito or disease control programs.

Summary

Surveillance and Evaluation Summary
The entomologist or vector control specialist should be in contact with the epidemiologist following a natural disaster. The epidemiologist is responsible for surveillance of the epidemic and endemic situations. The data obtained will serve as a basis for decisions on the implementation of control functions and their evaluation. This information will allow the vector control agency to better coordinate its activity and to define risk areas.

However, it should be remembered that the vector control staff may know the potential of epidemic situations before the epidemiologist has the data on human cases and laboratory confirmation. The vector control staff may have closer contact with the human population than the epidemiologist. Consequently they should be aware of the basic characteristics of the vector-borne diseases of the area and be instructed to pass on any observations and information to the epidemiologist.

Entomological evaluation is frequently underused, misused, or neglected. This is especially true during emergencies where vector control measures may be instigated without concern for cost or effectiveness. Evaluation of control requires a knowledge of the biology and ecology of the insect and the transmission cycle of the pathogen as well as correlation with insecticide application.

One of the first steps in evaluation is to determine if the control measure is correct. If insecticides are used, this would include testing the resistance of the target insect population.

Actually any evaluation should be sufficiently broad to include the entire control operation. This should be conducted more or less continuously and include evaluation on:

- Success or failure of any or all specific activities.
- Weakness in any phase of operation and possible remedies.
- Timing cycles of activities and operational changes in insecticide or application methods.
- Environmental impact, especially on nontarget organisms.
- Guidelines on equipment needs, insecticide susceptibility and toxicological procedure.
- Individual and/or group proficiency.
- Breakdowns in community acceptance of action.
- Projected activity requirements.
- Activity costing.
Each specific vector has its own evaluation requirements. Many of the methods are described in the individual lessons on specific vectors; these should be consulted. As an example, an outline for general *Aedes aegypti* surveillance/evaluation is included in this lesson.

Since a number of emergency control measures involve community participation, the community also can have a role in surveillance and evaluation. A natural disaster usually highlights community leadership. A crisis situation along with the awareness of the potential health problems involved should bring about a good level of cooperation in the community. To achieve the full benefits of the cooperation the community must receive guidance from the civil defense or other groups in charge of handling the aftermath of the disaster. This group must be willing to train the individuals and to provide an atmosphere and opportunity for skills to develop. Although the administrators of disaster aid may demand a great deal of authority to return order as soon as possible, still they should be willing to delegate to the community both authority and responsibility of many activities.

In most areas natural disasters are not a common occurrence and it is necessary for the health educator to work with the community to increase their awareness of the potential and to stimulate them to take an active part in any measures needed before, during and after the disaster takes place. If community health committees are already established these can be a focal point for the required community action. Some communities also have a number of other groups that can be brought into action for such activities as source reduction. It may be necessary to train certain individuals or groups in a community to perform specialized tasks.
Lesson 14 - Self-assessment test

Multiple Choice
Circle the correct answer(s):

1. Which of the following is not a key function of a surveillance system?
   a. determining what information is needed
   b. selecting the best sampling method
   c. collecting information
   d. analyzing the information
   e. taking appropriate action

True/False
Indicate T or F:

_____ 2. Personnel trained to collect samples in the field usually require a high level of supervision.

_____ 3. An effective surveillance system will include several different sampling methods.

_____ 4. Evaluation requirements may differ depending on the vector involved.

_____ 5. Sampling schedules and methods should be frequently changed to provide a variety of data.

_____ 6. Vector surveillance indices established for normal conditions can not be applied in conditions following a sudden natural disaster.

_____ 7. Following a sudden natural disaster, the community is usually very cooperative in supporting surveillance, control, and evaluation measures.

_____ 8. Evaluation includes measuring the impact of control measures on the environment, including nontarget organisms.

Answer Key
1. b
2. True
3. True
4. True
5. False
6. False
7. True
8. True
Emergency Vector Control after Natural Disaster

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HEALTH FOR ALL THE YEAR 2000

In 1977, the World Health Assembly decided that the main social target of the governments and of WHO should be the attainment by all people of the world by the year 2000 of a level of health that would permit them to lead a socially and economically productive life, that is, the goal popularly known as "health for all by the year 2000."

In 1978 the International Conference on Primary Health Care (Alma-Ata, USSR) declared that, as a central function of the national health system and an integral part of economic and social development, primary health care was the key to achieving that goal. Subsequently, the governments committed themselves at the global level at the World Health Assembly, and at the regional level at meetings of the PAHO Governing Bodies to implement the resolutions adopted for attaining health for all. In the Americas the high point of these mandates was reached on 28 September 1981 when the Directing Council of PAHO approved the Plan of Action for implementing the regional strategies for health for all by the year 2000. These strategies had been approved by the Directing Council in 1980 (Resolution XX) and today constitute the basis of PAHO’s policy and programming, and represent in addition the contribution of the Region of the Americas to the global strategies of WHO.

The Plan of Action approved by the Directing Council curtails the minimum goals and regional objectives, as well as the actions governments of the Americas and the Organization must take in order to attain health for all. The Plan, continental in nature, is essentially dynamic and is addressed not only to current problems but also to those likely to arise from the application of the strategies and the fulfillment of regional goals and objectives. It also defines priority areas that will serve as a basis in developing the program and the necessary infrastructure, for national and international action.

The exchange and dissemination of information constitutes one of the priority areas of the Plan of Action. PAHO’s publication program— including periodicals, scientific publications, and official documents—is designed as a means of promoting the ideas contained in the Plan by disseminating data on policies, strategies, international cooperation programs, and progress achieved in collaboration with countries of the Americas in the process of attaining health for all by the year 2000.

Contents
Foreword
Acknowledgment
Introduction
Part I: An Overview
Part II: Control measures for specific vectors
Part III: Consultants
Part IV: Annexes

Foreword
Most Latin American countries are highly vulnerable to natural disasters (earthquakes, hurricanes, floods, etc.). The consequences are immediate in terms of loss of lives and suffering. Longer term consequences can include serious setbacks in national development plans.

The impact of past disasters has been enormous: Nicaragua, 1972, 5,000 deaths; Honduras, 1974, 6,000 deaths; Guatemala, 1976, 26,000 deaths. In Peru alone, the 1970 earthquake caused 70,000 deaths and approximately 170,000 casualties.

The Caribbean area is also vulnerable to natural disasters, such as hurricanes. Barbados was hit in 1955, Haiti in 1964, Dominica and the Dominican Republic in 1979, Saint Lucia, Haiti and Jamaica in 1980. Earthquakes have also occurred in Trinidad and Tobago, Jamaica and
Antigua. Floods and landslides affect most of the islands. The disruption caused by natural disasters is magnified by the physical isolation of each country and the fact that, in most cases, the impact extended over the entire nation.

Disaster preparedness is a significant part of the overall strategy for achieving Health for All by the Year 2000. There is probably no event that so severely tests the adequacy of a nation's health infrastructure as the occurrence of a sudden natural disaster such as an earthquake, hurricane or flood. Especially in smaller developing countries, economic progress can also be jeopardized.

To a large extent, a solid, well-planned health delivery system that routinely includes the educated participation of the community is the most important preparation for a natural catastrophe. However, rapid recovery from large-scale natural disasters requires that special preparations and procedures be in place well before the disaster occurs. By definition, a disaster of large magnitude is one that overwhelms a community's normal response capacity.

The series of manuals on disaster preparedness issued by the Pan American Health Organization is designed to respond to the call from Member Countries to "disseminate the appropriate guidelines and manuals" so as to assist health workers in the Americas in developing disaster preparedness plans and training the necessary human resources. Given the suddenness of their occurrence and the importance of speedy measures to prevent potential morbidity and mortality, natural disasters demand that a nation use appropriate technology and its own human resources during the immediate emergency. Dependence on outside resources can create a time lag that may have serious consequences for the health and well-being of the affected population.

This manual is a companion piece to the guide *Emergency Health Management after Natural Disaster* (PAHO Sci. Pub. No. 407, 1981), and provides technical guidelines on specific chapters contained in the parent guide. The parent guide provides an overview intended to be of use to policy makers and the administrators responsible for health service delivery after the occurrence of disaster in developing nations. This manual is directed to an audience which consists of the senior technical officers involved in postdisaster health relief. Given the importance of intersectoral collaboration for effective relief efforts, the manual also provides guidelines for such cooperation.

The general principles and observations in this manual are relevant throughout the developing world. Special emphasis is, however, given to the experiences and needs of Latin America and the Caribbean. It is hoped that the manual will serve as a framework for developing national manuals, adapted to local circumstances, and that disaster preparedness will become an integrated component of national plans of action toward Health for All by the Year 2000.

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Director

**Acknowledgments**

Pan American Health Organization consultants, working in the Caribbean after Hurricane David in 1979, identified the need for guidelines concerning problems related to vector-borne disease after natural disaster. This guide was prepared in response to that need. It was written for countries that might be affected by natural disasters in order to alert them of potential vector
related problems and their possible solutions, and to provide guidelines for consultants assigned
to countries for postdisaster assessments.

This guide was also written for individuals with a broad range of backgrounds, from that of
health administration to that of vector control inspection. Certain subjects may not be discussed
in sufficient detail to provide answers for all technical decisions to be made. Therefore, this
information should be supplemented through additional reading of the references listed in the
bibliography.

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Introduction

This guide is intended to assist governments confronted with the problems related to vectors and pests that follow certain natural disasters. It will also be of value to evaluation teams asked to determine the probability of vector-borne disease related emergencies. The specific objectives of this guide are:

(1) To call attention to the vector, rodent, pest and related problems that may occur after a natural disaster

(2) To provide technical information necessary for evaluating the need for vector and rodent control following natural disaster

(3) To provide technical information for initiating immediate and postdisaster control measures

(4) To serve as a basis for the formulation of national and international training programs for the evaluation and control of vector-borne disease after natural disaster

(5) To provide guidelines for planning and carrying out surveillance and control programs under austere conditions.

Since every natural disaster has some unique characteristics, no guide can completely cover every situation. Individual judgment, fortified by knowledge of the environmental, public health, political and economic conditions of the affected area, will provide the real guidance for evaluating problems and finding adequate and acceptable solutions. This guide provides information about specific problems related to vectors and contains suggestions for solving them.

Part 1: An Overview

Chapter 1: The general problem

Although there are a number of types of natural disasters, the scope of this guide will be limited to those of hurricanes, cyclones, floods, earthquakes and volcanic eruptions. In each ease, the rapidly changing environment produces a general disruption of patterns of life, which results in stress to individuals and the weakening of health throughout the population. In many instances, people are forced into crowded, unsanitary conditions which can lead to outbreaks of epidemic diseases.

For the public health administrator, sanitarian, entomologist, epidemiologist and vector control specialist, the management of health relief and related responsibilities involves careful planning. Certain natural disasters may provide sufficient warning that some of their consequences can be alleviated. Predisaster planning, consisting of the establishment of disaster readiness committees and the formulation of contingency plans, can limit the risk. This is accomplished through organized preparedness, including the assignment of responsibilities to specific individuals and the establishment of intergovernmental relationships through which better use is made of any existing resources. Contingency planning should, however, be broad enough in scope to allow the response to be flexible. Too much detail may be counterproductive.
and self-defeating. Certain guides cited in the bibliography provide administrative procedures for planning and organizing public health activities during and following disasters.

‘The majority of’ vector control programs have static, inflexible administrative procedures. Consequently, there is a tendency to respond routinely to disaster situations, even when they call for innovation and flexibility. A disaster contingency plan may alleviate some, but not all of this problem. As a result, there may be some misdirection, confusion and waste, regardless of how well organized and adaptable the program is. Overreaction to actual and potential risks of vector-borne disease may occur because of our inevitable inability to predict the actual future needs. That this is inevitable should be recognized in determining the availability of resources and the most effective use that may be made of them. In many cases the confusion and overreaction that takes place in the aftermath of a natural disaster will be partially offset by the visibility of entomology and rodent evaluation and control teams, whose presence may benefit the population psychologically.

The life history of Aedes aegypti.

Courtesy Dr. M Giglioli, Cayman Islands
Disasters do not generate "new" diseases but, by altering the environment, they may increase transmission of diseases that already exist in a region through:

1. Direct effect of the physical event itself, such as fecal contamination
2. Indirect effects which result in such conditions as overcrowding and poor sanitation
3. Promoting or causing increase in the movement of populations
4. Disrupting routine vector control programs
5. Altering the distribution vector species.

Aedes aegypti breeding sites.

The increased risk of transmission of vector-borne disease must be seriously considered after all natural disasters. It is a matter of priority, therefore, that the potential of transmission of vector-borne disease is assessed early in the postdisaster period. It is important to note, however, that natural disasters do not necessarily lead to outbreaks of infectious diseases. This is particularly true of the mosquito-borne diseases, since the larval habitats and adult resting sites of mosquitoes often suffer from wind and water damage. As a result, such diseases as malaria, dengue and encephalitis may not appear until several weeks after the disaster, if they appear at all.
Chapter 2: Disaster preparedness

A Disaster Emergency Committee, with responsibility for maintaining a state of preparedness for natural disasters, should be in existence. Such a committee would include representatives from governmental and private agencies that deal with the routine problems that are accentuated in times of disaster. A Vector Control Subcommittee should be established in the health sector, and it should be responsible for updating information concerning the status and distribution of the vector-borne diseases that are endemic to the country, as well as nearby regions. Information should be continually updated on entomological surveillance of vector populations and on the location and status of manpower, insecticides and application equipment. The subcommittee should be responsible for implementing the emergency vector control operations. To accomplish this, it must have power to act without the bureaucratic constraints that are usual in normal circumstances. The subcommittee may include individuals from a number of agencies within the Ministry of Hearth, as well as those from other ministries and the private sector. The chairperson of such a committee may be the officer responsible for epidemiology, for malariology or for environmental health.

In areas of high risk of recurrent natural disasters, vector control personnel should attempt to rehearse disaster emergency control operations, in order to refine procedures and develop expertise and a more effective state of alertness. Even without a Vector Control Subcommittee, insect and rodent control personnel can develop a system of alertness to function during and after disasters. Continuous in-service training of all members of the staff should be included in all control programs. Training and program evaluation services offered by the Pan American Health Organization can assist administrators in identifying and resolving problems in control programs.

The vector control program should keep information current on the following:

1. The status of all instruments, aids and activities necessary for surveillance, evaluation, and control activities, including:
   (a) Distribution maps of areas of high risk of disease transmission, which delineate the sizes of vector populations, increases in larval breeding sites and the locations of potential reservoirs of disease
   (b) The distribution of all cases of malaria of autochthonous and foreign origin
   (c) Maps of the phases of progress in malaria and Aedes aegypti control programs
   (d) Population indices for Aedes aegypti, malaria vectors and other important species
   (e) Graphs of monthly variation in vector density per year and according to changes in rainfall and temperature
   (f) Incidence Graphs showing changes in the incidence of vector-borne and rodent-borne diseases
   (g) Status of seaport and airport Aedes aegypti and rodent surveillance programs.

2. The inventories of insecticides and vehicles and other types of equipment, and lists of personnel and variable funds, including:
   (a) Breakdowns for each vector and rodent control program
   (b) A list of similar or related programs that exist in other ministries, such as Agriculture and Defense, and an inventory of their equipment and insecticides that can be converted to public health use
(c) A list of private fumigation and agricultural spray companies that have ultra-low volume (ULV) and other application equipment (which might be owned by resorts or cities in touristed areas)
(d) A list of the names, telephone numbers and addresses of contacts in the Ministry of Health and other ministries and, in addition, of companies that supply and manufacture insecticides and dispersal equipment and of international representatives
(e) A list of any other known, local sources of expertise, supplies and material.

(3) The status of transportation, communication and intelligence, and other maps and reports that might assist in reconnaissance and other types of surveys, including:

(a) Road maps of larger political divisions and street maps of cities and towns
(b) Geographical and topographical maps
(c) Aerial photography surveys of high risk areas of vector-borne diseases
(d) Distribution maps of agricultural products
(e) Telephone directories, airline schedules and ham radio operators, and radio, television and newspaper services

(4) Directions for routing requests for interdepartmental and international sect, and a list of agencies.

(5) An operational contingency plan.
Chapter 3 – Postdisaster Action

Immediate Action
One of the first actions of the subcommittee should be to assess the potential of vector and rodent related problems, and to gather adequate baseline information. Vector and rodent control personnel should be consulted about the locations of temporary living quarters, so that human contact with these organisms is minimized. Vector and rodent control personnel, and sanitarians, can also provide advice about mosquito and rodent proofing of temporary structures. It is also necessary at this time to determine if the available staff members, insecticide resources and equipment are adequate. If not, appropriate measures should be taken.

Assessment of Situation
A significant problem that administrators of vector control face after natural disasters is accurately assessing the potential of vector and rodent related problems, and determining what resources are required. A considerable amount of unreliable information concerning the vector problem may be generated from other than official sources. In most cases, it will be exaggerated and panic may result in the population. Accurate and updated information collected before a disaster facilitates the proper evaluation of the postdisaster situation and it aids in the process of making logical decisions concerning a plan of action. Such information also helps in providing international relief agencies a clear picture of the problems a disaster can pose. It permits them to reach a clearer definition of their role in relieving shortages of insecticides, rodenticides and equipment. Adequate information from the predisaster period also improves the accuracy of the information that is given to government information services and the local population.

Each of the different types of natural disasters causes specific kinds of vector and rodent related problems, and the periods of time in which they remain problematic varies. This is particularly true of water related disasters that create breeding habitats. Certain types of information, which may be broken down according to type of disaster, are generally required in the postdisaster period. After all disasters, it is necessary to do the following:

1. Determine the geographical area and the size and distribution of the population affected, and the political and medical zones involved
2. Assess the extent of damage to transportation and communication systems
3. Determine the availability of staff, the availability and condition of equipment and supplies in the affected area, and the availability of additional resources in unaffected areas
4. Review the current information on the vector and rodent situation, including population densities in the affected area and the prevalence of vector and rodent related diseases in affected and adjacent areas.

After the specific occurrence of water related disasters, such as hurricanes, cyclones and floods, the following steps need to be taken:

1. Determine all migrations and redistributions of human populations within and adjacent to the affected area
2. Assess the extent of damage to the water supply system and sanitary facilities, and estimate the time required to restore these services
3. Appraise the crowding and exposure to mosquitoes and other vectors in postdisaster living situations, and the rodent-ectoparasite contact and fly breeding as they relate to the living situations
4. Determine the status of established mosquito breeding habitats and the extent to which new ones are created
5. Work with epidemiologists and other health officials to reestablish the disease surveillance network and the role of the vector control programs within the network.

When earthquakes and volcanic eruptions occur, these steps should be followed:

1. Determine population movements and the need for shelter, water and sanitation
2. Assess the risk of vector and rodent-borne diseases
3. Determine the need for vector control when there is emergency provision of water and sanitation in the area.

Aerial observation, where available, is one of the easiest methods of obtaining information on the geographical extent of damage to population centers and communication and transportation systems. It is useful, as well, for assessing vector breeding potential and human population movements. Light, single and multi-engine aircraft and helicopters may be available from the military and private sectors or from commercial agricultural aerial spray companies. Funds for aerial surveillance should be allocated in any budget. Maps and, if available, recent aerial photographs can be used for comparative purposes when the situation is assessed.

Additional information may be obtained from on-site reports from vector control staff members who live or work in the area and from local public health inspectors, physicians, administrators and teachers. Some caution should prevail, however, when interpreting information from these sources.

**Determining Priorities of Action**

Knowledge of the biology and ecology of pest organisms and their relevance to the current conditions is required when the effect that natural disaster damage has on vector and rodent problems is assessed. For example, flooding usually flushes out or destroys mosquito breeding sites. It subsequently creates additional habitats that can eventually produce even greater mosquito densities. When water and sewage systems are damaged, increased storage of potable water can provide additional breeding sites for *Aedes aegypti* while temporary pit latrines can provide habitats for synanthropic flies and *Culex quinquefasciatus*. Inadequate food storage, poor sanitation, and contamination by debris, animal carcasses and excreta may produce filth flies and increase the visibility of the rodent populations.

Problems related to vectors and rodents may not be confined to the affected region. Human movement away from the region may contribute to crowding in peripheral areas and, as a result, provide opportunity for proliferation of diseases associated with vectors and rodents. Following water related disasters, the peripheral areas may harbor potential mosquito breeding habitats that are more conductive as immediate oviposition sites than in the actual disaster area.

When setting priorities, types of vector-borne diseases in the area and density of the human population are factors to consider. When these are known, action should be immediately directed toward the areas of high population density, especially slum areas and camps where migrant populations are received. Every attempt should be made to restore and strengthen routine vector control operations within the area.
Under certain circumstances, the Ministry of Defense may be called upon to render aid in the wake of a natural disaster. Probably no other organization is so uniquely endowed with the necessary resources such as manpower and transportation, and possesses the necessary capability of quick reaction.

Urban, suburban, and rural areas of high priority for receiving control efforts should be determined from the following criteria:

1. Population at risk
2. Number of confirmed or suspected disease outbreaks
3. Recent history or disease transmission
4. Relative density of potential disease vectors
5. Significant increases in new breeding sites
6. Significant wind damage resulting in destruction of sprayed houses and increased exposure of displaced or homeless persons to mosquitoes
7. Presence of potential disease reservoirs
8. Seasonal accessibility by ground transport
9. Number and types of complaint calls regarding mosquito activity.

**Surveillance and Control**

The major activities in vector and rodent control occur during the postdisaster period. If the immediate surveys and other sources of information indicate a potential problem, the sooner that postdisaster programs are implemented to reduce the disease potential, the less is the chance that epidemics will occur and the less is the overall expense to the government. Delaying action until an epidemic is at its height can be medically and economically disastrous.

Reestablishing and upgrading routine control operations, surveillance activities and training of staff members will go far in lessening the chance and/or impact of an arthropod-borne epidemic. Operational manuals for control of malaria and *Aedes aegypti* caused diseases prepared by the World Health Organization and the Pan American Health Organization can assist in planning these activities.

**Emergency Action in the Event of a Vector-Borne Disease Outbreak**

Should the immediate action to bring vector populations under control prove insufficient, and a vector-borne disease outbreak result, all efforts should be made to reduce infective adult mosquito populations as soon as possible, by such space spray methods as aerial ultra-low volume (ULV) applications, vehicle-mounted and portable thermal foggers, aerosol generators or portable mist ultra-low volume blowers. Details about these methods are given in Part II under "Specific Vector Problems."
Chapter 4: Vector and Rodent Related Diseases

Mosquito-borne diseases, especially malaria, dengue and arboviral encephalitis, cause significant concern after disasters with which heavy rains and flooding are associated. The immediate effect is, however, the probable destruction of larval habitats and some accompanying reduction of the vector population with the secondary creation of new larval habitats. It is difficult to determine the probability that greater adult densities will be produced in these habitats and, subsequently, whether an increase in disease transmission will occur.

Such vector related diseases as endemic typhus and certain rickettsial diseases, should cause concern when they are already endemic in or near a disaster area. In addition, fly, cockroach, bedbug, human louse and rodent infestations may pose problems. Immediately after a natural disaster, the fly and rodent densities may appear to be greater, either because they become more visible or have indeed rapidly increased. This is partly due to disruption of sanitary services, such as garbage collection and disposal, and also because increased human crowding is accompanied by increases in the densities of populations of rodents and other vermin which seek the same sources of food and accommodation.

In some regions of the world, unsanitary and crowded temporary shelters and inadequate facilities for storing food provide ideal habitats for bedbugs, lice, fleas, mites, mosquitoes and rodents. Under conditions of this sort, the possibility of transmission of diseases such as louse-borne epidemic typhus, plague and malaria is enhanced.

The potential for increase of vector-borne disease occurrence and related problems during a postdisaster period is summarized on the next page. The immediate period is one to seven days after impact. The "delayed" effects refer to those that occur during the next 30 days or more.

The following sections will cover the issues of identification, evaluation and control of specific problems. The reader interested in routine control operations related to specific diseases, should consult the bibliography.

<table>
<thead>
<tr>
<th>Vector</th>
<th>Immediate</th>
<th>Delayed</th>
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<tbody>
<tr>
<td>Filth flies</td>
<td>annoyance</td>
<td>diarrhea, dysentery, conjunctivitis, typhoid, cholera, fly larvae infestation, annoyance</td>
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<tr>
<td>Mosquitoes</td>
<td>bites and annoyance</td>
<td>encephalitis, malaria, yellow fever (urban), dengue, filariasis, annoyances and bites</td>
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<td>Rodents</td>
<td>rat bites</td>
<td>rat bite fever, leptospirosis, salmonellosis, rat bites</td>
</tr>
<tr>
<td>Lice</td>
<td>bites and annoyance</td>
<td>epidemic typhus, louse-borne relapsing fever, trench fever, bites and annoyance</td>
</tr>
<tr>
<td>Fleas</td>
<td>bites and annoyance</td>
<td>plague, endemic typhus, bites and annoyance</td>
</tr>
<tr>
<td>Mites</td>
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<td>scabies, rickettsial pox, scrub typhus, bites and annoyance</td>
</tr>
<tr>
<td>Ticks</td>
<td>bites and annoyance</td>
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1 From 1-7 days
2 30 days or more
Part II: Control measures for specific vectors

Chapter 5: Aedes aegypti

Aedes aegypti is the vector of dengue, dengue hemorrhagic fever and urban yellow fever. It is a domestic mosquito that breeds in artificial containers in and around human dwellings. As containers proliferate, the species achieves high levels of density. This mosquito has also been known to breed in artificial containers placed some distance from human dwellings, and in natural containers, such as tree holes, bamboo, coconut shells and large snail shells. Any given area has slightly unique breeding habits, due to differences in the habitats and lifestyles of humans. In areas where water is stored or collected, open containers furnish ideal habitats. Such breeding sites should be given extra attention after a natural disaster, especially if the normal water supply is disrupted. Cisterns, cans, bottles, cemetery urns, tires and almost any discarded container that holds fresh water may also become infested.

The adult female mosquito deposits its eggs singly on the side of the container at, or immediately above, the waterline. Rains associated with some disasters provide the needed water to allow hatching, because the eggs are able to withstand drying for several months. Excessively heavy rains quite often wash away much of the initial egg deposition. However, large numbers of Aedes aegypti are quickly produced in numerous new oviposition sites. When conditions are favorable, hatching can occur within two or three days after ovipositioning.

Larval development, under favorable conditions, can be completed in five to seven days. The fourth instar larva molts to a pupal stage, and transformation to an adult is completed during the two to three day pupal period. Consequently, the life cycle can be completed in about ten or more days.

The emerging adults usually do not disperse more than a hundred meters and the females will readily enter nearby houses or any other man-made dwelling. In order to develop eggs, females require a blood meal for which humans are the preferred host. Biting usually occurs during, but is not limited to, daylight hours. In many cases humans are not aware of being bitten. The adult may live for six to eight weeks and, once infected with the viruses of yellow fever or dengue, remains so for life.

Surveillance

If the country has an eradication or control program for Aedes aegypti, baseline information on population densities in the affected or adjacent areas should be available. Wherever there is no control program, the distribution of the vector should be mapped, its favorable larval habitats should be determined and adult population densities should be studied by determining land rates and the distribution and examination of oviposition traps.

Initiation of new or additional control activities should be related to the prevalence of Aedes aegypti or virus activity in the immediate and nearby areas. The epidemiologist should be responsible for determining the presence or likelihood of the introduction of diseases.

Recruitment and training of new vector control personnel may be problematic and depends in part on the budgetary priorities of the government. Even with assistance from external sources, tremendous strain is placed on budgets during natural disasters. If paid personnel are
unavailable during emergencies, military recruits, school children, boy scouts and other volunteers may be used.

Backup availability of laboratories is necessary for identification of mosquitoes. This may be available from an *Aedes aegypti* or malaria control service. Universities and other research institutions might have a professional entomologist or student biologists capable of making taxonomic identification. All surveillance programs must have maps, office space, and clerical and other technical and administrative assistants to organize and evaluate field data. Information from the program should be made available to vector control and epidemiological personnel as soon as possible.

**Estimates of Larval Populations**

Even though adult populations are the most important of the populations of *Aedes aegypti*, when personnel trained to make species identification are available, the surveillance of larval populations is easier and more reliable than that of adults. The systematic collection of larvae serves to determine the presence, distribution and relative abundance of *Aedes aegypti*.

Estimates are usually limited to those obtained when the frequency of *Aedes aegypti* larvae in water-filled containers in the vicinity of occupied buildings is assessed. Larvae can, however, be found in containers in vacant lots and along roadsides.

Surveys can be rapidly performed in several manners. Biases in information gained can be minimized if: (1) blocks to be surveyed are selected by a randomized procedure and then all houses on the selected blocks are investigated, (2) every third (or some other ordinal number) house is systematically investigated, and (3) fifty or more houses per subdivision are placed randomly in the sample.

One or more collectors, who search for and examine all water-filled containers in the vicinity of occupied buildings, take part in surveys for larvae. During the initial survey, the species composition should be determined through the collection for laboratory identification of one larva from each positive container ("single-larva-per-container survey"). Simple inspection or "visual larvae surveys," may suffice thereafter. Each individual who participates in the survey will need the following:

1. Forms and pencils
2. A flashlight
3. A small mirror
4. A dipper (if possible made of white enamel)
5. A squeeze-bulb syringe or medicine dropper for transferring larvae
6. A tea strainer to remove larvae from debris or dark water
7. Collection bottles and a wax or grease marking pencil
8. A container or bag to carry the instruments and equipment.

The results of the surveys are usually expressed in terms of one or more of the following indices:

1. The House Index (or premises Index), in which the percentage of the houses examined and found positive for *Aedes aegypti* larvae is reported
2. The Container Index (or receptacle Index), in which the percentage of the water-holding containers that were examined and found positive for *Aedes aegypti* larvae is reported
3. The Breteau Index, in which the total number of containers with *Aedes aegypti* larvae is described per hundred houses.
Criteria for interpreting the probability of the transmission of yellow fever by Aedes aegypti, from the results of such surveys, have been published in the World Health Organization Weekly Epidemiology Record (49, 1971:493500). Urban transmission of yellow fever is unlikely if the Breteau Index is less than five, the House Index less than four and the Container Index less than three. But where these figures are, respectively, greater than fifty, thirty-five and twenty, there is a high risk of transmitted yellow fever. Comparable criteria have not yet been established for dengue, but a similar interpretation of the indices may also be valid. In both cases, the indices of Aedes aegypti, the transmission of virus and the level of immunity in a population are related.

Estimates of Adult Populations
Adult surveillance is particularly appropriate in areas where it is necessary to quickly assess the effect of an emergency adulticiding operation. There are both direct and indirect methods of sampling adult Aedes aegypti populations. The direct methods vary in their degree of difficulty in interpretation of data. Three direct methods may be employed: resting, landing and sheet drop collections.

Resting collections may be recommended over landing counts, especially if dengue has been reported to a substantial extent in the area. Resting collections consist of search for adults in bedrooms, and other rooms in houses, garages and outbuildings. They may also be performed in yards, cemeteries, tires and junkyards. The adults are captured with small vials, hand sweep nets, or mouth or battery powered aspirators. The adults usually rest in shaded places and dark corners on walls, clothing, or mosquito nets, and under tables, chairs, or beds. Aedes aegypti can be found resting throughout the day so there is no restriction on time of day in which they may be collected. The collector should spend a certain standardized period of time, such as 20 minutes, in each house. This allows density to be expressed in catch-per-house and catch-per-man-hour. Mosquitoes are identified by species and sex. Collection stations can be selected at random, or they can be located at predefined sites. It should be remembered that collecting depletes the population and thus, that the same house should not be sampled every day.

Landing counts are made on humans. Thus, a collector can collect either from his own body or that of a second person, if collectors are working in pairs. Trials should be made before initiating this type of survey and the methods to be used should be standardized because individuals vary in attractiveness to mosquitoes. It is recommended that a twenty-minute collecting period be made in each house, between the hours of 0900 to 1100, and that the results be expressed in terms of catch per man hours.

The following items of equipment are required for adult surveys:
   (1) Forms and pencils
   (2) Flashlight
   (3) vials
   (4) Aspirator
   (5) Sweep net

If a knockdown aerosol is available, the sheet drop technique is a quick and easy method of obtaining a representative sample of adult mosquitoes inside dwellings. In this technique, a white sheet is spread out on the floor and over the furniture of an occupied room, and then the occupants are asked to leave for approximately fifteen minutes. The room, made as airtight as possible, is sprayed with the knockdown aerosol. After having left the room for ten minutes, the collector enters again to collect all the mosquitoes that have dropped on the sheet.
It is important to make certain that collection procedures are standardized; otherwise, results that should not be compared will cause incorrect conclusions to be drawn about changes in populations. Collections at a simple location should be performed by the same individuals, in a uniform manner, and at the same time of day. The number of houses to be sampled can be decided on-site.

Ovitraps provide an indirect method of assessing the presence and size of the adult *Aedes aegypti* population after a natural disaster. This method is particularly good for detecting the presence of *Aedes aegypti* where the density is so low that larvae are difficult to find. Ovitraps cannot be used to effectively measure adult population densities, but if they are used routinely they can indicate changes in the population.

Ovitraps consist of black-enamelled, one-pint glass jars (of 130 mm height and 75 mm diameter). Almost any wide-mouthed glass jar with a glossy black ceramic paint on the outside can be used. Tin cans, beer cans or bamboo pots can be substituted for glass jars, but the same type of container must be used throughout the study. Clean water is added to a depth of two to three cm and a paddle is clipped vertically to the inside of the jar. The paddle should be made with an absorbent material; porous hardboard is recommended, but heavy cardboard, heavy velour paper or cloth can be used. When it has absorbed water, the paddle is an attractive surface on which mosquitoes deposit eggs. The size of the paddle should be standard, for example, 2 cm by 13 cm. The rough surface of the paddle should face the center of the jar. Paddles are usually changed at intervals of five or seven days; however, the exact schedule that should be used depends upon the number of positives identified per collection.

To obtain the full benefit of ovitrap surveys, the area should be fairly extensively covered. Maps should be consulted for deciding locations in which to place the traps, and visits should be made to the area for selecting the sites. Transects or grids should be used in the survey. It is
recommended that sites should be from one to two hundred meters apart, and that the traps are placed within thirty meters of the grid line.

Points to be considered are:
(1) The traps should be placed at or near ground level because females usually fly near the ground
(2) Traps should be visible to the female mosquitoes that fly over them
(3) Traps should not be placed where they will fill by rain
(4) All traps should be placed where children, cats, dogs and other small animals do not have access to them
(5) Oviptraps should be located in partial or total shade, in adult resting places such as shrubbery or junk. Placing them in the rear of a house is preferable to placing them in the front
(6) Females tend to prefer tires to ovitraps, so ovitraps should not be located in tire yards or near other locations where tires are piled.

When the paddles are collected, the water should be changed and the inside of the jar should be wiped clean. Ovitraps should be assigned numbers or otherwise marked with an identifying code. Paddles should be dated and should also be marked according to the code. If collectors miss a site, the date will help the laboratory technician in recording information. When transported to the laboratory, paddles may be placed in a plastic bag or wrapped in toilet tissue or other soft paper. Some workers have designed carrying cases similar to microscope slide boxes for the transporting of paddles.

The occurrence, distribution and changes in population density of *Aedes aegypti* in an area are revealed by the presence of its eggs on ovitrap paddles. All mosquito eggs found on the paddle might not, however, be *Aedes aegypti*.

If there is a question concerning accuracy of identification of the eggs, they should be hatched so that the larvae can be identified. Some workers recommend counting all of the eggs on the paddle; however, for disaster followup the mere recording of the presence or absence of *Aedes aegypti* eggs should be sufficient.

**Control of Aedes aegypti**

Ideally, *Aedes aegypti* populations are controlled through rigorous environmental sanitation and the availability of a piped water supply that eliminates many of the man-made habitats of the species. In a postdisaster period, the disruption of existing water supplies causes people to store increased quantities of water in containers, thereby increasing the availability of man-made habitats.

The appropriateness of measures for the emergency control of *Aedes aegypti* that should be taken after a natural disaster depends upon the presence or absence of dengue or yellow fever in the affected area, and upon the population density of the vector. As stated previously, larval habitats may be rushed out or destroyed during a disaster. Nonetheless, if rains occur during or after the disaster, new larval habitats may be created. However, it may take several weeks before the mosquito populations reach such a level that there is concern that disease will be transmitted. This lag in time should be sufficient for the initiation of routine control activities and for sanitation crews to haul away or empty many of the potential larval habitats. Through health education, the public should be asked to cooperate in a source reduction campaign especially since community involvement may be at a high level after a disaster. This is a key ingredient in a successful *Aedes aegypti* borne disease prevention program.
**Larval Control**

If the risk to health is immediate prior to the emergence of appreciable number of adults, source reduction will be recommended. The success of this type of campaign will depend upon the extent of organization, discipline and adequacy of number of staff members, and upon the completeness of the treatment of potential larval habitats. The Pan American Health Organization *Manual of Operations for an Aedes aegypti Eradication Service* can be consulted for basic organization of a campaign.

There are two insecticides that can be used for treating containers which hold potable water: one percent temephos (AbateR) sand granules and methoprene (AltosidR) miniquets. In many parts of the world temephos has been used as a larvicide for a number of years. Its effectiveness usually lasts from one to three months; an eight-week treatment cycle is recommended. The treatment dosage of temephos is 1 ppm. There may be objections made to the taste of the treated water, but these may be counteracted through public relations efforts.

Methoprene, an insect growth regulator, has been placed on the market only recently. Odorless and tasteless, methoprene is considered to be safe for use in potable water. It has been successfully used in Thailand, Indonesia, and Venezuela. The label must be consulted to determine proper dosage of the miniquets, which are available in a number of sizes. Since the period in which methoprene remains effective is considered to be shorter than that of temephos, a four-week treatment cycle may be necessary.

Both the temephos and methoprene insecticides can be used to treat watering containers used by animals. In many cases, however, it is unnecessary to treat containers used by animals with insecticides because frequent cleaning and changing of the water leads to effective control over the mosquito.

Other insecticides or formulations can be used for the treatment of larval habitats that are not in close association with man. As a temporary measure, tin cans and other containers can be treated before they are removed with emulsifiable concentrates and wettable powder insecticides applied with hand-operated compression sprayers and power spray equipment. Insecticides such as fenthion, temephos, pirimiphos-methyl, malathion, fenitrothion, chlorpyrifos, and methoxychlor may be used as well as diesel fuel, kerosene, and proprietary mosquito-control oils. The product label should be consulted about the rate of application and the safety recommendations. Since some of the products are highly toxic to mammals, operators should strictly observe the precautions. It is essential to prevent toxic or ecological accidents by very clearly defining the dosage to be used and the places to be treated.

**Adulticiding**

Efforts to control adult populations of *Aedes aegypti* in dwellings with residual sprays are not generally effective since as few as ten percent of the adults rest on the walls at any point in time: most rest on clothes, pictures, bedspreads, mosquito net poles and other objects. Residual spraying is also slow. As an effective means of *Aedes aegypti* control in urban areas it is, therefore, of doubtful value. However, it may be of greater usefulness in refugee camps. There, pirimiphosmethyl, malathion, resmethrin and synergized pyrethroids can be used. Again the manufacturer's instructions should be strictly followed.

Adulticiding, in conjunction with larviciding, will more rapidly cause decrease in the population. Use of modern application equipment can increase coverage and should be considered when (1) either dengue or yellow fever is endemic to the area, or at epidemic levels in the vicinity, (2) there is already an *Aedes aegypti* operational program in which this equipment is used and has
effectively brought the *Aedes aegypti* populations under control, and, (3) the larviciding program is ineffective.

One problem that use of modern equipment poses is logistical. If the equipment is not readily available, considerable time may be lost while waiting for its arrival. Vehicles are usually taxed to the limit after a disaster, and unless vector-borne epidemic is imminent, they are usually put to other more urgent purposes than transporting modern equipment. Other problems posed by the use of modern equipment, especially in newly created programs, concern the lack of trained staff, inadequate organization and the tendency to attempt too much with limited equipment and resources. Use of modern equipment does not always entail simply negative aspects, however; it may create beneficial psychological effects, and the use ultra-low volume aerosols and thermal fogs is speedy and efficient.

A number of companies manufacture ground and portable space-spray equipment (see Annex IV). When these are utilized, the manufacturer's instructions for the operation, maintenance and calibration of the equipment should be followed. Usually, aircraft equipment that is used in agricultural work is adapted to public health use.

Thermal fogging is the oldest of the two space spray methods. The equipment used for thermal fogging can be vehicle-mounted and portable. The portable equipment should not be used in indoor applications because it can create fire hazard. The outdoor machines are rather noisy and the fog can create a traffic hazard. There are also the disadvantages of the need to purchase and transport large quantities of nonactive oil carriers and the possible thermal decomposition of the insecticides. Despite these problems the machines are popular and provide an acceptable level of control. Thermal fog applications of chlorpyrifos, fenthion, fenitrothion, malathion, naled and pyrethroids have all shown promise in the control of *Aedes aegypti*. Concentrations, dosages and safety handling procedures should follow the recommendations on the label of the manufacturer.

In emergencies, one or two portable thermal foggers can be mounted on a vehicle, which serves as a mobile unit. The sizes of *Aedes aegypti* populations generally decline sharply within a few hours of fogging; the adults, however, reappear within a day or two. Treatment schedules should be adjusted accordingly.

The use of ultra-low volume equipment for the application of low dosages and volumes of undiluted, or partially diluted, insecticides has steadily increased. Ultra-low volume applications are rapid, and are effective against *Aedes aegypti*. They are also less expensive than thermal fogs because the cost of the solvent or carrier and of the transportation of thermal fogs is unnecessary.

Many control programs have had good results with vehicle-mounted, ultra-low volume cold aerosols, which are available from a number of companies (see Annex IV). Chlorpyrifos, fenthion, fenitrothion, malathion, naled, pirimiphos-methyl, and pyrethroids such as resmethrin have been used. Although initially expensive, these are relatively free of problems, and they can be operated for several years. The generator can be mounted on any one of a number of different types of vehicles. The type of vehicle that should be used will depend upon road conditions, which also determine whether or not a heavy-duty, four-wheel drive or a light, two-wheel drive vehicle should be used.

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).

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 chemophrophylaxis, 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 \textit{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," briquette, and granules can be
dispersed by hand.

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

\section*{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.

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.

One 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 DEFT 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.
Chapter 7: Culex quinquefasciatus and other pest mosquitoes

_Culex quinquefasciatus_ will in most cases be considered pest mosquitoes. In some areas, however, they are vectors of St. Louis encephalitis and bancroftian filariasis. A number of other mosquitoes that are also normally considered pest mosquitoes may be vectors of arboviruses. These mosquitoes are treated superficially because of the variety of larval habitats encountered and because of their limited medical importance. In many cases, they will cause complaints, and some type of action against them may become necessary.

Surveillance

There will be little available baseline information about pest mosquito densities unless it has been collected because of a tourist industry or in a municipal mosquito control program. The pest mosquito population density immediately after a natural disaster may be low as in the case of _Aedes aegypti_. Changes in the environment which occur both during and after a disaster may, however, favor rapid population increases.

Mosquitoes that breed in certain habitats may increase in number within one month after a disaster. These habitats are salt marshes, bogs, fresh-water swamps, mangrove swamps, sewage effluents, semi-permanent ponds, woodland pools, artificial containers, ditches, irrigation wastes, water impoundments, rice fields, and natural containers such as tree holes, rock holes, and crab holes. Although problem species will differ greatly from area to area, they should not go unidentified. Surveillance, if meaningful, must include knowledge of the species and habitats of all mosquitoes encountered.

Checklists of the mosquitoes and other biting insects that have been collected in the area may exist in universities or libraries. Basic information about flight range, host preferences, life cycle, larval habitats, adult resting places and specific control methodology, may be obtained from the literature. Topographical maps and aerial photographs assist in locating potential problems, as they do in the case of _Aedes aegypti_. In areas where there has been some type of environmental management such as diking for purposes of mosquito control, reconnaissance flights provide valuable information about the condition of the control method. (Maps and photographs can also be used to locate sampling stations for use in evaluating population densities.) If topographical maps or photographs do not exist or do not produce the information required, taking simple photographs and making maps while in flight can help in orientation and location of breeding places. Such flights can also be of service for planning chemical control and drainage operations.

_Culex quinquefasciatus_ breeds in highly polluted water. Rapid increases in populations might occur where pit latrines have been constructed as a temporary measure after a disaster has disrupted normal sewerage systems. Refugee camps should, therefore, be examined regarding the placement of latrines, open dumping of garbage in flooded areas, and the existence of any other standing water (especially artificial containers) that might become polluted.

Population sampling can generally be accomplished at weekly intervals in marshes, swamps and impounded water habitats. Biweekly collections of _Culex quinquefasciatus_ may be necessary. It must be emphasized, however, that these mosquitoes are unlikely to be a medical problem and sampling should be considered only if staff and resources are already available. Control of most _Culex quinquefasciatus_ habitats can be effected without a great amount of
surveillance. Complaints from the refugee or resettlement sites may provide sufficient surveillance.

**Estimates of Larval Populations**

In initial surveys, the collector must assume that wherever there is standing water there are mosquito breeding sites. As the collector becomes familiar with the area, species and preferred larval habitats, the observations can be refined. Entomologists can assist in identification of the specimens.

Larvae are collected with a white enamel dipper, white enamel pans or other water containers or a siphon. Flashlights or mirrors can be used to illuminate breeding places and to locate water and evidence of breeding. Medicine droppers and other types of pipettes can be used to transfer larvae from the collecting device to vials and bottles. For convenience, dips are usually done in multiples of ten, and inspections are made either weekly or every two weeks.

**Estimates of the Adult Population**

Adult surveys must be designed to show a relationship between breeding sites and the human population. Changes in population densities observed through one or more collecting methods can be used to determine the need for adult control measures, their effect, the extent of the mosquito problem and the possible arboviral trouble spots. As with all surveys, it is essential to have maps of the area, well designed forms for collecting data, use of standard collecting methods and sites, and a well organized and trained staff. Under some conditions, it is possible to use the adult collections to attempt to isolate arbovirus. This should be considered only if there is an indication of Venezuelan, eastern, western, or St. Louis encephalitis or other arbovirus activity in the vicinity of the disaster. There must be a laboratory that can handle the isolation attempts, as well as the necessary field and laboratory entomological equipment, and trained staff available to carry out this type of work.

There are a number of methods that can be used to collect mosquitoes. The following is a listing of possible methods:

1. For landing/biting collections in which either animals or man are used:
   - (a) Determine the biting habits of the vectors
   - (b) Standardize the time of day and the location of collection, the length of collecting period, and the type of bait used
   - (c) When a vector-borne disease problem is known or the population densities are high, employ landing rates.

2. For window traps (used if time and staff permit):
   - (a) Use either entry or exit traps (the latter are used in some malaria entomological evaluations)
   - (b) Employ entry traps (non-blooded mosquitoes only) for virus isolation attempts
   - (c) Operate during the night when the bait is in the shelter
   - (d) Standardize the number of collections per unit of time.

3. For animal bait traps:
   - (a) Use traps of sufficient size and strength to hold the bait animal comfortably and to permit easy entry and removal
Operate at night and standardize the time at which the bait is placed in the trap and removed (even early morning temperatures can be uncomfortable for a caged animal).

If the specimens collected are to be used for virus isolation attempts, use traps that are designed to separate the caught mosquitoes from the bait.

If a carbon dioxide trap is also desired, use smaller bait traps like the Lard Can Trap designed by Bellamy and Reeves (Mosq. News 12: 256258).

(4) For light traps:

(a) Choose from several types, the two most popular of which in the Americas are the New Jersey and the Centers for Disease Control miniature light traps, or modifications of them, and if there is no electricity, consider use of battery models.

(b) Remember that light traps attract both males and females from considerable distances, and that collection with the CDC light trap can be enhanced with a supply of carbon dioxide or by hanging dry ice nearby.

(c) When locating or positioning light traps, take care not to place them in competition with other light sources.

(d) Remember that collections can be made of live mosquitoes by attaching a mesh bag, and of dead mosquitoes by attaching a killing jar; and that live collections can be used for virus work.

(e) Run traps on a schedule and, preferably, at established sites.

(f) Take care in handling and separating material, since many other insects are also attracted to light traps.

(5) In regard to natural and artificial resting stations, it is useful to know that:

(a) Many mosquitoes (especially some species of Anopheles and Culex) seek out dark, cool humid places to rest during the day.

(b) It may take some searching to find natural resting places for different mosquitoes; buildings, especially unscreened ones that shelter man and animals, bridges, culverts, caves, and hollow trees, may serve as resting sites; collections can be made with an aspirator.

(c) Artificial resting boxes have been used with some success, but during emergencies that follow disasters their use might not have to be considered.

(d) Large mechanical aspirators and vacuum devices may be used for collecting mosquitoes that are resting in vegetation.

(6) Use of the sheet drop technique, described in Chapter 5, is questionable in disaster situations.

The interpretation of larval and adult surveys depends upon the baseline data that are available and the types of vector-borne diseases found in the disaster stricken area. Pest mosquitoes will cause a great amount of discomfort in many postdisaster situations. However, priorities have to be weighed before funds and staff are committed to controlling them.
Culex Control

Larval Control
Environmental management is an ideal method of mosquito control. If a natural disaster highlights pest mosquitoes, long-term environmental management (i.e., filling, draining, stabilization of water, and source reduction) should be considered in the future. Immediate corrective measures, however, are most likely to take the form of a type of chemical control directed towards adults or the larvae.

In addition to the usual chemicals (i.e., organophosphorus, carbamates and chlorinated hydrocarbons) petroleum oils, nonpetroleum monolayers, synthetic pyrethroids and insect growth regulators are available as larvicides. The selection of a larvicide should depend on insecticides, the susceptibility of the target mosquito to the chemical, the effect of the larvicide on nontarget organisms, the type of habitat that is being treated, and the relative costs. To avoid the development of resistance, it is recommended that a different chemical be used for larviciding than that used for adulticiding.

Adult Control
The same general space spraying methods used for the control of Aedes aegypti (i.e., thermal fogging and ultra-low volume aerosol application) can be used for most pest mosquitoes. Aerial applications of pest mosquito insecticides are used effectively for the abatement of mosquitoes in the United States of America. This type of control should probably not be considered for pest mosquitoes, however, unless aircraft used for public health are readily available. Exceptions are in areas with arboviral diseases in which pest mosquitoes have been incriminated as vectors, or in situations in which malaria vectors and pest mosquitoes are both increasing in number.

Individuals should be encouraged to use repellents, to burn pyrethrin coils at night and to sleep under mosquito nets. Small aerosol dispensers can be used in local situations, including refugee camp sleeping areas.
Chapter 8: Flies, rodents and other vectors

Synanthropic Fly Problems
Synanthropic flies are those that enter and adapt to the human ecological community. The unsanitary habits of man cause this relationship to develop. Increases in the fly populations may be expected after natural disasters, because of breakdown of sanitary services. The presence of synanthropic flies has potential epidemiological and hygienic implications, and the flies are an annoyance interfering with human comfort. The house fly, Musca domestica, is both a filth feeder and breeder, and health problems can occur when it comes into contact with human food and drink. The contamination of food and drink by pathogens can take place mechanically, through its legs, body, proboscis and wings.

The pathogens can also be defecated or regurgitated. Flies have been incriminated in the transmission of many of the enteric diseases of man, including dysenteries, cholera and typhoid fever. Yaws, conjunctivitis, enteroviral infections, and intestinal parasites may be transmitted by different species of flies.

Female house flies oviposit in a number of habitats, especially in garbage and animal wastes. When the average outside temperature is between 25° and 30°C, the life cycle of the fly from egg to adult, is approximately one to two weeks.

Surveillance and Survey Methods
Active fly control is not often included in most health programs. The first indication of a fly problem may be that of complaints from people living in refugee areas or who return to their homes in the disaster areas.

There are a number of fly traps, such as sticky paper, that can be used to appraise population densities. Not all synanthropic flies, however, enter houses and thus, markets, garbage areas, and even outdoor resting places have to be included as areas of appraisal. The easiest way of performing a survey is to count flies as they rest on refuse, vegetation, the walls of buildings and other resting places. Comparable information can be obtained with fly grills. (Ann. Rev. Ent. I: 323-346).

There are a number of other diseases of which rodents may be reservoirs. These include rabies, rat bite fever, rickettsial pox, spotted fevers, and rodent associated viral hemorrhagic fevers. For any rodent-borne disease problem, it is essential to determine if the disease is or recently has been in the disaster area. Since many of these diseases are associated with ectoparasites of the reservoir, it is important to know the natural histories of the diseases and to implement an appropriate control program against rodents and their ectoparasites.

Control and Evaluation
Prevention is recommended over control. High priority should be placed on sanitary services in refugee camps because of crowding and other unhealthy conditions. Sanitary services should also be restored to communities as soon as it is possible. Dead animals should be immediately cremated or buried, pit latrines should be made flyproof, and the rooms in refugee buildings, particularly kitchens and eating places, should be screened.

The public should receive health education about ways to prevent fly breeding. Other activities to recommend include burying garbage when sanitary services are not available, and using
fabric curtains at doors and windows to limit fly entry. When available, the use of sticky tapes and household aerosol sprays inside of buildings may help to reduce fly numbers.

Chemical control of filth flies over a long period of time is usually not recommended because their resistance to insecticides develops rapidly and is already widespread. During disasters, however, it may be necessary. Residual spraying of indoor resting places may be required and, if available, sugar and syrup baits with insecticides can be utilized once the sanitary program is well underway. Use of diesel oil in pit latrines is a quite effective control measure. Space spraying resting and breeding places with available insecticides (those used for malaria and anti Aedes aegypti programs) can help to reduce fly numbers.

Evaluation may be largely based on direct observation. If an insecticide is not causing an appropriate level of mortality, an alternative should be used. Walking through an area, especially around pit latrines, food preparation areas and garbage collection sites, provides a means of visually assessing the reduction of the population. In control operations, it should be taken into account that flies can migrate up to four miles to new food attractants or to breeding areas. More accurate information may be obtained through the use of standardized fly grill surveys.

**Rodent Problems**

The environment of the rodent undergoes the same change as that of man after a natural disaster since their harborage and food sources are also damaged or destroyed. The rodent will consequently be in competition with man for whatever food and shelter remain. Commensal rodents and other animals are more visible to man following a disaster and may migrate into his environment. Unfortunately, what the rodent does not directly, consume, it may damage and contaminate.

The rodent species that are of concern are the Norway or brown rat (Rattus norvegicus Berk), the roof rat (Rattus rattus L.), also known as the ship or black rat, and the house mouse (Mus musculus L.). Rodents have been involved in transmission of a number of infectious diseases to man. The most important ones are:

1. **Plague**, which is endemic to Brazil, Bolivia, Ecuador, Peru and Western United States, frequently involves rodents other than domestic rats
2. **Murine typhus**, cases of which occur throughout the world in areas of warmer climates where commensal rats, especially R. norvegicus, are the chief reservoirs
3. **Leptospirosis**, with a worldwide distribution, is maintained in reservoirs of commensal rodents, dogs, pigs and cattle
4. **Salmonellosis**, which occurs when commensal rodents are infected with Salmonella and the infection is transmitted to man in contaminated foods and liquids, spread by infected fecal droppings or by urine; the house mouse probably plays a greater role than rats in the transmission of food-borne illnesses.

The economic and nutritional importance of loss of foodstuffs because of rodent contamination must also be considered. Damages and losses caused by rodents are substantial, and during natural disasters this extra burden can be serious.

In many cases, since rodent control is not the direct responsibility of the central government, it may be difficult to obtain predisaster information. Rodent surveys and control work are usually undertaken by the port authority in seaports, by the local governments of cities, or by the
Ministry of Agriculture. These agencies may be sources of background information, supplies and materials for rodent control, and expertise regarding surveys and the organization of control activities. In the private sector, pest control operators may be an excellent source of assistance and relevant information.

**Rodent Surveys**

Information about rodents can be collected in interviews with people who live in temporary housing and refugee camps after natural disasters. The location and relative density of rodents sighted should be determined at this time.

If an individual familiar with the signs and traces of rats and mice can be located, a survey of large areas can be performed fairly rapidly. The major signs are fecal droppings, rodent runways, rodent footprints or tail marks in dust and tracking powders, gnaw marks of rats and mice, burrows, and nests. Rodent odors, especially of house mice, and urine stains that can be seen under ultraviolet light are also indicative.

Sightings increase when the cover of the rodents is disturbed. After natural disasters it is possible to obtain information through daylight surveys in affected residential areas and near rescue centers. Additional information can be obtained during dusk and early evening surveys. These may be undertaken at random, or through the selection of potential trouble spots. Strong flashlights can be used to search in such places as under buildings, and in refuse disposal areas. Maps are essential for this type of work and if they are not available, sketch maps should be made by the workers. Record should be kept of potential habitats, such as temporary refuse dumping areas and harborage, and of the number of sightings.

A more detailed survey can be accomplished when pest control operators, biologists or personnel from a rodent control program are available. Forms should be reproduced for recording information in such surveys as: the location of the survey, the type of premise, the condition of the structure, the construction materials, the number of occupants, and the presence or absence of food, water, harborage, rodent signs and traces.

Some surveyors use traps to assess the density and determine species of rodents in an area. Live traps can be used when available; otherwise, snap traps serve the purpose. If food markets or hardware stores are still standing after a disaster, snap traps can usually be purchased locally. Care should be taken not to use large numbers of snap traps if a rodent associated disease exists in which an ectoparasite is a vector.

**Control**

The World Health Organization document (WHO/VBC/79.726) should be consulted for the selection of rodenticides for control purposes. There are two general types of rodenticides in use. The first is the *chronic type*, a multiple dose, slow-acting compound. The second type is the *acute*, or single dose, quickacting compound. In general control operations, the rodenticide of choice is considered to be a slow-acting anticoagulant poison. Many acute rodenticides are toxic to man and other animals. Thus, in a disrupted environment, such as that which follows a natural disaster, extreme care should be taken in using acute rodenticides. They should be used only in extreme emergencies and by well-trained control operators. Red squill is an exception that can be used against *R. norvegicus*, but it is not as effective against *R. rattus*. Anticoagulant rodenticides such as diphenacimone, difenacoum, brodifacoum or chlorophacinone are available in a number of areas and have been used in emergency rodent control. The immediate needs of the control program should be determined with survey information or through estimates of
Locally available supplies of rodenticides should be located, and if inadequate, they should be supplemented immediately.

Rodenticides either come as preprepared bait or as concentrate. The concentrates might prove less expensive to order, but in emergencies either formulation is acceptable. In preparing food baits, it is necessary to know the rodents' food preferences. Contrary to popular belief, rats and mice prefer fresh, palatable food. Food dyes and other coloring materials that do not affect the flavor of the bait can be used as a warning to humans. Great care should be taken in mixing baits, especially those in which acute rodenticides are used. It is best to have a single individual responsible for mixing and/or packaging the bait.

Control operations should be based on the findings of the rodent surveys. Members of field teams need to be trained in placement of the bait and in public relations. Control personnel must be careful to develop positive working arrangements with the populace after a natural disaster. They should carry identification; and they should be trained well enough to understand what they are doing and why, and to communicate this information to the people.

Bait must not be haphazardly placed. Care must be taken to put the bait where the rodent will find it, but where children and other animals cannot. When the supply of rodenticides is inadequate, only the more hazardous areas should be treated. These areas include rescue centers, refugee camps, food warehouses, markets, ports and hospitals.

In areas of potential outbreaks of rodent-borne diseases where rodent control is necessary, special consideration should be paid to controlling ectoparasites. Before a trapping program is underway, rodent runs must be dusted with DDT, carbaryl, diazinon, pirimiphos-methyl or some other approved insecticide powder. Special care should be taken in handling and disposing of rodents in these areas.

The use of rodenticides is only a small part of a well-organized rodent control program. During a natural disaster, however, it is of greater importance than during routine operations. Sanitation is another important aspect, and it must be remembered that by creating harborage, the accumulation of garbage and debris encourages the establishment of rodent populations. Refuse and debris should be thoroughly incinerated when sanitary landfills are unavailable, because on-site burning is of limited value.

No control program can be successful without the cooperation of the people it serves. Such programs should always incorporate sanitary education, and other campaigns to enlist the help of community groups and individuals.

**Other Vector Problems**

Lice, fleas, mites, ticks and other arthropods may produce serious problems following natural disasters, (see Annex III). The lice of medical importance belong to the order Anoplura, or sucking lice. The important species are the crab louse, *Pthirus pubis*, the head louse, *Pediculus capitis*, and the body louse, *Pediculus humanus*. Of these, *Pediculus humanus* is the only species that is an important vector. It is the only proven vector of two diseases, louse-borne (epidemic) typhus and epidemic relapsing fever, a spirochete disease. *Pediculus humanus* and other lice can also cause a great deal of discomfort through their bites.

Surveys of human lice, with a reasonable population sample, should be conducted in order to determine the extent of the problem and the number of individuals who require treatment, and to
determine the effectiveness of the control program. A louse survey involves searching for the insects and their eggs, or nits. Body lice are found on shirt collars, the waistband, pockets and seams of trousers, and the seams of underwear. Head lice are normally found in the hair of the head, particularly around the ears and nape of the neck. The nits of head lice found within 7 mm of the scalp may be considered viable. Crab lice are usually found in the pubic and perianal areas of the body.

There must be a quick reaction to a serious increase in body louse infestations, with the threat of an epidemic outbreak of disease. In an emergency, the method of choice is that of mass delousing of the population with insecticide dust delivered by a compressed air duster. Use of cans with holes punched in one end will also suffice. Since there is widespread resistance to DDT, the dusting powders of choice include temephos (Abate), malathion, or gamma HCH (lindane). If time permits, the effectiveness of various pesticides should be assessed with the World Health Organization's insecticide susceptibility test. In emergency camps, clothing fumigants such as HCN, methyl bromide or ethyl formate can be used if the fumigation is supervised by properly trained personnel. Mass laundering of clothing is effective only if a water temperature of 52°C or more can be maintained. It is necessary to alert the population through public education to the dangers of louse-borne diseases and the need for mass delousing.

Head lice are not important as disease vectors, so that mass treatment may only be necessary when the prevalence is extremely high. Lotions or shampoos of malathion, pyrethrins or gamma HCH provide effective treatment. When school children are infested, treating of all family members is recommended for successfully controlling infestation. Crab lice that are not disease vectors, may be treated on an individual basis using shampoo, lotion or creme formulations of malathion gamma HCH, or pyrethrins.

Fleas belong to the order Siphonaptera. In the adult stage, all known species are obligate parasites. A number of these feed on the blood of man and his domestic animals. The most important diseases transmitted by fleas are plague and murine (endemic) typhus. Both of these diseases have host reservoirs so that attempts to eliminate the vectors should be coordinated with rodent control programs. Fleas can be collected by hand from the bodies of infested persons or animals. They can also be removed by combing small wild animal hosts, or trapped alive and anesthetized or killed. If a plague outbreak is imminent, rodent runs and burrows should be dusted and bait boxes should be rinsed with carbaryl or diazinon dust. The mass rodent control should begin only after flea populations have been eliminated, so that newly emerged fleas, deprived of their normal hosts, will not seek humans.

Mites are small, sometimes microscopic organisms that belong to the class Arachnida. Although they transmit diseases such as scrub typhus and Q fever, in times of natural disasters the disease is not an important factor. The annoyance created by itching and dermatitis can, however, be important. When people are crowded and mammals and birds share the same conditions with man, these animal ectoparasites may flow over to man. Sudden epidemics of the "itch" may thus occur in refugee or temporary camps. An attempt should be made to find the cause of the problem. Ointments exist which can be used to treat individual cases, but the best method of solving the problem is to improve sanitary habits and remove the animal source.

The mite, *Sarcoptes scabiei*, causes an infectious disease of the skin called scabies. In scabies, the penetration of the mite can be seen in visible papules or vesicles, or tiny linear burrows which contain the mites and their eggs. Scabies may be widespread during disasters. This is particularly true in developing countries. The disease is transmitted through prolonged intimate contact with scabietic skin, especially during sexual intercourse. Treatment on a coordinated
mass basis involves the use of gamma HCH, crotamiton (Eurax), precipitated sulfur in petrolatum, or an emulsion of benzyl benzoate. A second course of treatment is necessary within seven to ten days. Case finding efforts should be extended to the screening of whole families, and soap and facilities for mass bathing and laundering should also be made available.

Ticks belong to the order Acarina. Ticks are vectors of Rocky Mountain Spotted Fever, Colorado Tick Fever, Q fever, tick-borne relapsing fever and several other diseases. Certain species also cause tick paralysis. Tick surveys involve either collecting specimens from wild animal hosts, or using a tick drag. A tick drag is a piece of white flannel which is slowly pulled over the vegetation along trails and road ways for a specific distance, and is then examined. A tick problem can be reduced by clearing the vegetation fifty to one hundred feet around a refugee camp. In chemical control, an area is treated with an insecticide such as chlorpyrifos or tetrachlorvinphos.

Ants, spiders and scorpions may cause problems, especially during flooding. Since these arthropods seek high ground, they often invade houses and other shelters. Their bites can be painful; some produce intense suffering for which therapy must be considered. Health education may help to alert people of this danger. Through such efforts people should be asked to shake out clothing, check shoes before dressing and turn back bedding before retiring. Removal of debris and improvement of all general sanitation can also be of help. Insecticides can be used, especially in temporary housing, to limit the problem. Severe infestations of bedbugs may also occur under crowded conditions. Bedbugs can be easily eliminated by spraying malathion in infested areas with a hand compressed air sprayer.

Poisonous snakes seek high ground during flooding and may enter houses. The chance that they will come into contact with man is therefore increased. Occupied areas should be cleaned of debris and grass should be kept as short as possible. Universal antivenin should be available for members of the staff who clear debris, for vector control field staff, and at temporary housing camps.
Part III: Consultants

Chapter 9: The role of consultants in vector control

Frequently, entomological and vector control consultants or teams of multidisciplinary control personnel are needed in the period following a natural disaster. The composition of such teams will depend upon the nature of the disaster and the needs of the country. In general, the team may include an entomologist, a vector control specialist, a rodent control specialist and a sanitarian. If the country has a serious malaria problem, a malariologist should be added to the team. Any individual or team should collaborate with members of epidemiological teams and existing medical and vector control staffs.

Perhaps also needed are personnel who have had practical experience and training in the assembly, calibration, operation and maintenance of vector control equipment.

The Pan American Health Organization maintains a list of experts in these fields, some of whom have had experience as consultants during natural disasters. The Organization also has a procurement unit that is experienced in handling orders for equipment and supplies, and the unit is available to assist governments in emergency situations.

Recruitment
The Pan American Health Organization and cooperating international and bilateral agencies which provide assistance to other nations have developed a system for rapidly recruiting consultants to disaster relief efforts in cooperation with other international and bilateral aid agencies. Any country that needs this type of technical collaboration should determine the exact consultant requirements such as entomologist, technical officer, sanitarian, or malariologist, and express this need to the PAHO Country Representative so that prompt action can be taken.

Briefing and Equipment
Consultants should be briefed both before and after arrival to the requesting country. The Pan American Health Organization should furnish the consultant the following information prior to departure:

1. The general objectives of the visit
2. The expected duration of the visit
3. Names of contacts, especially of the officers in positions of responsibility and, whenever possible, names of entomologists, vector control specialists, civilian and military public health officials, and other potential sources of assistance within the country
4. The status of the disaster and its relation to potential problems
5. The types of supplies and equipment that the consultant should take (beyond those listed in Annex 11)
6. A list of individuals who will supply logistic requirements, such as food, transportation, shelter and communication support
7. A profile of the country containing information about geographic, climatic and demographic features, political and socioeconomic conditions, past communicable disease history and the public health infrastructure
(8) Current information concerning the following:

(a) The vector control staff
(b) Vector control equipment
(c) Insecticides and rodenticides
(d) Transportation and communication systems

(9) Information for purposes of communication, such as:

(a) The address, telephone, cable and telex number of the Pan American Health Organization office
(b) Names and addresses of hotels, especially if the consultant is to reside in an area that is not near an office of the Pan American Health Organization
(c) United Nations Development Program, other United Nations, and international or national agencies which operate in the country.

(10) Information regarding passport and visa requirements, appropriate currency, airline ticket, and excess accompanied luggage allowance.

The consultant can supplement this by reviewing information about diseases, vectors and geographical conditions of the country. Possible sources of such information are libraries, newspapers, United Nations country background reports, universities, area handbooks, other consultants' reports, and individuals with past experience of the conditions in the country. Local amateur radio operators who have contacts in the country can provide valuable additional information.

The Pan American Health Organization, other international agencies and bilateral aid programs handle arrangements for travel and local contacts. They will inform their officials within the country about the consultant's arrival and request arrangements be made to meet with the appropriate national authorities.

The local contact in the Pan American Health Organization should brief the consultant about the following:

(1) Government contacts who work in the areas of public health, agriculture, defense, and natural resources
(2) The current status of disaster and vector or rodent problems
(3) Past reports about vector and rodent-borne diseases, in the possession of the Pan American Health Organization or the national government
(4) Other assistance being provided by international agencies and organizations
(5) Nongovernmental contacts and/or other sources of information, including local pest control firms and aerial spray operators
(6) Any recent changes in government plans
(7) The political or economic implications of the disaster
(8) Road conditions and the availability of ground transportation for field work
(9) A sample of press reports about disaster conditions.
Activities of Consultant upon Arrival

We recommended that the consultant initially contact the international or bilateral agency that arranged the visit. The emergency or disaster committee with a vector control subcommittee if one exists, should then be contacted. Whatever the points of technical contact may be, it is the consultant's responsibility to obtain a clear concept of what is required to identify his designated counterpart in the government and to maintain close communication with appropriate authorities.

In most cases, the consultant will be asked to help the government assess the problem, outline control procedures and train personnel. The initial assessment may be difficult because of problems in transportation and communication. Maps and graphs prepared by the government will provide some information. However, there will be areas from which little or no information is available, and there will have to be adjustments to insufficiency of the information. There may be inventories of vector control equipment and supplies. These should be inspected as soon as possible.

Evaluation of information gathered in an early reconnaissance of the distribution, densities and stages of development of vector species is very useful. The consultant should be provided ground transportation for surveillance purposes and, if possible, the assigned vehicle should have four-wheel drive. In addition, information obtained in aerial reconnaissance can quickly provide a comprehensive overview of the areas and can give indication of possible methods of attack.

Outlining control procedures is often a difficult task. The effects of a given disaster may warrant the use of new technology to rapidly control vectors. Not all modern technology, however, is appropriate for use under all circumstances. A country may be aware of the existence of certain new types of equipment, insecticides and technology, and will seek to find out if they should be used. Sophisticated equipment may be used for the short-term relief from vector related problems. However, usual vector control methods, directed toward the larvae or the resting adults, may prove to be more effective and less expensive. Equipment that rusts on shelves kills few mosquitoes.

Recommendations and Reports

Recommendations should be practical and directed toward that which the local government actually can accomplish in vector control. However, recommendations can also assist governments in obtaining long-term goals that are only secondarily related to the natural disaster. It is worthwhile, therefore, to discuss all recommendations with members of international agencies and the government before writing them.

Reports should contain definitions of the potential for vector related problems and the current and future implications of the availability of manpower and other resources. Ongoing evaluation of the situation, as well as of training programs, is important because the primary concern in the report is that of the probability of the occurrence of future problems and future consequences. Actions that need to be undertaken at different points in time, or because the potential of vector related diseases is altered, should be clearly specified. Also to be included in the report are alternative ways to respond to problems that develop in regard to staff or equipment.

An outline of ways to implement and evaluate control measures should be presented in the report, and actions to be undertaken in the event that epidemic occurs should be suggested. A discussion of logistics of control (including work schedules, geographical areas to be covered...
and ways to implement control of diseases that may contribute to epidemics) should be included in the report. The report should also contain an enumeration of methods of supervising the staff and a list of supplies and equipment that are needed to augment current stocks.

The report and recommendations can provide guidelines when such are lacking, and they may also be used for educational purposes. It should be noted, however, that because of the existence of divergent opinions an entire program is rarely accepted and implemented unchanged.

**Follow-up**
Consultants, remembering that it is the prerogative of the country to make final decisions, nevertheless, often outline actions to be taken in the future. To assist the government, the consultant should do the following:

1. Be certain that everyone is briefed and that the report and recommendations are discussed before they are formally presented
2. Inform the international organizations and country representatives of the recommendations and discuss the possibility of the organization's involvement
3. Ensure that the personnel who are actually entrusted with the work, as well as the administrators, understand what they are doing and why
4. Brief (by letter, telephone or in person) the technical staff of the international organization about the situation and the reasons for the recommendations.

Too often, at the departure gate, consultants forget the country and its problems. In the age of instant photocopies, sending occasional reprints of scientific reports, or a personal letter is an easy method to bridge gaps that international organizations find impossible. In many instances, such little extra effort can make the difference between the success or failure of the country to implement recommendations.

**Training**
Weaknesses in training are never more vividly manifested than during the period after natural disaster. Vector control programs are designed to meet the needs of normal circumstances in which adequate response may follow an inflexible routine. During disasters a flexibility that is often lacking is called for. In addition, extra staff is frequently required during disasters and demands for immediate actions are made. All of this leads to confusion, waste, and tactical error. Most critics will be more concerned about these aspects than about any real progress that is made. There are few solutions to this dilemma, but a good, visible training program may lessen the critics' blows.

Because most malaria and other vector control programs have on-the-job training and annual refresher courses, continual upgrading of the courses and the educational and proficiency levels of the staff will add to the success of any surveillance or control program. The consultant, while visiting the country, should be asked to perform on-the-job training (apart from formal training courses) of national staff members with whom the consultant has contact.
Part IV: Annexes

Annex 1: Bibliography


Annex II: Suggested vector surveillance equipment and supplies

Collecting bag
Mouth or battery powered aspirators
Flashlight and spare batteries
Memo pad
Pencil
White enameled dipper
Labels
Collecting vials
Bulb syringe or medicine dropper
Mirror

Collecting forms
Tea strainer
Grease pencil
Sweep net
Tweezers
Keys and other references
CDC light traps (optional)
Aedes aegypti ovitraps (optional)
Fly grill

Suggested Rodent Surveillance Equipment and Supplies

Teaching aids
Plastic bags
Plastic cups
Rubber bands
Scissors
Snap traps
Live traps
Gloves
Flashlights and batteries

Transfer bags
Vials
Alcohol
Forceps
Insecticide dusting pan
Formaldehyde
Acute rodenticides
Anticoagulant rodenticides
Annex III: Pesticides and applications for the chemical control of vectors, rodents and Pests*

<table>
<thead>
<tr>
<th>Type of Application</th>
<th>Pesticide and Application</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ants; General</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>propoxur</td>
<td>diazinon</td>
<td></td>
</tr>
<tr>
<td>bendiocarb</td>
<td>1.0%</td>
<td></td>
</tr>
<tr>
<td>0.1%</td>
<td>0.25 %</td>
<td>See control recommendation for cockroaches.</td>
</tr>
<tr>
<td><strong>Bed Bugs cimex sp.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rooms, beds or furniture (also chicken nests for source)</td>
<td>malathion</td>
<td>ronnel</td>
</tr>
<tr>
<td>Rooms, beds or furniture (also chicken nests for source)</td>
<td>dichlorvos</td>
<td>diazinon</td>
</tr>
<tr>
<td>Rooms, beds or furniture (also chicken nests for source)</td>
<td>1.0%</td>
<td>1.0% E</td>
</tr>
<tr>
<td>Rooms, beds or furniture (also chicken nests for source)</td>
<td>0.5% E</td>
<td>0.5% E</td>
</tr>
<tr>
<td>Apply lightly to mattress surfaces and more heavily to bed frame. Allow to dry before using. Never apply to children's crib.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cockroaches</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>1. Residual sprays in oil solutions or emulsion concentrates</td>
<td></td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>a. propoxur</td>
<td>b. chlorpyrifos</td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>c. bendiocarb</td>
<td>d. diazinon</td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>e. dichlorvos</td>
<td>f. malathion</td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>g. ronnel</td>
<td>1.0%</td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>0.5%</td>
<td>0.25-0.5%</td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>0.5%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>5.0%</td>
<td>2.0%</td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>Apply to hiding places and runways; use a spray and not a mist. Pay attention to warm humid places. Do not treat where children are likely to contact surfaces.</td>
<td></td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>2. Powders in inert dusts</td>
<td></td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>a. boric acid</td>
<td>90-99%</td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>b. silica aerogel</td>
<td>100%</td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>c. diazinon</td>
<td>2.0-5.0%</td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>d. malathion</td>
<td>4.0-5.0%</td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>3. Baits</td>
<td></td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>a. chlorpyrifos</td>
<td>0.5%</td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>b. propoxur</td>
<td>2.0%</td>
</tr>
<tr>
<td>Enclosed spaces as kitchens, pantries or storerooms</td>
<td>Pyrethrins have been used as a ULV at 3-5% in unoccupied areas</td>
<td></td>
</tr>
<tr>
<td><strong>Fleas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rooms</td>
<td>1. Solutions in kerosene, fuel oil or in emulsion concentrates</td>
<td></td>
</tr>
<tr>
<td>Rooms</td>
<td>a. bendiocarb</td>
<td>b. malathion</td>
</tr>
<tr>
<td>Rooms</td>
<td>c. ronnel</td>
<td>d. diazinon</td>
</tr>
<tr>
<td>Rooms</td>
<td>e. lindane</td>
<td>0.25%</td>
</tr>
<tr>
<td>Rooms</td>
<td>2.0%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Rooms</td>
<td>1.0%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Rooms</td>
<td>2. Powders in inert dusts</td>
<td></td>
</tr>
<tr>
<td>Rooms</td>
<td>a. diazinon</td>
<td>2.0%</td>
</tr>
<tr>
<td>Rooms</td>
<td>b. malathion</td>
<td>4.0-5.0%</td>
</tr>
<tr>
<td>Rooms</td>
<td>c. carbaryl</td>
<td>5.0%</td>
</tr>
<tr>
<td>Rooms</td>
<td>d. lindane</td>
<td>1.0%</td>
</tr>
<tr>
<td>Rooms</td>
<td>3. DDT</td>
<td>10.0%</td>
</tr>
</tbody>
</table>
### Animals

**1. Powders of inert dusts**

<table>
<thead>
<tr>
<th>Inert Dust</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>malathion</td>
<td>4.0%</td>
</tr>
<tr>
<td>rotenone</td>
<td>1.0%</td>
</tr>
<tr>
<td>pyrethrins</td>
<td>0.2% plus 2.0% synergist</td>
</tr>
<tr>
<td>carbaryl</td>
<td>5.0%</td>
</tr>
<tr>
<td>lindane</td>
<td>1.0%</td>
</tr>
<tr>
<td>DDT</td>
<td>5.0%</td>
</tr>
</tbody>
</table>

Apply dust to domestic animals with a small duster. Do not apply DDT, or lindane to cats or puppies.

### Filth Flies, adults

**1. Enclosed spaces, e.g. houses and barns**

1. Space sprays or aerosols in oil solutions or emulsion concentrates (Spray into air for 4 sec/10m© when using aerosol bombs):

   a. synergized pyrethrins 0.1%
   b. dichlorvos 0.5%
   c. ronnel 2%
   d. malathion 5%

2. Residual contact sprays in oil solutions, emulsion concentrates or wettable powders

   (Apply 1% solutions at 10-20 l/100m² and 5% solutions at 2-4 l/100m² to give dosages of 1-2 g/m²)

   a. bromophos 1-5%
   b. ronnel 1-5%
   c. fenitrothion 1-5%
   d. iodfenphos 1-5%
   e. trichlorfon 1-5%
   f. diazinon 1-2%

   (Apply at 4/100m© to give dosages of 0.4 or 0.8 g/m².)

   g. dimethoate 1-2%

   (Apply 8 l/100m© to give dosages of 0.8 or 1.6 g/m².)

   h. malathion 5%

   (Apply 2-4 l/100m© to give dosages of 1 or 2 g/m².)

   i. naled 1%

   (Apply at 4-8 l/100m© to give dosages of 0.4-0.8 g/m².)

Space sprays have no long-lasting effects and must be applied frequently. Avoid contamination of food or food processing equipment. Treat garbage, refuse, manure and other fly breeding sites. Can be used also in milk-rooms, restaurants and food stores.

Same as above.

Animals must be removed. Not to be used in milk-rooms.

Only premium grade malathion can be used in milk-rooms and food processing plants.

Not to be used in milk-rooms. At 0.25 % strength can be applied to chicken roosts, nests, etc. without removing the birds.

### 3. Baits containing insecticides and sweetening agents as sugar, malt or molasses. Dry baits contain 1-2% and wet baits 0.1-0.2% of insecticide (Apply 60-120g/100m² of dry bait or sprinkle the liquid bait at the rate of 4 l/100m²):

a. diazinon
b. dichlorvos
c. dimethoate
d. ronnel
e. malathion

Fly baits should not be used inside dwellings. Care should be taken that they are not placed where children or domestic animals can easily come into contact with them.
Emulsion or fuel oil formulations are applied at the following dosages: (g/ha)

- diazinon 336
- dichlorvos 336
- dimethoate 224
- ronnel 448
- fenthion 448
- malathion 672
- naled 224

The listed organophosphorus compounds used as emulsion or fuel oil formulations are applied at rates of 24-48 1/km to obtain the required dosage. Also, ULV applications from the ground, with bioresmethrin at 10g/ha have been found effective.

Aerosols: Resmethrin, bioresmethrin or d-phenothrin 2% + 98% Freon 11 + Freon 12 (1:1) as propellant. (Spray into air from aerosol canister for 10 see/100m²)

Approximate cabin volumes of aircraft are:
- Boeing 747: 2800m³
- Boeing 707: 800m³
- DC-9: 345m³
- DC-8: 800m³

Fly larvae
1. Outdoors by spraying manure and refuse, human-excrement

Fly larvae Sprays applied as emulsions concentrate or wet-table powders. (Thoroughly spray decaying vegetation, manure and refuse at 28-561/100 m². Pay particular attention to animal manure, privies and garbage. In addition to the insecticides listed, ronnel, fenitrothion, fashion and trichlorfon can be applied as finished sprays at concentrations from 0.25-2.5%)

- diazinon 1%
- dimethoate 1%
- malathion 1-2%
- dichlorvos 0.5%
- ronnel 1%

Applications must be made once or twice each week to maintain good control.

Lice
1. Head Lindane 1.0% ointment or shampoo Keep out of eyes and mucous membranes.
2. Body Lindane 1% dust or shampoo Sterilize clothing and bed clothes by laundering.
3. Pubic Lindane 1.0% ointment or shampoo Do not apply to eyelashes

Benzyl benzoate emulsion 25% (Pediculosis of eyelashes may be treated with 0.25% physostigmore ophthalmic ointment twice daily or a vaseline ointment containing pyrethrins may be used.) Apply by spray or hand.

Mites: Chiggers, etc.

Clothing 1. Mosquito repellents toxic to mites:
- diethyltoluamide (DEET, OOF)
- dimethyl phthalate
- benzyl benzoate

Keep out of eyes. Damages some plastics.
### Outdoor vegetation

1. Residual as wdp or powders in inert dusts:
   - chlorpyrifos
   - diazinon
   - lindane
   - chlordane
   - toxaphene

   Spray plants thoroughly. Check label for dosage. Keep children away until spray dries.

### Scabies

#### Body
1. Lindane 1.0% cream, lotion or shampoo.
2. Benzyl benzoate (25%).

Keep away from eyes and mucous membranes. Do not overtreat.

### Mosquito adults

1. Enclosed spaces in buildings, as barracks, rooms, barns

   1. Aerosols: Pyrethrins 0.25% + piperonyl butoxide or sulfoxide 2%. *(Spray into air from aerosol canister for 4 sec/100m$^3$)*

   2. Space sprays
      - naled 1%
      - malathion 2-5%
      - resmethion 1-2%
      - dichlorvous
      - methoxychlor

   3. Residual fumigant: Dichlorvos dispensers, containing 20% of toxicant are suspended in enclosed spaces at one dispenser per 14-28 m$^3$. *(Spray on interior walls and ceiling of building (1 1/25m$^2$))*

   4. Residual contact sprays in oil solutions, emulsion concentrates or wettable powders.
      - DDT 5%
      - methoxychlor 5%
      - lindane 0.5%
      - malathion 3-5%
      - fenitrothion 1-2%
      - propoxur 0.5-1%
      - chlorphoxim 3-5%
      - pirimiphos-methyl 2-3%
      - permithrin 0.5%

2. Aircraft

   Aerosols: Resmethrin, Bioresmethrin or D-phenothrin 2%. *(Spray into air from aerosol canister for 10 sec/100m$^3$)*

   Approximate cabin volumes of aircraft are:
   - Boeing 747: 2800m$^3$
   - Boeing 707: 3800m$^3$
   - DC-9: 345m$^3$
   - DC-8: 800m$^3$
### 3. Outdoors-exterior space treatment

Applications from aircraft, mistblowers or thermal aerosol machines as oil solutions or emulsion concentrates:

- a. malathion 100-500 g/ha
- b. fenitrothion 200-400 g/ha
- c. fenthion 112 g/ha
- d. naled 56-280 g/ha
- e. chlorpyrifos 10-40 g/ha
- f. pyrethroids

These sprays usually furnish immediate but only temporary relief. High volume thermal fogging may be preferable when vegetation is dense.

### Mosquito larvae

1. **Potable water receptacles around houses** *(Aedes aegypti)*
   
   Temephos only is currently used. In treating containers with drinking water temephos 1% sand granules are applied by a measured plastic spoon at 1 mg/1 (e.g. 1 g of granules for 10 liters of the volume of container-whether full of water or not).

2. **Streams, lakes, swamps, pools, ruts and non-potable water containing receptacles around houses**
   
   Applications from aircraft or ground equipment as emulsions, wettable powders, solutions or granules:
   - a. chlorphoxim 100 g/ha
   - b. chlorpyrifos 56-100 g/ha
   - c. fenitrothion 100-3000 g/ha
   - d. fenthion 22-112 g/ha
   - e. iodfenphos 50-100 g/ha
   - f. malathion 224-1000 g/ha
   - g. methoprene 100-1000 g/ha
   - h. Paris green 850-1000 g/ha
   - i. phoxim 100 g/ha
   - j. temephos 56-400 g/ha
   - k. fuel oil 142-190 l/ha
   - l. larvicidal oil 19-47 l/ha
   - m. methoprene

Do not use insecticides on water intended for drinking by humans or animals. Use all materials with care to avoid hazards to fish and wildlife. Granular formulations are more suitable for penetrating heavy vegetative cover than solution or emulsion concentrates. Higher doses are necessary in highly polluted water and by residual and prehatch treatment.

### Scorpions and centipedes

**Rooms**

Residual sprays as EC, wdp or powders in inert dusts.

- a. diazinon 0.5%
- b. bendiocarb 0.25%
- c. malathion 3.0%
- d. lindane 5% liquid 1.0% dust

Make spot applications such as baseboards, windows, wall cracks, openings around water pipes, underneath sinks, corners. Also can treat ground and outbuildings.
### Spiders - Black widow, Brown, etc.

Residual indoors, outbuildings, and around houses, stores, etc.

<table>
<thead>
<tr>
<th>Spray Type</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>bendiocarb</td>
<td>0.25%</td>
</tr>
<tr>
<td>chlorpyrifos</td>
<td>0.25-0.5%</td>
</tr>
<tr>
<td>diazinon</td>
<td>5%</td>
</tr>
<tr>
<td>ropoxur</td>
<td>0.5%</td>
</tr>
<tr>
<td>malathion</td>
<td>1.0%</td>
</tr>
<tr>
<td>lindane</td>
<td>2.0% - 0.5%</td>
</tr>
</tbody>
</table>

Do not use as space spray. Treat as for scorpions and centipedes. Watch out for falling spiders as they sometimes bite.

### Ticks (most species)

1. **Animals**
   - Washes, sprays or dips as emulsions
     - malathion 0.5%
     - rotenone 0.05%
     - lindane 0.05%

2. **Buildings**
   - Residuals in oil solutions or E.C.:
     - propoxur 1.0%
     - diazinon 0.5%
     - chlorpyrifos 0.5%
     - bendiocarb 0.25%
     - malathion 2.0%
     - carbaryl 2.0%
     - lindane 0.5%

3. **Outdoors vegetation**
   - Residual sprays in E.C., wdp or inert dusts:
     - tetrachlorvinphos
     - carbaryl
     - dieldrin
     - chlordane
     - lindane

Use indicated concentrations for washes or sprays but reduce to half for dips.

### Triatominae

1. **House and furniture**
   - Residual wdp and E.C.:
     - HCH 1.0%
     - fenitrothion 2.0%
     - malathion 2.0%*

Treat ceiling and walls of houses and furniture when necessary.

*not for *R. prolixus*
### Repellents for flies, mosquitoes, gnats, mites, black-flies, sandflies, fleas, and ticks

1. **Diethyltoluamide (OFF, DEET)**
   - (Application on skin. Shake 1/2 teaspoonful into palm of hand; rub hands together and then apply in thin layer to face, neck, ears, hands and wrists. Do not get into eyes and mouth. On clothes, spray or apply by hands. Effective for a number of days. Best all-around repellent.)
   - Nontoxic. Avoid eyes and mucous membranes.

2. **Dimethylphthalate**
   - (Particularly effective against Anopheles and larval mites (chiggers).)
   - Use same as above (1).
   - Same as above.

3. **Indalone**
   - (Same as (1) above. Best use against biting flies.)
   - Same as above.

4. **2-ethyl hexanediol—1,3 (repellent 612)**
   - (Same as (1) above. Particularly effective against Aedes.)
   - Same as above.

---

### Rodents Domestic rats and mice

<table>
<thead>
<tr>
<th>Baits</th>
<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>brodifacoum</strong> (Talon)</td>
<td>0.005% bait</td>
<td>Single dose anticoagulant. Effective against warfarin-resistant Norway rats. Formulated as grain-based pellets.</td>
</tr>
<tr>
<td><strong>Diphacinone</strong> (Diphacin)</td>
<td>0.005% bait</td>
<td>Anticoagulants. Various brands are formulated as ready to use baits, paraffinized blocks and pellets, concentrates, and as tracking powders. Also available as liquid baits. Use both liquid and dry baits where possible. Expose liquid bait in glass or plastic bait chicken watering devices.</td>
</tr>
<tr>
<td><strong>Coumafuryl</strong> (Fumarin)</td>
<td>0.025% bait</td>
<td></td>
</tr>
<tr>
<td><strong>pivaldalone</strong> (Pival)</td>
<td>0.025% bait</td>
<td></td>
</tr>
<tr>
<td><strong>warfarin</strong></td>
<td>1.0%</td>
<td></td>
</tr>
<tr>
<td><strong>warfarin</strong></td>
<td>0.025% bait</td>
<td></td>
</tr>
<tr>
<td><strong>chlorophacinone</strong> (Rozol Hot shot)</td>
<td>0.025% bait</td>
<td>Single dose poison. Mix toxicant with fresh bait materials (corn meal, fish, meat, fruit). Do not use food attractive to children.</td>
</tr>
<tr>
<td><strong>zinc phosphide</strong></td>
<td>1-2% bait</td>
<td></td>
</tr>
</tbody>
</table>

---

1 Common or genetic names begin with a small letter; trade or other names are in parentheses. No discrimination against similar products is intended.

*Information from WHO publications, *Pocket Guide to Pest Management* (US Navy) and *Tropical Medicine* 5th Edition (Hunter, Swartzwelder and Clyde). Mention of specific companies or manufacturers’ products does not imply that they are recommended by the Pan American Health Organization.*
Annex IV: Guide to insecticides, rodenticides and equipment

**Insecticides**

*Abate* (temephos)
American Cyanamid Company
Berdan Avenue
Wayne, NJ 07470
Telex: 130400
Tel: (201) 831-1234

Southern Mill Creek Products
P.O. Box 1096
Tampa, FL 33601

*Actellic* (pirimiphos - methyl )
ICI Americas Inc.
Agricultural Chemical Division
Wilmington, DE 19897

Imperial Chemical Industries
Plant Protection Division
Fernhurst
Haslemere
Surrey, England GU27 3JE
Telex: 858270 Ic. pp Fernhurst
Tel: Haslemere (0428) 4061
Tel: Somerset Court (0428) 4061
Cable: Plantecton

*Altosid* (methoprene)
Zoecon Industries
975 California Avenue
Palo Alto, CA 94304
Telex: 345-550
Tel: (415) 329-1130

*Baygon* (propoxur)
Mobay Chemical or Chemagro Corp.
P.O. Box 4913
Howthorn Road
Kansas City, MO 64120
Tel: (816) 242-2000
Cable: KEMAGRO, Kansas City

Johnson Wax Company
1525 Howe St.
Racine, WI 53403
Telex: 264429
Tel: (414) 554-2000
Cable: JON WAX RON, Wisconsin

*Baytex* (fenthion)
Mobay Chemical or Chemagro Corp.
P.O. Box 4913
Howthorn Road
Kansas City, MO 64120
Tel: (816) 242-2000
Cable: KEMAGRO, Kansas City

*Baythion* (phoxim)
Bayer AG
Pflanzenschutz
509 Levenkusen Bayerwerk
Federal Republic of Germany
Telex: 8510881
Tel: 02172-301
Cable: BAYER

*Baythion* C (chlorophoxim)
See Baythion Chlordane
Velsicol Chemical Corporation
341 East Ohio St.
Chicago, IL 60611
Telex: 910-221-5738
Tel: (312) 670-4500

*Cyanophos* (Cyanox)
Sumitomo Chemical America, Inc.
345 Park Avenue
New York, NY 10022
Telex: 640249
Tel: (212) 935-3813

*Cygon* (dimethoate)
American Cyanamid Company
See Abate

*Cythion* (malathion)
American Cyanamid Company
See Abate

*Diazinon*
Ciba-Geigy Corporation
P.O. Box 11422
Greensboro, NC 27409
Tel: (919) 292-7100

Ciba-Geigy International AG
Postfach 4002
Basel
Telex: 62991
Tel: 061/361111

Markteshim Chem Warks Ltd.
Box 60
Beer Sheva, Israel

Pennwalt Chemical Corporation
1630 East Shaw Ave.
Fresno, CA 93710

Thompson-Haywood Chemical Co.
5200 Speaker Road
Kansas City, KS 66110
Tel: (913) 321-3131

Dibrom (naled)
Chevron Chemical Com.
Ortho Division
575 Market Street
P.O. Box 3744
San Francisco, CA 94105
Tel: (Orlando, Florida)
(305) 288-0414
Tel: (San Francisco, CA)
(415) 894-7800

Dimetilan
Ciba-Geigy Ltd.
P.O. Box 11422
Greensboro, NC 27409
Tel: (919) 292-7100

Dimilin (diflubenzuron)
Thompson-Hayward Chemical Co.
5200 Speaker Road
Kansas City, KS 66110
Tel: (913) 321-3131

Dursban (chlorpyrifos)
Dow Chemical Co.
P.O. Box 1706
9008 Building
Midland, MI 48040
Tel: (517) 636-2231

Thompson-Hayward Chem Co.
5200 Speaker Road
Kansas City, KS 66110
Tel: (913) 321-3131

Fenitrothion (Sumithion)
Sumitomo Chemical America, Inc.
345 Park Avenue
New York, NY 10154
Telex: 232 489 (RCA)
Tel: (212) 935-7000

Bayer AG
Pflanzenschutz
509 Levenkussen Bayerwerk
Federal Republic of Germany
Telex: 8510881
Tel: 02172-301
Cable: BAYER

Ficam (bendiocarb)
BFC Chemicals, Inc.
4311 Lancaster Pike
P.O. Box 2867
Wilmington, DE 19805
Tel: (302) 575-7847

Fison Inc.
Ag Chemicals Div.
2 Preston Court
Bedford, MA 07130
Telex: 951-253
Tel: (617) 275-1000

Fisons Ltd.
Fison House
9 Grosvenor Street
London W1XOA9, UK
Telex: 263184
Tel: (01) 493-1611

Flit MLO
Exxon Company
P.O. Box 21801
Houston, TX 77001
Tel: (713) 656-3636

Heptachlor
Velsicol Chemical Corporation
341 East Ohio St.
Chicago, 11. 60611
Telex: 910 221-5738
Tel: (312) 670-4500

Iodofenphos
Rentokil Ltd.
Export Product Division
Felcourt East Grinstead
West Sussex
England RH 19 104

Lindane
Hooker Chemical Co.
P.O. Box 344
1042-7 Iroquois Ave.
Niagara Falls, NY 14302
Telex: 91-575
Tel: (716) 278-9000

All India Medical
185 Princess Street
Mulji Jetha Bldg.
Bombay, India 400 002

Thompson-Hayward Chemical Co.
5200 Speaker Road Kansas City, KS 66110
Tel: (913) 321-3131

Malathion
American Cyanamid Company
Berdan Avenue
Wayne, NJ 07470
Telex: 130400
Tel: (201) 831-1234

All India Medical
185 Princess Street
Mulji Jetha Bldg.
Bombay, India 400 002

Sumitomo Chemical America, Inc.
345 Park Avenue
New York, NY 10154
Telex: 232489 (RCA) SUMISHO
Tel: (212) 935-7000

Thompson-Hayward Chemical Co.
5200 Speaker Road
Kansas City, KS 66110
Tel: (913) 321-3131

Mesurol (methiocarb)
Mobay Chemical or Chemagro Corp.
P.O. Box 4913
Howthorn Road
Kansas City, MO 64120
Tel: (816) 242-2000
Cable: KEMAGRO, Kansas City

Methoxychlor
E.C. DuPont de Nemours
Chemical Dyes and Pigment Dept.
1007 Market Street
Wilmington, DE 19898

Nexion (bromophos)
Celamerck GmbH and Co.
P.O. Box 202
6507 Ingelheim am Rhein
West Germany

Permethrin
Shell International
Chemical Co. (talcord)
Agro-Chem. Division
Shell Center
London S.E. 17PG England
Telex: 919651
Tel: 01-934-1234
Cable: CHEMISHELL.
London SE 1

Imperial Chemical Industries
Plan Protection Division
Fernhurst
Surrey, England GU27 3JE
Telex: 858270 lc.pp Fernhurst
Tel: Haslemere (0428) 4061

Fairfield American Corporation
3932J Salt Road
Medina, NY 14103
Tel: (716) 798-2141

McLaughlin Gormley King and Co.
8810 10th Avenue, North
Minneapolis, MN 55427
Telex: 290-544
Tel: (612) 544-0341
Wellcome Industrial (coopex)
Ravens Lane
Berkamsted
Herts, England HP4 2DY

Cooper Pegler and Co. Ltd.
Burgess Hill
Sussex RH159L.A, UK
Tel: Burgess Hill 42526
Cables: 87354 COOPEG G

d-phenothrin
McLaughlin Gormley King and Co.
(Multicide)
8810 10th Avenue, North
Minneapolis, MN 55427
Telex: 290-544
Tel: (612) 544-0341

Pyrethrins
McLaughlin Gormley King
and Company 8810 10th Avenue, North
Minneapolis, MN 55427
Telex: 290-544
Tel: (612) 544-0341

S.B. Penick and Company

Pyrethrins (encapsulated) (sectrol)
3M Company
J.F. Piper/Industrial Tape Division
Building 220 3M Center
St. Paul, MN 55101

Resmethrin
S. B. Penick and Company (SBP- 1382)
1050 Wall Street, West
Lyndhurst, NJ 07071
Telex: 133525
Tel: (201) 935-6600
673-1335

Rotenone
S.B. Penick and Company
1050 Wall St., West
Lyndhurst, NJ 07071
Telex: 133525
Tel: (201) 935-6600
673-1335

Sevin (carbaryl)
Union Carbide Corporation
7825 Bay Meadow Way
Jacksonville, FL 32216
Telex: 510661 2634
Tel: (904) 731-4250
**Insect Repellents**

*Deet* (diethyl toluamide)
Cutter Laboratories
2200 Powell Street
Emeryville, CA 94608

McLaughlin Gormley King Co.
8810 10th Avenue, North
Minneapolis, MN 55427
Telex: 290-544
Tel: (612) 544-0341

Hills Pet Chemicals Inc.
P.O. Box 660656
Miami Springs, FL 33166

*Dibutyl phthalate*
Eastman Chemical Products, Inc.
P.O. Box 431
Kingsport, TN 37664
Telex: 55-34-50
Tel: (615) 246-2111

**Insecticide Application Equipment**

*Fogger, Thermal*

Burgess Vibrocrafters
RT 83
Grays Lake, IL 60030
TWA 910-651-2531
Tel: (312) 223-4821
Cable: VBE Grays Lake

Curtis Dyna-Products Corporation
(Dyne-Fog)
P.O. Box 297
Westfield, IN 46074
Tel: (317) 896-2561

J. Hofman Overseas USA,
(Dynafog)
P.O. Box 318
Carmel, IN 46032
London Fog Co.
505 Brimhall
Long Lake, MN 55356
Tel: (612) 473-5366

Motan GMBH
(Swingfog)
P.O. Box 1260
Max-Eyth-Weg 42
D-7972 Isny, W. Germany
Telex: 7321 524
Tel: 07562-66
Cable: Motan ISNY

Lowndes Engineering Co.
125 Blanchard St. Box 488
Valdosta, GA 31601
Telex: LECO VALD 810-786-5861
Tel: (912) 242-3361
Cable: LEGO VALD

Public Health Equipment
and Supply Co.
P.O. Box 10454
San Antonio, TX 78210
Tel. (512) 532-6351

Dr. Stahl & Son
(Pulsfog)
P.O. Box 1227
Uberlingen D-777
West Germany

Tifa (Cl) Ltd.
50 Division Avenue
Millington, NJ 07946
Telex: 136340
Tel: (201) 647-4570 and 647-4573
Cable: TIFA Stirling

Beemer Products Company
(Ground ultra-low volume sprayers)
FT Washington, PA 19034
Tel: (215) 646-8440

Buffalo Turbine
(Mity Moe: SONIC ultra-low volume)
Agricultural Equipment Co., Inc.
70 Industrial St.
Gowanda, NY 10470
TWA 716-532-2210
Tel: (716) 532-2272

FMC Corp: John Bean Div.
516 Dearborn St.
Tipton, TN 46072

Gerbruder Holder, BmbH and Co.
(Holder)
P.O. Box 66
D7418
Metzingen, West Germany
Telex: 7245319
Tel: 07123-2036

H.D. Hudson MFG Co.
(Per-pakR, Compression Sprayers
and Dusters)
500 North Michigan Avenue
Chicago, IL 60611
Tel: (312) 644-2830

Hatsuta Suzuki Industrial
(Hatsuta Mistblower)
Av. Monteiro Lobato 2700
Guarulhos 0700, Sao Paulo, Brazil
Cable: HATSUMEC
Tel: PABX 209-2133
Telex: HABR 1125046

Hatsuta Industrial Co. Ltd.
4-39, 1-Chrome Chifune
Nishiyodogawa-ku
Osaka, Japan

Kioritz Corporation
P.O. Box 10
M. Taka
Tokyo, Japan

Ultra-low volume Devices

AFA Corp. of Florida
(Fogmaster)
14201 NW 60th Ave.
Miami Lakes, FL 33014

Andreas Stojl Maschinenfabrik
Postfach 1760
7050 Walblingen - Neustadt
West Germany

Ultra-low volume Devices
Kioritz Corporation
350 Wainwright
North Brook, IL 60062

Maruyama Manufacturing Co. Ltd.
4-15, Uchi-Kanda, 3-Chome
Chiyoda-ku
Tokyo, Japan

London Fog Company
505 Brimhall
Long Lake, MN 55356
Tel: (612) 473-5366

Lowndes Engineering Company
125 Blanchard St. Box 488
Valdosta, GA 31601
Telex: LECO VALD 810-786-5861
Tel: (912) 242-3361
Cable: LECO VALD

Micro-Gen Equipment Corporation
10700 Sentinel Drive
San Antonio, TX 78217
Telex: 9108711000
Tel: (512) 654-8570
Cable: MCROGEN

Micron West Inc.
(ULVAFAN R portable)
8582 Katy Freeway
P.O. Box 19698
Houston, TX 77024
Telex: 792911
Tel: (713) 932-1405
Cable: MICRONW HOV

Motan GMBH
(Fontan)
P.O. Box 1260
Max-EythWeg 42
D-7972 Isny, Germany
Telex: 7321 524
Tel: 07562 - 6/6
Cable: Motan ISNY

Public Health Equipment & Supply
(London Aire)
P.O. Box 10458
San Antonio, TX 78210

Root-Lowell Corporation
1000 Foreman Road
Lowell, M1 49331
Tel: 1-800-253-4342

San Mar Tool & Equipment Company
(Root & Lowell)
50 Broadway
New York, NY 10004
Tel: (212) 797-1382

Solo Incorporated
5100 Chestnut
Box 5030
Newport News, VA 23605
Telex: (710) 823 644
Tel: (804) 245-4228

Solo Canada Caribbean
Deppe Ag -Tec.
Box 464
Burlington, Ontario L7R 3Y3
Canada

Turbair
(ULV Spraying Systems)
Britannica House
Waltham Cross
Herts, England
Telex: 23957
Tel: Lea Valley (0992) 7633008

Vandermolen Corporation
(KWH-44 Mistblower)
119 Dorsa Avenue Livingston, NJ 07093

Wambo Co. Ltd.
Postfach 102606
D-8900 Augsburg I
West Germany

Whitmire Research Laboratories, Inc.
3568 Tree Court Industrial Blvd.
St. Louis, MO 63122

Yanmar Diesel Engine Co. Ltd.
(ULV Knapsack)
1 - 11 - 1 Marunouchi, Chiyodo-Ku
Tokyo, Japan
Rodenticides

*Baran* (fluoroacetamide)
Archem
1514 11th Street
Box 767
Portsmouth OH 45662

Tamogan Ltd.
3 Hakhshmal Street
P.O. Box 2438
Tel Aviv, Israel

*Brodifacoum*
ICI Americas Inc. (Talon)
Agricultural Chemicals Division
Wilmington, DE 19897

Rodent Control Ltd.
70/78 Queens Road
Reading, Berks, England
Tel: READING 54740

*Sorex Ltd.*
St. Michaels Road
Widnes, Cheshire WA8 8TJ England
Tel: 051420 7151

*Bromadiolone*
Chempar Chemical
60 E 42nd St., Ste. 652
New York, NY 10016

Sanex Chemicals Inc.
(Bromone) (MAKI)
1307 South 30th Avenue
Hollywood, FL 33020
Tel: (305) 921-5666

*Castrix* (crimidine)
Bayer AG
Pflanzenschutz
509 Levenkusen Bayerwerk
Federal Republic of Germany
Telex: 8510881
Tel: 02172-301
Cable: BAYER

*Calcium Cyanide*
Degesch America Inc.
P.O. Box 116
Weyers Case, VA 24486
Telex: 910-221-5738
Tel: (310) 670-4500

**Coumatetralyl** (Racoumin)
Bayer AG
Pflanzenschutz
509 Levenkusen Bayerwerk
Federal Republic of Germany
Telex: 8510881
Tel: 02172-301
Cable: BAYER

**Fumarin**
Union Carbide
Agricultural Products Co.
300 Brookside Ave.
Ambler, PA 19002

**Pival**
Motonco Inc.
267 Vreeland Ave.
P.O. Box 300
Paterson, NY 07513

**Cymag** (Sodium Cyanide)
Imperial Chemical Industries
Plant Protection Division
Fernhurst
Haslemere
Surrey, England GU27 3JE
Telex: 858270 IC.pp Fernhurst
Tel: Haslemere (0428) 4061
ICI American Inc.
Agricultural Chemical Div.
Wilmington, DE 19897
Tel: Summerset Court (0428) 4061
Cable: Plantecton

**Red Squill**
S.B. Penick & Co.
1050 Wall Street, West
Lindhurst, NJ 07071
Telex: 133525
Tel: (201) 935-6600
Prentiss Drug & Chemical Co.
363 Seventh Avenue
New York, NY 10001

**Difenacoum** (Ratak)
ICI American Inc.
Agricultural Chemical Div.
Wilmington, DE 19897
Tel: Summerset Court (0428) 4061
Cable: Plantecton

**Warfarin**
Bell Laboratories
3699 Kinsman Boulevard
P.O. Box 5133
Madison, WI 53705
Tel: (608) 256-2632
Hopkins Agricultural Chemical Co.
Manufacturing Division
P.O. Box 7532
Madison, WI 53707
Prentiss Drug and Chemical Co.
363 Seventh Avenue
New York, NY 10001

**DPL/-87** (Vacor)
Rohm & Haas Co.
Agricultural &
Sanitary Chemicals Dept.
Independence Mall West
Philadelphia, PA 19105
Tel: (215) 592-3032

**Dipacinone**
Bell Laboratories
3699 Kinsman Boulevard
P.O. Box 5133
Madison, W1 53705
Tel: (608) 256-2632
Roberts Laboratories
4995 N. Main
Rockford, IL 61101

Velsicol Chemical Co.
341 East Ohio St.
Chicago, IL 60611
Telex: 910-221-5738
Tel: (312) 670-4500

**Fumarin**
Union Carbide
Agricultural Products Co.
300 Brookside Ave.
Ambler, PA 19002

**Pival**
Motonco Inc.
267 Vreeland Ave.
P.O. Box 300
Paterson, NY 07513

**Cymag** (Sodium Cyanide)
Imperial Chemical Industries
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Fernhurst
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Surrey, England GU27 3JE
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Tel: (608) 256-2632
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Manufacturing Division
P.O. Box 7532
Madison, WI 53707
Prentiss Drug and Chemical Co.
363 Seventh Avenue
New York, NY 10001
Zinc Phosphate
ARCHEM
1514 11th St.
Box 767
Portsmouth, OH 45602

Bell Laboratories
3699 Kinsman Boulevard
P.O. Box 5133
Madison, WI 53705
Tel: (608) 256-2632

Hooker Chemical Co.
1042-7 Iroquois Ave
P.O. Box 344
Niagara Falls, NY 14302
Telex: 91-575
Tel: (716) 278-7000

Special Insecticide Products

Bell Laboratories Inc.
(ZPR, RAZE R, PCO and FINAL R)
P.O. Box 5133
Madison, WI 53705
Tel: (608) 256-2632

Chempar Chemical Co. (ROZOL R)
60 E. 42nd St.
New York, NY 10165
Telex: 710-581-2318
Tel: (212) 687-3990

J.T. Eaton & Co. Inc.
1393 East Highland Road
Twinsburg (Cleveland), OH 44087
Tel: (216) 425-7801

J.E. Bolt Corporation
P.O. Box 25103
Chicago, IL 60625
Tel: (312) 327-7173

Southern Mill Creek Products, Inc.
(PARA-BLOX R)
P.O. Box 1096
5414 56th Street
Tampa, FL 33601

Velsicol Chemical Corporation
(PromarR and RamikR)
341 East Ohio St.
Chicago, IL 60611
Telex: 910-221-5738
Tel: (312) 670-4500

Rodenticides (Prepared Baits)

Bell Laboratories Inc.
(ZPR, RAZE R, PCO and FINAL R)
P.O. Box 5133
Madison, WI 53705
Tel: (608) 256-2632

Chempar Chemical Co. (ROZOL R)
60 E. 42nd St.
New York, NY 10165
Telex: 710-581-2318
Tel: (212) 687-3990

J.T. Eaton & Co. Inc.
1393 East Highland Road
Twinsburg (Cleveland), OH 44087
Tel: (216) 425-7801

J.E. Bolt Corporation
P.O. Box 25103
Chicago, IL 60625
Tel: (312) 327-7173

Southern Mill Creek Products, Inc.
(PARA-BLOX R)
P.O. Box 1096
5414 56th Street
Tampa, FL 33601

Velsicol Chemical Corporation
(PromarR and RamikR)
341 East Ohio St.
Chicago, IL 60611
Telex: 910-221-5738
Tel: (312) 670-4500

Rodenticides (Prepared Baits)

Bell Laboratories Inc.
(ZPR, RAZE R, PCO and FINAL R)
P.O. Box 5133
Madison, WI 53705
Tel: (608) 256-2632

Chempar Chemical Co. (ROZOL R)
60 E. 42nd St.
New York, NY 10165
Telex: 710-581-2318
Tel: (212) 687-3990

J.T. Eaton & Co. Inc.
1393 East Highland Road
Twinsburg (Cleveland), OH 44087
Tel: (216) 425-7801

J.E. Bolt Corporation
P.O. Box 25103
Chicago, IL 60625
Tel: (312) 327-7173

Southern Mill Creek Products, Inc.
(PARA-BLOX R)
P.O. Box 1096
5414 56th Street
Tampa, FL 33601

Velsicol Chemical Corporation
(PromarR and RamikR)
341 East Ohio St.
Chicago, IL 60611
Telex: 910-221-5738
Tel: (312) 670-4500
Stephenson Chemical Co., Inc.
(Aerosol Flea Control)
P.O. Box 87188
College Park, GA 30337
Tel: (404) 762-0194

Time-Mist Inc.
(Insecticide Aerosols)
135 South Main Street
Thomaston, CT 06787
Tel: (203) 283-8226

Wyco International, Inc.
(Tossit)
4811 Carnegie Avenue
Cleveland, OH 44103
Tel: (216) 391-5047

Entomology Equipment

Light Traps
CDC Miniature
Housherr's Machine Works
Old Freehold Road
Toms River, NJ 08753
Tel: (201) 349-1319

John W. Hock, Co.
P.O. Box 12852
Gainesville, FL 32604

BioQuip Products Company
P.O. Box 61
Santa Monica, CA 90406
Tel: (213) 322-6636

New Jersey-like
Concession Supply Company, Inc.
1016 Summit St.
P.O. Box 1007
Toledo, Ohio
Tel: (419) 241-7711

Plastic Larval Dippers
Clarke Spraying Company
P.O. Box 288
Roselle, IL 60172

Aerial Applications

Commercial ultra-low volume adulticiding
Environmental Aviation Services Inc.
P.O. Box 176
Belle Glade, FL 33430
Tel: (305) 996-2369

Equipment (ULV)

BEECO Products Co.
(Beecomist spray head)
Industrial Park
Fort Washington, PA

Bockenstette
Agricultural
Aviation Services
(CACU-Mist Mark IV)
P.O. Box 227
Abilene, KA 67410
Tel: (913) 263-2033

Ciba-Pilatus and Micron Sprayers Ltd.
(Electric rotary disc atomizer)
Three Hills
Bromyard, Herfordshire HR 7 4HU
United Kingdom

Micronair (Aerial) Ltd.
Bembridge Fort
Sandown
Isle of Wight, PO36 8Q3, England
Tel: grading 461
Cable: Micronair Sandown England
Telex: 86448

Spraying Systems Co.
P.O. Box 12735
St. Petersburg, FL 33733
Tel: (813) 360-3907

Specialized Ultra-low Volume Materials

Marco Chemical Division
(HAN, heavy aromatic naphtha)
W.R. Grace & Co.
800 N.W. 36th Avenue
Miami, FL

Southern Mill Creek Products
(Tritons and HAN)  
P.O. Box 420981 Allapetlah Station  
2490 N.W. 41st Street  
Miami, FL 33601

Home & Farm Chemicals Co.  
(Oil sensitive dye cards)  
P.O. Box 6055  
Charlotte, NC

Pierce Chemical  
(Dri-film SC-87)  
P.O. Box 6055  
Rockford, IL

Rohm & Haas Co.  
(Tritons)  
Independence Mall West  
Philadelphia, PA 19105

The mention of specific companies or products does not imply that they are endorsed or recommended by the Pan American Health Organization in preference to others of a similar nature that are not mentioned.