Emergency Vector Control after Natural Disaster – A Study Guide
# Table of Contents

**Emergency Vector Control after Natural Disaster – A Study Guide** ............................................................. 1

- Health for all by the year 2000 ......................................................................................................................... 2
- Foreword .......................................................................................................................................................... 2
- Acknowledgements ........................................................................................................................................ 4
- Introduction .................................................................................................................................................... 4
- Pretest ............................................................................................................................................................ 5
- Outline of content ........................................................................................................................................ 8
- Course objectives ........................................................................................................................................ 8

**Lesson 1 – The General Problem** .................................................................................................................. 10

- Summary .................................................................................................................................................... 11
- Self-assessment test ...................................................................................................................................... 12

**Lesson 2 – Contingency plans** ..................................................................................................................... 13

- Supplementary reading ............................................................................................................................... 13
- Summary .................................................................................................................................................... 15
- Self-assessment test ...................................................................................................................................... 16

**Lesson 3 – Postdisaster action** ................................................................................................................... 17

- Summary .................................................................................................................................................... 17
- Self-assessment test ...................................................................................................................................... 18

**Lesson 4 – Vector- and rodent-related diseases** ........................................................................................ 19

- Supplementary reading ............................................................................................................................... 19
- Summary .................................................................................................................................................... 23
- Self-assessment test ...................................................................................................................................... 23

**Lesson 5 – Aedes aegypti** ........................................................................................................................... 24

- Summary .................................................................................................................................................... 24
- Self-assessment test ...................................................................................................................................... 29

**Lesson 6 – Anopheline vectors** .................................................................................................................... 30

- Supplementary reading ............................................................................................................................... 30
- Summary .................................................................................................................................................... 38
- Self-assessment test ...................................................................................................................................... 39

**Lesson 7 – Culex quinquefasciatus and other pest mosquitoes** ...................................................................... 40

- Summary .................................................................................................................................................... 40
- Self-assessment test ...................................................................................................................................... 41

**Lesson 8 – Synanthropic flies** ..................................................................................................................... 42

- Summary .................................................................................................................................................... 42
- Self-assessment test ...................................................................................................................................... 43

**Lesson 9 – Other vectors** ........................................................................................................................... 43

- Supplementary reading ............................................................................................................................... 44
- Summary .................................................................................................................................................... 45
- Self-assessment test ...................................................................................................................................... 45

**Lesson 10 – Rodents** ..................................................................................................................................... 46

- Summary .................................................................................................................................................... 47
- Self-assessment test ...................................................................................................................................... 47

**Lesson 11 – Program management** ............................................................................................................ 47

- Supplementary reading ............................................................................................................................... 48
- Summary .................................................................................................................................................... 55
- Self-assessment test ...................................................................................................................................... 57

**Lesson 12 – Epidemiology and vector control** ........................................................................................ 58

- Supplementary reading ............................................................................................................................... 58
- Summary .................................................................................................................................................... 72
- Self-assessment test ...................................................................................................................................... 73

**Lesson 13 – Pesticides and application equipment** ..................................................................................... 74

- Supplementary reading ............................................................................................................................... 75
- Supplementary reading ............................................................................................................................... 78
- Supplementary reading ............................................................................................................................... 84
- Summary .................................................................................................................................................... 91
- Self-assessment test ...................................................................................................................................... 93

**Lesson 14 – Surveillance and evaluation** ..................................................................................................... 94

- Introduction .................................................................................................................................................. 94
- Supplementary reading ............................................................................................................................... 97
- Summary .................................................................................................................................................... 100
- Self-assessment test .................................................................................................................................... 101
Emergency Vector Control after Natural Disaster – A Study Guide

Disaster Management Center

To be used in conjunction with
Pan American Health Organization
Scientific Publication No. 419

PAN AMERICAN HEALTH ORGANIZATION
Pan American Sanitary Bureau, Regional Office of the WORLD HEALTH ORGANIZATION
525 Twenty-third Street, N.W.
Washington, D.C. 20037, U.S.A.

Disaster Management Center
UNIVERSITY OF WISCONSIN–EXTENSION
Engineering and Applied Science
432 North Lake Street
Madison, Wisconsin 53706
608–262–2061
Telex No: 265452

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 for the Pan American Health Organization.

This self–study series is designed to use scientific publications of the Pan American Health Organization (PAHO) as texts for the study of health–related issues in disaster management. Each module of the series includes a PAHO text, a study guide, pre–study test, self–assessing examination questions and a final examination.

Copyright © 1984 by University of Wisconsin Regents

For permission to reprint contact:

Disaster Management Center
Department of Engineering and Applied Science
University of Wisconsin–Extension
432 North Lake Street
Madison, Wisconsin 53706

Prepared by Dr. Robert W. Tonn, Richard Hansen, and Don Schramm

Legal Notice

This report was prepared by the University of Wisconsin (UW). Neither the UW nor any of its officers or employees makes any warranty, express or limited, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, mark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement by the UW.

Five self–study courses, based on Pan American Health Organization scientific publications, are now available. They are designed to assist in the development of disaster management plans or the improvement of existing plans. These publications and their companion study courses are entitled:

Scientific Publication No. 407
Emergency Health Management after Natural Disaster

Scientific Publication No. 443
Health Services Organization in the Event of a Disaster

Scientific Publication No. 430
Health for all by 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 contains 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.

Foreword

Emergency Management after a Natural Disaster
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 above.

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 at right.)
Acknowledgements

The Disaster Management Center at the University of Wisconsin−Extension thanks the Pan American Health Organization for early support of course development. In particular, Dr. Claude de Ville de Goyet and Ellen Wasserman deserve special recognition for their understanding of this innovative educational process. At the University of Wisconsin−Extension, Linda Hook, Darrell Petska, Susan Kummer, Lolette Guthrie, and Angela Armstrong must be thanked for their efforts in editing, design and production. The course development process is never over, and each of these people understands that very well.

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:

______ 6. In areas where malaria and dengue are endemic, an increase in disease can be expected within seven days of a hurricane.

______ 7. To be truly effective, contingency planning should be inflexible and detailed.

______ 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 assuring a constant flow of information to the statistics and evaluation unit and feedback of analysis to those in the field.

Answer Key

1. d
2. b
3. d
4. a
5. d
6. False
7. False
8. False
9. False
10. False
11. True
12. True
13. False
14. False
15. False
16. True
17. True
18. True
19. False
20. True
21. False
22. True
23. False
24. True
25. False
26. False
27. True
28. True
29. True
30. True
31. False
32. False
33. False
34. False
35. True
36. True
37. True
38. True
39. True
40. True
41. False
42. False
43. False
44. False

7
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

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.

**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**
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:

Storms (hurricane, cyclone, tornado)
- Destructive winds
- Flooding
- Heavy rains
- Landslides
- Power outages

Earthquakes
- Destructive vibration
- Fires
- Power outages
- Disrupted water and sewage system

Volcanic Eruptions
- Earthquake (and its consequences)
- Volcanic debris
- Tsunamis

Tsunamis (sea surges)
- Floods
- Power outages

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.

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

1. True
2. False
3. False
4. False
5. True
6. False

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 tight 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.

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
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.

**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.

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.
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

Supplementary reading

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.

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 1: Host relationships in two mosquito–borne diseases.

<table>
<thead>
<tr>
<th>Type of Host</th>
<th>Malaria</th>
<th>Filariasis</th>
</tr>
</thead>
<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>

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 dysentary, 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
- Scabies
- Typhus Fever, Endemic Louse–borne
- Yellow Fever

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.

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**

1. True
2. True
3. False
4. True
5. False
6. True

**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. (Ovitraps 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.

**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.
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 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 Caribbean 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%.

![Figure 1: Monthly rainfall in millimeters, Petit-Goave, Haiti (in zone affected by hurricane).](image)

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

<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>

**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 rising 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.**

<table>
<thead>
<tr>
<th>Date</th>
<th>Blood slides collected by</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Voluntary collaborators</td>
<td>Voluntary collaborator No.</td>
</tr>
<tr>
<td></td>
<td>Malaria service case finders</td>
<td>Malaria service case finder No.</td>
</tr>
<tr>
<td></td>
<td>No.</td>
<td>% pos.</td>
</tr>
<tr>
<td>June '62</td>
<td>361</td>
<td>3.3</td>
</tr>
<tr>
<td>July</td>
<td>365</td>
<td>1.6</td>
</tr>
<tr>
<td>Aug.</td>
<td>589</td>
<td>3.1</td>
</tr>
<tr>
<td>Sept.</td>
<td>742</td>
<td>1.5</td>
</tr>
<tr>
<td>Oct.</td>
<td>850</td>
<td>0.7</td>
</tr>
<tr>
<td>Nov.</td>
<td>681</td>
<td>2.8</td>
</tr>
<tr>
<td>Dec.</td>
<td>35</td>
<td>189</td>
</tr>
<tr>
<td>Jan. '63</td>
<td>257</td>
<td>2.3</td>
</tr>
<tr>
<td>Feb.</td>
<td>1,008</td>
<td>0.9</td>
</tr>
<tr>
<td>March</td>
<td>486</td>
<td>0.4</td>
</tr>
<tr>
<td>April</td>
<td>898</td>
<td>0.2</td>
</tr>
<tr>
<td>May</td>
<td>519</td>
<td>0.2</td>
</tr>
<tr>
<td>June</td>
<td>644</td>
<td>0.6</td>
</tr>
<tr>
<td>July</td>
<td>1,012</td>
<td>2.4</td>
</tr>
<tr>
<td>Aug.</td>
<td>1,024</td>
<td>5.0</td>
</tr>
<tr>
<td>Sept.</td>
<td>1,310</td>
<td>3.6</td>
</tr>
<tr>
<td>Oct.</td>
<td>724</td>
<td>2.2</td>
</tr>
<tr>
<td>Nov.</td>
<td>896</td>
<td>6.0</td>
</tr>
<tr>
<td>Dec.</td>
<td>1,524</td>
<td>19.8</td>
</tr>
<tr>
<td>Jan. '64</td>
<td>3,276</td>
<td>26.0</td>
</tr>
<tr>
<td>Feb.</td>
<td>3,805</td>
<td>37.8</td>
</tr>
<tr>
<td>March</td>
<td>3,829</td>
<td>20.4</td>
</tr>
<tr>
<td>April</td>
<td>4,487</td>
<td>14.9</td>
</tr>
<tr>
<td>May</td>
<td>1,993</td>
<td>12.1</td>
</tr>
<tr>
<td>June</td>
<td>1,100</td>
<td>11.8</td>
</tr>
<tr>
<td>July</td>
<td>1,875</td>
<td>13.8</td>
</tr>
<tr>
<td>Aug.</td>
<td>1,731</td>
<td>17.3</td>
</tr>
<tr>
<td>Sept.</td>
<td>5,978</td>
<td>10.8</td>
</tr>
<tr>
<td>Oct.</td>
<td>3,835</td>
<td>20.2</td>
</tr>
</tbody>
</table>

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.

![Graph showing 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)

**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).

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

<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>Total</td>
<td>6,276</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Table 4: Blood slides collected by voluntary collaborators, by age group, October 1963–March 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>Total</td>
<td>11,734</td>
<td>2,724</td>
<td>23.2</td>
</tr>
</tbody>
</table>

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.
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)
   - where mosquitoes rest before and after biting
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.

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
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

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.

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
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 the summary in this lesson.

Evaluation

Complete the self-assessment test.

Notes

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.

**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.

**Answer Key**

1. True  
2. True  
3. True  
4. True  
5. False  
6. True

**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**

**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 pubic*. 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 babesiosis. 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.

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

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 icterohemorrhagiae*, 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 corners. 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.

**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

**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.

**Organization at the Planning Level**

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.
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 populus 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.
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 inhabitations 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.

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
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.
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, Siphonapter, Orthoptera, Anoplura, Hemiptera, and Acarina. These are illustrated in Figure 3.

![Figure 3: Principal orders of arthropod vectors.](image)

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 gambiæ* 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.

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 1: Host relationships in two mosquito–borne diseases.

<table>
<thead>
<tr>
<th>Type of Host</th>
<th>Malaria</th>
<th>Filariasis</th>
</tr>
</thead>
<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>

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.
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 *Borellia* 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.
**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.

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.
Figure 10: EE virus cycle in U.S.

Figure 11: Endemic cycle of VE*.
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.

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:

73
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

1. e
2. b
3. e
4. False
5. True
6. True
7. False
8. False
9. True
10. True
11. True
12. False

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 arthropods.

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. Chlordpyrifos and fenthion 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 ant traps was found effective for seven months. Jodifenphos 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 bioresemthrin 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. Chlordpyrifos and temephos have given good control. Aerial or ground ULV application of chlordpyrifos 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, chlordpyrifos, bioresemthrin, 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 overcrowding. 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 offish, 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 larvicide wettable powder, a larvicide 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 ovicides); taxonomy of the target arthropod (acaricides for ticks and mites, pediculicides for lice); biochemical activity (cholinesterase inhibitor, microsomal oxicase 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
ground–water. The following recommendations can be suggested for the disposal of large amounts of
unsusable 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 metal pesticide 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 inflammable 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.

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.
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 back-bone 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


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.


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 from 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.

**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

Pan American Health Organization
Pan American Sanitary Bureau • Regional Office
World Health Organization