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PESTICIDE MANUAL

PART I: SAFE HANDLING AND USE OF PESTICIDES

R. VON RÜMKER

F. HORAY

DEPARTMENT OF STATE

AGENCY FOR INTERNATIONAL DEVELOPMENT

P E S T I C I D E M A N U A L

PART I : SAFE HANDLING AND USE OF PESTICIDES

PART II : BASIC INFORMATION ON THIRTY-FIVE PESTICIDE CHEMICALS

PART III : SPECIFICATIONS

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August, 1972

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PREFACE

This Manual was prepared under the auspices of the University of California/AID Pest Management and Related Environmental Protection Project, Contract No. AID/csd 3296, Dr. Ray F. Smith, Project Director. The Project's Panel on Pesticides under the Chairmanship of Dr. Gordon E. Guyer provided the outline for the Manual, supervised its preparation, reviewed the draft, and furnished important data, literature references and other inputs. The authors gratefully acknowledge these contributions, and the guidance and encouragement received from Dr.'s Gordon E. Guyer, Ray F. Smith, David E. Schlegel, John E. Davies, Virgil H. Freed, James G. Horsfall, Allen B. Lemmon, and from Dr. W. H. Garman, AID.

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Rosmarie von Rümker

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Shawnee Mission, Kansas

August, 1972

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P E S T I C I D E M A N U A L

PART III: SPECIFICATIONS

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PART I: SAFE HANDLING AND USE OF PESTICIDES

INTRODUCTION.

Pesticides are substances which will destroy or repel pests, or offer protection from pests. Pesticides include insecticides, miticides, fungicides, herbicides, nematicides, rodenticides, plant growth regulators, desiccants, insect growth regulators, attractants, repellents, sterilants, and fumigants. Pests are unwanted animals, plants, or viruses which cause injury, disease or destruction to desirable plants, animals, structures, goods, or to man himself. Forms of life which may be pests include insects, mites, other arthropods, snails, slugs, birds, certain mammals such as rodents, bats or moles, nematodes, weeds, fungi, bacteria, viruses and certain parasitic plants.

Man-made pesticides, primarily based on natural substances or inorganic chemicals, have been used for centuries. The large scale development, production and use of synthetic organic pesticide chemicals started in the 1930's with the discovery of the herbicidal properties of 2,4-D, and the insecticidal properties of DDT, followed shortly by the discovery of organic phosphate insecticides.

Many benefits have resulted from the use of pesticides,

including increased production and production efficiency of food and fiber and improvement of human health and comfort. Today, chemical pesticides are an important and indispensable tool in agricultural, industrial and public health technology. At least for the foreseeable future, the growing world-wide demand for foods, feeds, fibers, forest products, and high standards of living, public health and human comfort cannot be met without the use of chemical pesticides.

However, pesticides are by nature toxic to one or more forms of life. Most pesticides are, unfortunately, toxic not only to the pest or pests against which they are used, but also against other organisms. Undesirable side effects from the use of chemical pesticides have become increasingly apparent in recent years, including damage to non-target organisms, unbalancing of ecosystems, and general environmental contamination by persistent pesticides which tend to accumulate and magnify biologically in aquatic and terrestrial food webs. In addition, an increasing number of pests, especially insects and mites, have developed resistance to pesticides, and organisms which were not originally of economic importance have developed into serious problems. Possible effects of long term exposure to low levels of pesticides on many forms of life including man himself have

become of increasing concern.

Pesticides are potent, biologically active chemicals which not only produce many benefits when used properly, but also have great potential for causing harm to man himself, to non-target species, and to the local as well as the global environment. In the use of pesticides, the benefits to be expected have to be carefully weighed against the risks involved. This manual is intended to assist government officials concerned with pesticide programs in developing countries in making benefit and risk evaluations of contemplated pesticide uses, and in planning and taking all steps necessary to the safe and efficient use of the pesticide(s).

Many properties and effects of pesticides are well known and documented, such as their chemical and physical properties, their spectrum of effectiveness, and their toxicity to laboratory animals. By contrast, many other facets of pesticides are little explored and/or poorly understood at the present time, including their mechanism of action; toxicity to humans; sublethal effects; effects in conjunction with other stresses; pathways of transportation, metabolism, and degradation in the environment; and their overall, long term effects on humans and on the environment.

Accordingly, rather precise instructions can be given

on many aspects of pesticide handling and use, while in other areas, we can at present only record existing knowledge gaps and point to research, educational, administrative or other actions in progress or about to be initiated to fill these gaps.

This manual is not intended to provide "how to do"-type details to persons actually applying pesticides. It is the pesticide manufacturer's responsibility to furnish all necessary information and directions on how to use his pesticide product safely and effectively, by way of the product label. It is the user's responsibility to study and comply carefully with all label directions.

The use of a pesticide product by the grower is only one link in a longer chain of events, with other important links preceding and succeeding it. This manual will give an overview of all of the links in this chain, with special emphasis on points involving hazards or unknowns, since these are the points which require special attention in the planning and execution of pesticide programs.

PESTICIDE DEVELOPMENT, REGULATION, FORMULATIONS AND CONTAINERS.

Development, Registration and Control of Pesticides.

Many chemical pesticides have originated from synthesis work in the laboratories of industrial companies. Promising candidates are screened through increasingly complex laboratory and greenhouse tests on insects, weeds, disease organisms, and other pests. Compounds which show promise in these tests are taken to the field for further investigations under actual use conditions.

In addition to these efficacy tests, candidate pesticides must pass many chemical, physical, analytical, toxicological, physiological and economic tests on their way to becoming a commercial product. Through these tests, suitable formulations, containers, and analysis methods for quality control and for the determination of residues are developed; the acute and chronic toxicity of the chemical and necessary safety precautions are determined; and the nature and amounts of residues in or on treated crops are determined.

In the United States, the proposed label for a pesticide

along with all supporting data must be submitted to the Environmental Protection Agency, and pesticides cannot be moved in interstate commerce or offered for sale before this Agency has granted registration and established finite or negligible tolerances for residues which remain at time of harvest, or exempted the product from the requirement of a tolerance. With much justification, it has been said that the registered label on a pesticide product is among the most expensive printed matter in the world.

The pesticide label must contain the following information:

-- the name and address of the manufacturer or person for whom the product is manufactured;

-- the name, brand or trademark under which the product is sold;

-- the net content of the package (exclusive of packaging materials) by weight for dry, and by volume for liquid products;

-- a statement of the active and inert ingredients contained in the pesticide formulation, including the percentage(s) and description of the active ingredient(s) by their accepted common names or chemical names;

-- claims and directions for use, including the crops on

which the product may be used, the names of the pests to be controlled, the amount of pesticide to be used, and any precautions or limitations, especially limitations on the number of times the product may be used on the same crop, and the minimum interval between last application and harvest required to prevent unsafe residues at harvest time;

a warning or caution statement which, if complied with, is adequate to prevent injury to man, and to useful animals and vegetation.

In the U. S., federally registered labels must bear the registration number assigned by the Environmental Protection Agency.

Some states within the U. S. issue registrations for pesticides which are manufactured, sold and used within the state and thus do not move in interstate commerce, or permit variances from federally registered labels within the state in order to accomodate special local or regional pest control needs.

Many countries outside the U. S. have pesticide laws and regulations. Many developing countries are interested in establishing national pesticide registration and control systems. Recognizing this need, the Food and Agriculture Organization of the United Nations (FAO) in 1963 established

an FAO Working Party on the Official Control of Pesticides.

Section A of this Working Party developed a "Model Scheme for the Establishment of National Organizations for the Official Control of Pesticides", which is available in booklet form from the UN or the FAO (Ref. 10). It provides a great deal of valuable and practical information on the topic.

Section B of the Working Party sets specifications for plant protection products. The principles and procedures adopted for this purpose are described in the "Manual on the Use of FAO Specifications for Plant Protection Products", also available from the UN or the FAO (Ref. 11).

These FAO pesticide specifications rely on methods of analysis and quality control developed and published by the Collaborative International Pesticides Analytical Council (CIPAC) in the CIPAC Handbook (Ref. 9). The FAO/CIPAC system of pesticide specifications and quality control methods provides both the buyer and the seller of pesticides with effective and reliable quality criteria. It prevents much confusion which would result if different countries would use different quality standards and control methods. Therefore, the U. S. AID has decided to follow the FAO/CIPAC system in its pesticide programs. The Specifications section of this manual implements this decision.

Pesticide Formulations.

Chemical pesticides are sold in several different forms. Those most frequently encountered are as follows

Technical active ingredient.

This is the active chemical, along with unavoidable impurities remaining from the manufacturing process. It may be a solid, a liquid or a gas. Some solids with low melting points occur as liquids at elevated temperatures. Liquid technical active ingredients display varying degrees of viscosity. Some liquids become gases at elevated temperatures.

Most technical active ingredients cannot be used for control of pests without further processing. Sometimes this is done at the manufacturing plant. Oftentimes, technical active ingredients are packaged and shipped in large containers to a formulation plant, for formulation and repackaging into ready-to-use pesticide products. "Formulation" is the process by which technical active ingredients are made ready to be used by mixing with liquid or dry diluents, grinding, and/or by the addition of emulsifiers, stabilizers, and other formulation adjuvants.

It is normally advantageous that technical active ingredients be as pure as possible, since impurities may

cause, or contribute to problems of solubility, formulation, grinding, stability, phytotoxicity, mammalian toxicity, odor, off-flavor, explosive hazards, etc.

Emulsifiable concentrate (also called "spray concentrate").

This is a liquid formulation obtained by dissolving the technical active ingredient in a liquid solvent. One or more emulsifiers are added, so that the formulated pesticide can be further diluted with oil or water for spray application. Sometimes several technical active ingredients are formulated into one emulsifiable concentrate formulation.

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 gallons 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.

Wettable powder (also called "dispersible powder").

These are finely ground, dry powders intended for dispersion or suspension in a liquid, usually water, for application in spray equipment.

To produce a wettable powder, 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 plant or other surfaces. Sometimes stabilizers, anti-foaming agents and/or further adjuvants are added.

Wettable powders are packaged in sturdy paper or plastic bags. Often a number of these are overpacked in larger "baler bags", in boxes, in 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 plys including a polyethylene or aluminum foil liner. Larger craft 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.

Soluble powder.

Soluble powders 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 and from compaction is even more important for soluble powders.

Dust.

A pesticide dust consists of dry, finely ground carrier material containing a pesticide active ingredient. Dusts are intended for direct application, without further dilution, in suitable dust dispensing equipment. Dilute dusts are usually prepared from dust concentrates. Sometimes wettable powders are used as dust concentrates; in other instances, dust concentrates are specially prepared, omitting wetting and dispersing agents and other typical wettable powder adjuvants.

Pesticide 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 material may suffice.

Granular.

In a granular pesticide formulation, the technical active ingredient is mixed with, or coated on inert carrier material 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, without further dilution, by seeders, spreaders, or other granular application equipment. Uniformity of particle size is necessary to assure proper application and distribution of granular pesticides. Freedom from very fine particles is important to avoid dustiness which may be a health hazard, especially in the case of highly toxic pesticide active ingredients.

Granular pesticide formulations are usually applied directly to the soil and are dispensed close to the soil surface. There is no drift problem. The granular pesticide particles tend to remain where they are deposited and are not as prone as other pesticide formulations to be transported away from the target area. Some granular pesticides are applied topically to plants, especially insecticide granules for control of pests lodging in stems or leaf axles.

The packaging requirements for granulars are similar to those for other dry pesticides.

Seed dressings.

Some pesticides are applied to seeds, or to bulbs, corms, tubers or other plant parts to prevent their decay after planting, and to protect them from seed-borne and soil-borne disease organisms, insects or other pests. Pesticides are usually specially formulated for this purpose.

Dry seed dressings are applied to seeds in dust form in a mechanical mixer. Wet treatments can be made by a "slurry" or a liquid pesticide. In the slurry method, a dry, wettable seed treatment formulation is suspended in water to form a soup-like suspension which is then applied to the seed in a special "slurry treater". Liquid seed treatment pesticides likewise can be properly applied only in special seed treaters.

Treatment of seed is best carried out by the seed house which will have adequate equipment and trained personnel available.

Many countries require that seed treatment formulations contain a special color which transmits to the treated seed in sufficient intensity to show that it has been treated. Some countries have color codes which indicate the nature

of the pesticide in the seed dressing. However, there is no uniform international color coding system. The problem is complicated by the fact that sometimes several different pesticides are used in combination for the treatment of seed.

Treated seed must be sown. It must not be used for food or feed. There are no methods by which seed dressings can be removed from treated seed so as to render it safe for consumption by humans or animals. In a recent instance in which this was attempted, it was believed that the seed would be safe once the coloring had been removed by washing. It was overlooked, however, that seed adherence of the coloring agent was not correlated with that of the pesticide. Consumption of the seed believed to be safe resulted in many deaths and illnesses.

Fumigants.

Fumigants are volatile chemicals applied into confined spaces or into the soil to produce a gas that will destroy insects or other pest organisms. There are two basic types of fumigants.

The first group comprises chemicals of low molecular weight and high vapor pressure, such as methyl bromide, ethylene oxide, hydrogen cyanide, and hydrogen phosphide. These products penetrate quickly into stacks of stored

products or into cracks and crevices. They are used to fumigate commodities and containers or enclosed spaces which can be completely sealed.

The second group consists of compounds of higher molecular weight and somewhat lower vapor pressure which tend to volatilize and diffuse slowly. Examples are ethylene dibromide and ethylene dichloride. These products are more persistent and are used for soil fumigation, for fumigation of commodities in storage areas which cannot be made completely gas-tight, etc.

Fumigants which develop pressure at ambient temperatures have to be packaged in special, pressure-resistant containers.

Pesticide Containers.

A pesticide product consists of the pesticide and the container. The manufacturer of the product is responsible for the quality and performance of both. The container is an important element of the product A good pesticide may be ruined by an improper container.

Technical pesticides and pesticide formulations differ widely in their physical, chemical, toxicological and other properties and consequently, in their requirements as to container construction, lining, gaskets, closures, etc.

The container industry offers a wide variety of drums, pails, cans, bottles, bags, boxes, over-packs, liners, closures, etc., in all conceivable combinations. It is the responsibility of the pesticide manufacturer to select the container which is most suitable for each specific pesticide product.

All pesticide products should be packaged in suitable, clean containers which do not affect, and are not affected by the product contained. The container should adequately protect the product from exterior influences including moisture, loss by vaporization and contamination. Where necessary, containers should be lined with a suitable material to prevent corrosion or deterioration of contents or container, including container closures. Outer surfaces of containers should be so constructed or treated as to prevent corrosion or deterioration of the container and/or product labelling.

Dry pesticide formulations may be packaged in a suitable bag, box, fiber or metal drum, adequate to protect the product from exterior influences, including compaction, moisture, oxidation, loss by vaporization and contamination. Containers must provide an adequate moisture barrier by an inner bag or liner of polyethylene of sufficient thickness, or alternative means of giving the same or better protection.

The inner liner or bag must be carefully sealed after filling.

All pesticide containers must comply with all applicable national and international transportation and safety regulations.

In the United States, containers for, and transportation of, all pesticides in the "Highly Toxic" (Group I) category which are classified as "Class B Poisons" are subject to laws and regulations administered by the Department of Transportation.

The pesticide product, container and contents, must be sufficiently stable to withstand the rigors of handling, loading, stacking and unloading as encountered in international cargo movements, and to meet all product specifications for a period of at least two years. If the product is less stable, then the seller must so inform the buyer in writing.

Preface

This chapter supercedes the chapter prepared originally by R. von Rümker and F. Horay on Handling, Transportation and Storage of Pesticides which appeared in the 1972 U.S. Agency for International Development's Pesticide Manual. It has been modified to incorporate the changes which have occurred in previous regulations and to add new regulations. This revision and updating of the chapter assures that it conforms to the existing regulations and policy of federal agencies and provides for the continued usefulness of the Pesticide Manual.

Virgil Freed

Corvallis, Oregon
January 1976

HANDLING, TRANSPORTATION AND STORAGE OF PESTICIDES

Hazards in the Movement and Storage of Pesticides.

Most pesticides products present hazards during handling, transportation ınd storage on account of their toxicity to humans, animals and the environment. ;ome pesticides are highly flammable and/or may be converted to toxic gases ıpon burning.

For these reasons, the transportation and storage of pesticides is sub- lect to laws and regulations by many countries, states or other government ınits. In the acquisition and movement of pesticides, it is important for :he persons or agencies responsible to be fully cognizant of all applicable aws and regulations, and to assure full compliance.

Major hazards associated with pesticides handling, transportation and ıtorage, and precautions to minimize these are discussed in the following ıections.

'oxic leaks and spills in transit.

The movement and storage of toxic pesticides is associated with the risk ıf leaks or spills from defective containers, seams or closures, or from punc- :uring, beakage or tearing of containers. Toxic pesticides must not be shipped n the same containers or compartments with cargo that could become a hazard f contaminated, such as food, drugs, toys, clothing, cosmetics, or household 'urnishings.

Pesticide spills may be acutely dangerous to transportation and ware- ıousing personnel, people involved in clean-up operations, and people or ınimals in the vicinity of the spill. Serious secondary dangers arise if

other cargo becomes contaminated. In addition, water supplies and other elements of the environment may become contaminated by the spilled toxic material directly, and/or by clean-up operations.

The importance of preventing spills and of taking all necessary steps and preparations for the proper handling and protection of shipments of toxic pesticides cannot be overemphasized. Such steps and preparations should include the following:

1. Prior to or during loading, each pesticide container should be inspected for tightness of closure or seal, and for any evidence of leakage around the closure, on the top, along the sides, on the bottom, and under the container. Containers showing any evidence of leakage should not be loaded. If a high percentage of containers in a shipment show evidence of leakage, the entire shipment should not be loaded.
2. Pesticide containers should be loaded into the carrier and secured inside the cargo compartment in such a way that they are held in place securely, without possibility of damaging each other, or damaging or being damaged in transit by other cargo. Toxic pesticides must not be shipped in the same compartment with cargo that could become a hazard if contaminated by the pesticide(s).
3. In the loading and unloading of pesticides, only equipment and tools which will not damage the pesticide containers should be used. In particular, the use of hooks which may puncture or tear pesticide containers must not be permitted.

All personnel involved in the loading, transporting and unloading of pesticides should be fully informed about the toxicity and the hazard potential of the pesticide(s) they are handling. They should be provided with information on how to deal with spills of the particular chemical(s) they are

handling, and whom to call in an emergency for (a) medical and (b) technical information.

Personnel, especially supervisory persons, should be trained in appropriate first-aid and rescue procedures. All necessary safety, first aid and rescue equipment and supplies which may be required should be available and readily accessible before the handling of pesticide shipments begins. Depending on the toxicity of the material being handled, such necessary supplies may include all-purpose gas masks; respirators; goggles or face shield for eye and face protection; water-proof and impervious complete outer clothing, including gloves, boots, hat and long-sleeved, buttoned coat or suit completely covering the worker; adequate emergency water supply for washing off corrosive or toxic materials getting on the skin; and facilities for washing eyes such as fixed or portable eye-wash fountains.

The facility where pesticides are being handled should have access to a qualified physician who has been informed beforehand about the nature and toxicity of the pesticides involved.

Careful observation of these precautions is especially important in the transfer of large quantities of pesticides from docks to ships or vice versa. Crane drivers, stevedores and other workers must be instructed to handle the material with extreme care. Dockside spillage of contamination of the cargo must be prevented. Emergency clean-up supplies and equipment should be available before movement of the pesticide shipment starts.

Port and Public Health Officials should be notified of arriving pesticide shipments. They should inspect the conditions of the shipment in the shiphold prior to unloading and supervise the unloading operation, especially the proper clean-up and decontamination of any spillage.

Flammability and fires.

Liquid pesticide products, especially those containing organic solvents with low temperature flash points, present special hazards because of their flammability. Some dry powder formulations may also present fire or explosion hazards.

In the United State, pesticides with low flash points are required to carry the following warning statements:

--Flash point at or below 20°F (-6.7°C): "Danger - extremely flammable! Keep away from fire, sparks, and heated surfaces".

--Flash points between 20°F and 80°F (-6.7 to 26.7°C): "Warning - flammable! Keep away from heat and open flame".

--Flash point between 80°F and 150°F (26.7 to 65.5°C): "Do not use or store near heat or open flame:.

Persons handling pesticide shipments should check labels for these warnings and make certain that products are handled and stored in accordance with these directions which are intended to prevent fires and explosions.

Pesticides are especially dangerous when they become involved in fires. Highly flammable products will readily ignite and burn, or explode when overheated. Finely divided dusts or powders such as sulfur will ignite almost as easily as gases or vapors and thus, present an explosive hazard. Aerosol containers will explode when overheated.

Fumes or smoke given off by burning pesticides may be highly toxic to fire fighters and persons in the vicinity of the fire. They may also be highly poisonous to plants or animals.

Run-off water from fighting pesticide fires is likely to be highly toxic. Such water may carry heavy concentrations of pesticides and be toxic to humans, animals, plants and the environment at large. Contamination

of streams, rivers, ponds, lakes or other bodies of water may cause grave secondary hazards and magnify the toxicity hazards.

It is obvious that every possible precaution must be taken to prevent pesticide fires. This is an important consideration in the construction, selection and use of storage areas for pesticides.

In case of an actual fire involving pesticides, the firemen fighting the fire and police on duty in the area must be given full information on the kinds, quantities and location pesticide stocks in or near the area affected by the fire. Firemen must wear protective clothing over the entire body including rubber boots, gloves, hat and coat, and self-contained breathing equipment for protection against toxic fumes or smoke. The fire should be attacked from upwind or at right angles. Use of water should be kept to the absolute minimum so as to avoid toxic run-off. If possible, the affected area should be diked to prevent water run-off.

Residents and other persons in the area, especially down-wind from the fire may have to be evacuated. All unauthorized persons must be kept out of the fire area and the vicinity.

A qualified physician familiar with pesticide problems should be notified immediately and stand by to assist fire fighters and others who may be poisoned. All persons who become exposed to toxic pesticides or toxic fumes or smoke should take immediate action to remove the toxicant(s) by thorough washing with large volumes of soap and water and should be checked for symptoms of poisoning.

The affected area should be roped off and posted to prevent entry by all unauthorized persons. This protection must be kept in effect until after clean-up.

Clean-up operations after the fire should be directed and carried out by qualified personnel well informed about the toxicity, chemical and physical and other pertinent properties of the pesticide(s) involved in the fire. If this information is not available, it should first be obtained from the manufacturers, their representatives, or appropriate national or local government agencies.

Clean-up operations must be closely coordinated with local police, public health, environmental protection and other appropriate agencies.

Items which are sometimes overlooked during or after a fire or other catastrophic event involving pesticides include the following:

--Footwear may become contaminated and absorb pesticides both on the inside and outside. Leather and lighter footwear should be discarded if contamination has taken place because it cannot be effectively decontaminated. Heavy rubber boots such as those worn by firemen must be thorougly washed and cleaned inside and out before re-use.

--All personal clothing, protective clothing, respirators, etc., must be carefully washed or cleaned before re-use. If such items are heavily contaminated, they should be properly disposed of because otherwise, their cleaning may create new hazards of toxicity or contamination.

--Special care must be taken not to track pesticides or toxic residues out of the area.

--Mechanized equipment should be used for clean-up as much as possible to minimize human contact with contaminated material.

--Toxic debris must be treated and disposed of in the same manner as toxic pesticides and pesticide containers. (See that section of this manual for further details).

--All operations, including decontamination of tools, vehicles, equipment, etc., should be conducted in such a way as to avoid toxicity or environmental contamination hazards from the clean-up operations.

Floods.

Stored pesticides are liable to create grave problems if they become involved in floods. Products packaged in water-tight containers may be swept or float away and may break and spill their contents upon hitting an obstacle, or later on upon deterioration of the container. Products packaged in paper, cardboard, or similar material may release the contained pesticide very quickly after getting soaked. In either event, and depending upon the toxicity of the pesticide(s) involved, grave danger from water contamination may result.

Pesticide stocks which have become soaked may become unusable and may present extremely difficult problems of handling and disposal even after they dry out again.

Every precaution must be taken to protect stored pesticides from flood waters. Pesticides must not be stored or kept in areas, buildings or parts of buildings (basements) which may be subject to flooding.

If pesticide inventories nevertheless become involved in floods, a problem exists which requires very careful evaluation and handling by the joint efforts of public health, environmental protection and police officials. If any pesticide quantities have been carried away from the storage site, every effort must be made to locate and secure them and to prevent further spillage. If water has become contaminated, persons or communities downstream must be warned, especially communities, farms, livestock operations, irrigation districts or other organizations drawing their water supplies from the contaminated body of water.

The manufacturer(s) of the pesticide(s) concerned should be contacted for information on the most effective decontamination methods and for any other assistance they may be able to render in coping with the emergency.

Spills in storage.

In each storage facility, precautions should be taken against spills of chemicals. This is particularly true of the highly toxic organophosphates. However, the spill of any chemical no matter how innocuous it appears to be should be treated as a hazard. It is highly recommended that in each storage facility or anywhere that quantities of chemicals are handled, there be an ample and readily accessible supply of charcoal and various clays to adsorb the chemical. In addition, there should be a supply of lime or calcium carbonate to neutralize those materials such as the phosphates and carbamates that are readily broken down by lime. If large quantities of liquid are involved, it is desirable to have an adsorbent material such as vermiculite or a clay available to assist the carbon in the adsorbtion. Appropriate protectiv clothing such as masks, gloves, rubber boots, and clothing should be available for the workers that must deal with such spills.

The material used to adsorb the spilled material should be disposed of in the same manner as excess pesticide. Further where the area must be flushed to complete the clean-up, the water should be drained into a decontamination basin or sump and not into sewers or streams. The chemical may be further degraded in the sump by addition of other chemicals e.g. lime and adsorbents.

If the plant is properly constructed the spills and leaks will be contained on the concrete floor where they may be absorbed with carbon or a clay, neutralized with lime and this waste then disposed of by soil degradation at an appropriate site. If such spills are to be flushed into a drain, the drain should be fitted with a charcoal filter and the effluent water lead

to a pond or an additional treatment facility before it is released into the sewer system or discharged into a stream. Such facilities as the filter and treatment are not at all expensive and can usually be fabricated right at the plant.

A special warning should be issued about storage and formulating facilities in reference to the type of floor on which these operations are carried out. Several times in this presentation we mentioned that concrete floors should be used. This is to avoid having a floor into which the chemical can soak and later be relased as vapor or picked up on water in the case of a flood. Wooden floors or earth floors absorb and hold the chemical and because of the extremely high concentrations, little or not breakdown occurs. Consequently, the risk of human exposure in this situation is high.

Cross contamination.

Some pesticides are volatile and may contaminate other pesticides. Herbicides of other highly volatile pesticides must not be transported or stored with other pesticides.

Fumes from volatile pesticides may not only be harmful as contaminants of other products, but may also cause direct injury to persons or animals in the vicinity or to plants, seeds, etc. Special care is advised in situations where volatile herbicides are handled or stored in the vicinity of greenhouses or other areas containing sensitive plants.

Odor.

Some pesticides emit odors. Where such odors are present in the vicinity of pesticide stocks, they may indicate a leak or spill, or the presence of improperly tightened or defective closures. They may also indicate decomposition or other deterioration of the product. Some pesticides become increasingly malodorous upon deterioration.

Pesticide stocks with an odor problem should first be examined for a possible spillage, leakage or deterioration problem. If examination shows that no other corrective action is required, an odor problem may be alleviated by holding temperatures in the storage area down and/or by installation of exhaust fans. Such fans must be located carefully and their exhausts may have to be channeled through scrubbers or charcoal filters made by filling a section of air duct pipe with granular charcoal in order to avoid environmental contamination.

Pesticide Storage.

All pesticides, regardless of quantity, should always be stored in the original, labelled container with the label plainly visible. Pesticides must never be stored in any other containers, especially not in old bottles, food or other containers where they could be mistaken for food, beverage, drugs, etc., for humans or animals. Pesticides must not be stored near food feed, or other items which may become contaminated by spilled material, volatile pesticides, odors. etc.

Larger quantities of pesticides should be stored in warehouses or warehouse areas specifically designated for this purpose. Pesticide storage areas should have concrete floors with drainage to a sump or other holding area where contaminated water can be decontaminated before release. Earthen or wooden floors are not suitable because they cannot be adquately decontaminated. The storage area should be dry and well ventilated. The storage building should be located on high enough ground as to be above any flood. Some pesticides must not be stored at temperatures below freezing, while others cannot be stored at more high temperatures. Specific storage requirements of each pesticide product should be ascertained from the label and complied with.

Pesticide storage areas should be locked, or other suitable steps be

taken to prevent theft, and to prevent unauthorized persons, especially children, from entering. Pesticide storage areas should be marked with prominent, water-proof signs over each entrance indicating the material stored.

A complete inventory of all pesticides in the storage area is essential. The age of pesticides in inventory should be monitored to prevent that they become unusable due to deterioration. In case of emergencies, a list of the products stored and their locations should be given to safety and fire department personnel.

All pesticide stocks must be examined periodically for leaks, spills, or any signs of deterioration. Any spilled material, broken containers, etc., should be completely removed, and the area decontaminated and cleaned promptly.

Steps should be taken to make certain that run-off water from cleaning and housekeeping activities will not contaminate residential areas, livestock feeding areas, or bodies of water. Pesticide storage areas should be diked or otherwise arranged in such a way that all run-off water can be trapped in a suitable pool or sump for proper decontamination and disposal.

Since pesticide fires present grave dangers, as discussed above, fire prevention and protection measures in pesticide storage and warehousing areas are particularly important. These should include effective fire detection systems and use spark-proof electrical wiring and equipment such as safety lamps, motors, switches, outlets, etc. Pesticides should be kept away from steam lines, heating units, exposed windows and other heat sources.

Appropriate fire fighting and safety equipment of adequate capacity and in adequate numbers should be available throughout the pesticide storage area, and all operating personnel should be thoroughly familiarized with its use not only in theory, but also by regular practice drills. Protective and safety equipment such as fire blankets, complete protective clothing including

hats, boots, coats or suits; gas masks, respirators, face shields, etc., should be readily accessible, regularly checked and maintained in workable conditon.

Local police, fire department, public health, environmental protection and other concerned agencies should be familiarized with the pesticide storage area, with the facility's operating procedures, and with the safety program and equipment.

The safety program should include anticipation of, and planning for all emergencies which may arise, including but not limited to fires, floods, tornadoes, hurricanes, typhoons, theft, abnormally hot or cold weather, and other calamities. The probable direct and indirect effects of each potential calamity should be anticipated as completely as possible. Steps should be taken to prevent calamitous results to the largest extent possible, and contingency plans be made on how to deal with catastrophies involving the stored pesticides if and when they occur.

All workers and supervisory personnel involved in the handling, transportation and storage of pesticides should have ready access to qualified medical aid, to information on the chemical, physical and toxicological properties of the pesticide products, including detailed information on how to deal with spills.

Stability of Pesticides.

Many pesticides, no matter how well manufactured, formulated and packaged, deteriorate upon storage, especially under conditions of high temperature and high humidity. Such deterioration may include loss of active ingredient due to chemical decomposition; loss of emulsifiability in the case of emulsifiable concentrates; compaction and caking in the case of dry formulations, and corrosion or other loss of integrity of containers and labelling. Some pesticides convert into more toxic substances upon aging.

In general, formulations containing low concentrations of active ingredient tend to lose active ingredient more rapidly than more concentrated pesticide forms. Some liquid pesticide products tend to develop gas upon deterioration which may make containers very hazardous to open and lead to eventual explosive rupture of containers.

Stocks of pesticide products which have deteriorated in one or more of these ways may develop into very serious problems. It becomes increasingly difficult to handle and transport them without serious breakage and spills which in turn present serious human and/or environmental safety hazards. If such products deteriorate to the point where they become unsuitable for their intended pest control use, their safe disposal may present an even bigger problem.

It is very important for persons involved in the purchasing of pesticides for use in other countries and in making arrangements for their transportation and delivery to be aware of these problems. Acquisition of pesticides for use in tropical countries should be scheduled andd implemented so as to minimize storage time, and to move the pesticide from the original supplier to its ultimate use as expeditiously as possible. Sometimes, pesticides will have to be held over from one season to the next. Such storage should be held to a minimum, and under no circumstances should the time lapse between manufacture and use be allowed to exceed 24 months.

Disposal of Used Pesticide Containers and Surplus Pesticides.

The proper handling and disposal of emptied pesticide containers and of left-over or unwanted pesticide quantities, concentrated or dilute, is basically the responsibility of the person, company, or other organization who received and emptied the full container. Improperly handled or stored "empty" pesticide containers or surplus pesticides may present or become a serious safety hazard to people, especially children and unsuspecting persons, and to livestock, pets,

wildlife, fish and many other forms of life. They may cause contamination of water, soil or air, damage to crops and other plants, unsafe pesticide residues in crops, and many other adverse effects. Safe disposal of emptied pesticide containers and of surplus pesticides is therefore a very essential although sometimes neglected step in the proper handling of pesticides.

In the movement of pesticides from the manufacturer to the end user, the need to dispose of emptied containers and/or surplus or obsolete pesticides may occur at least at two different points. Larger containers and/or commercial quantities of unwanted pesticides may accumulate at facilities where technical pesticide active ingredients are formulated and repackaged, or where finished pesticide formulations are received in large containers for repackaging into smaller ones. Secondly, the end user of the formulated pesticide ends up with empty containers, and sometimes also with obsolete or unwanted pesticide formulation(s) or dilute spray. These two situations differ in several important aspects and will therefore be discussed separately.

The problem of how to dispose of used pesticide containers, especially large, heavy steel drums, has received a great deal of attention in recent years, but no truly satisfactory or universally applicable solution has been found to date. This is not surprising in light of the fact that pesticide containers, as pointed out elsewhere in this manual, have to be very durable to afford adequate protection of the pesticide product during transportation, often over great distances, involving different modes of transportation and rigorous handling during transfer from one vehicle to another, and storage under conditions of high moisture and high humidity. On the other hand, it would be very desirable for pesticide containers to be easily disposable after they have been emptied at their final destination. No technology has been developed to date which would satisfactorily fulfill these seemingly incompatible requirements.

General Considerations on Disposal of Chemicals

For a variety of reasons it becomes necessary from time to time to dispose of quantities of pesticides and/or containers used for packaging them. It may be that the chemical to be disposed of is a waste from a storage or formulating plant; the chemical may have deteriorated below a quality acceptable, or for some other reason the chemical is no longer useful. The question then is, how to dispose of this chemical without danger to humans or serious contamination of the environment? The ultimate in disposal, of course, is the destruction of the chemical, but during the destruction process it is essential to avoid exposure of humans and the serious contamination of air, water, and soil.

There are four major means of disposing of chemicals, they include: use, chemical destruction, incineration, and soil disposal. A few important features of each is given below.

1. Chemical Destruction. Chemical destruction of a pesticide depends upon utilizing specific chemical reactions to destroy the chemical. This may be by oxidation with another chemical like permanganate or chlorate, or it could be as simple a reaction as an alkaline hydrolysis. Chemical destruction, though effective, also tends to be costly in its requirement for equipment, additional chemicals, and final problem of the disposal of the waste following the reaction.

2. Use. Using the chemical as a pesticide is perhaps the most effective and economical means of disposal where such a practice is possible. At the low doses normally used for pest control, the environment through photochemical and microbiological degreadation will destroy the material. In the meantime, benefit has been gained by pest control from the chemical. The usual precautions in use of chemicals could be observed in disposal in this fashion.

3. Incineration. In this instance the terms incineration or burning does not refer to destruction by open fires or burning such as often seen at landfills. Incineration of chemicals in this case involves using specially constructed burners (furnaces) that have a flame temperature of over 900°C, adequate air intake, and a long residence time in the combustion chamber to insure destruction of the chemical. Moreover, such incinerators require suitable smoke stacks with treatment devices to avoid air pollution.

4. Soil Disposal. Properly managed soil disposal is a quite satisfactory means of disposing of limited amounts of certain types of chemicals. It is much more effective in disposing of organic chemicals such as many of our pesticides than it is for disposal of inorganic chemicals such as heavy metals. Soil disposal relies on a combination of chemical treatment and microbiological attack to degrade the chemical to innocuous products. The sites for soil disposal of chemicals must be carefully chosen so as to avoid problems of water contamination, also they should be removed from other sites of human activity and should be large enough to handle the amount of chemical to be disposed of. The site may be set aside indefinitely for chemical disposal, or if properly managed and not over treated, it may be brought back into use for other purposes after a few years.

Pesticide and Container Disposal at Commercial Facilities

Pesticide Containers.

Technical pesticide active ingredients to be formulated, or formulated pesticides for repackaging are ususally shipped in bulk or in larger containers smaller than 30 or 55 gallon drums.

In the case of bulk shipments of liquid technical active ingredients or concentrates, it is usually not possible or not practical to clean the shipping container or tank sufficiently so that it could be used for other cargo. Bulk pesticide containers are therefore usually "dedicated" to the transportation of one or several closely related pesticides. The bulk container is emptied

at the receiving point and returned empty to the manufacturing plant from where it came, without clean-out or other treatment. This practice is very desirable from the standpoint of safety to humans and to the environment because it does not generate a hazard to clean-out crews, toxic refuse, clean-out fluids or other safety or enviornmental hazards. It is important, of course, that the emptied containers be properly and tightly reclosed, and that all safety precautions required for handling of the full containers be observed.

With 55 gallon or smaller metal drums, return of empties to the source is usually not feasible or practical. In some cases, it may be possible to re-use these drums for onward transportation of formulations of the same pesticides which they contained on the incoming trip. Such drums should be completely and carefully emptied. They should then be rinsed thoroughly, carefully inspected for integrity of seams, bungs, closures, and for any other indication of damage, and only fully intact drums should be further used.

If metal drums are not to be reused or returned to the supplier, they may after thorough rinsing be sold to cooperage firms equipped to handle drums contaminated with toxic materials. The container immediately on emptying should be rinsed three or more times using at least one tenth to one quarter of the container volume of appropriate solvent. If the product is an emulsifiable chemical being used in spray application rinsing the container with water and adding this to the spray mixture not only serves to clean the container but serves to recover pesticide that might otherwise be wasted. However, rinse material that cannot be used should be disposed of as if it were excess pesticide.

If this is not possible either, ways must be found for the safe destruction and disposal fo such drums. Applicable laws and regulations vary greatly between countries and from state to state and are subject to change as new and better methods for dealing with this problem are developed. It is there-

fore not possible to supply generally applicable instructions at this time. Persons, companies or agencies who have to dispose of large, noncombustible pesticide containers should discuss this problem with appropriate local or regional public health, environmental protection or other agencies and jointly develop suitable procedures. However guidelines of assistance in disposal problems are offered in The Federal Register, Volume 39, Number 85, Part IV, pp. 15236-15241. Here it is suggested that properly rinsed containers, if they cannot be reused or recycled as metal should be disposed of in appropriately designated sanitary landfills.

Pesticide containers constructed of combustible materials such as paper, cardboard, fiberboard or plastic which have been thorougly emptied can be disposed of by incineration where this is permissible, <u>except</u> that containers which have conained 2,4-D, 2,4,5-T or other hormone-type herbicides must not be burned. Fumes and smoke from the burning of such containers may damage plants and crops for great distances.

Such containers, and combustible containers which cannot be destroyed by burning for other reasons must be disposed of by other methods. Again, procedures should be developed cooperatively with the appropriate local agencies and in accordance with applicable laws and regulations.

<u>Surplus pesticides</u>.

The disposal of larger quantities of obsolete or surplus pesticide technical active ingredients or formulations is a very difficult problem. ("Larger quantities" in this context are all quantities too large to be used up in accordance with the label recommendations for the product concerned.) One method is incineration under carefully controlled time and temperature conditions, and it can be carried out only in special incinerators properly equipped to prevent air, water or soil contamination. More stable pesticides require temperatures above 900°C for complete incineration. At present, only very few incinerators

capable of handling toxic pesticides in this manner are available anywhere in the world.

Soil Disposal.

There are two quite different practices in disposal of chemicals in soil. The one practice utilizes the so called "sanitary landfill" where a pit is dug in the soil and the chemical disposed in the pit. Usually, some chemical additive, such as lime and charcoal, are used to accelerate the breakdown of the chemical in this sanitary landfill. The practice then is to line the pit with quantities of lime and charcoal. A layer of the chemical to be disposed of is next placed in the pit, covered with more lime, and a layer of soil used to cover it. A second layer of lime is added, then more chemical, more lime, and finally another layer of soil. For the sanitary landfill handled in this manner, the site must be chosen with extreme care since the breakdown of the chemical will not be so rapid, but what some leaching from the landfill may not occur causing contamination of ground water and/or nearby streams.

It is recommended that where pesticides or toxic chemicals are to be disposed of in this manner, the individual pit, be limited in size and relatively small quantities of chemical disposed of in each pit. The pits should be 10-30 meters apart, have a maximum depth of not more than 2 1/2 meters, and have a covering of 1/2 to 1 meter of soil. The purpose of the lime used in sanitary landfills provides an alkaline media that will hydrolyze the organophosphates and carbamates to relatively less toxic products. Moreover, the lime as it diffuses into the soil encourages microbiological activity that brings about further destruction of the hydrolysis products. In the case of the chlorinated hydrocarbons, the alkaline media dechlorinates that substance to another product. In some instances, further breakdown occurs

fairly rapidly. If rapid breakdown of the chlorinated hydrocarbons is desired, the addition of animal manure or good organic compost plus some fertilizer creates an aerobic condition that brings about fairly rapid degradation of the organochlorines.

The other method of soil disposal consists of distributing the material over a larger area incorporating into the soil to a depth of 5 or 6 inches and depending on the microorganisms of the soil to break the chemical down. Management of such an area by means of adding fertilizer and maintaining soil moisture accelerates the rate of breakdown. Where organophosphates are to be disposed of in this fashion, the addition of lime at the rate of 2 1/2 tons per hectare will accelerate breakdown. The amounts of chemical that may be applied in using the soil for biodegradation can range from 10-20 times the normal rate of application.

The site selected for biodegradation as described above is very important. Again, it must be removed from other human acitivities, it should not drain into streams or bodies of water, and some provisions should be made to drain any surface run off into a sump area before being released. With proper site selection and management, the soil biodegradation technique can be an effective way of disposing of unwanted organic chemicals.

Other possible methods of disposal of large quantities of toxic pesticides have also been considered, including ocean disposal, and disposal in deep wells. According to present thinking, these methods involve unacceptable risks to human and/or environmental health and safety and are therefore not recommended.

It is thus obvious that the need to dispose of sizable quantities of pesticides should be avoided if at all possible. If such a need nevertheless arises, handling procedures compatible with local and national laws and

regulations, and with available technology and equipment must be developed on a case by case basis. It is strongly recommended to involve the basic manufacturer of the product(s) in the development and execution of such plans since he usually knows his own product best and will have a self-interest in its safe disposal. He may also be in the best position to advise on possibilities of re-working or re-furbishing the material in question so as to avoid the need to destroy it.

Pesticide and Contaner Disposal by the End User.

It must again be emphasized that the disposal of emptied pesticide containers and the prevention of their misuse is one of the responsibilities of the person, enterprise or agency who received and used the pesticide. This must be clearly recognized and understood by the pesticide user himself as well as by persons or agencies involved in planning or training activities relative to pesticides.

Emptied pesticide containers are never completely empty and therefore are a serious hazard to people, animals or the environment if they are not properly handled. The same is true, of course, of left-over or unwanted pesticide products o .ute tank mixes of pesticides. Containers and conten alike are dangerous to persons, especially to children and other unsuspecting persons, to livestock, pets and other animals. They may contaminate food, feed, water, soil or air, result in damage to plants or crops, or in the secondary contamination of crops by uptake of residues.

The following procudures are recommended to eliminate or minimize these hazards.

Pesticide Containers.

Pesticides are expensive, and for economic as well as for safety reasons pesticide containers should be emptied carefully and completely.

For containers of liquid pesticides, the following procedure is recom-

mended. After "normal" emptying, drain container into the spray tank in a vertical position for another 30 seconds. Then rinse three times and drain into the spray tank in a vertical position for 30 seconds after each rinse. Use one quart for each rinse for a one gallon can; one gallon for each rinse for a 5 gallon can; and 5 gallons for each rinse for 30 or 55 gallon drums. This so-called "rinse and drain procedure" has been found to be a simple, quick and economical method for significantly reducing the potential hazard of used pesticide cans and drums.

This procedure will render the container ready for proper disposal, but not for re-use in another service. No amount of cleaning or decontamination at the farm level, including rinses with detergents, caustic soda or other agents, can decontaminate pesticide conainers sufficiently for safe use in other services. In particular, such containers must not be used for storage or transportation of food, feed, water, or other itmes for consumption by humans or animals.

Light weight, single trip containers which have been thorougly drained and rinsed should be crushed and buried in a safe location on the farm premises. Burial pits should be dug in clay or loam soil, in an isolated, level spot at least 150 to 200 meters away from livestock feeding areas, wells and streams, where water supplies will not be contaminated. The pit should be dug deep enough to provide for a soil cover not less than three quarters to one meter thick.

Heavier, 30 to 55 gallon steel drums are very difficult to crush and dispose of without heavy equipment. Such drums may be returned to the seller for proper handling, or sent to a facility equipped to recondition and recycle them, to salvage them for scrap metal, or to crush and dispose of them in an approved manner.

Pesticide containers which are under pressure must not be punctured.

Small, hand-size pesticide aerosols or pressurized sprays should be sprayed out completely, then buried as described above without puncturing or crushing. Heavier pressurized pesticide containers such as fumigant containers should be emptied completely, then returned to the supplier.

Combustible pesticide containers, except those having carried hormone-type herbicides, can best be disposed of by the end user by burning, provided this is permissible under local laws and regulations. In burning pesticide bags, boxes fiberboard drums, etc., care must be taken not to expose people or animals to the smoke or fumes from the fire. Combustible containers in which 2,4-D, 2,4,5-T or similar hormone-type herbicides have been transported must not be burned because smoke and fumes from this material may damage sensitive plants and crops for great distances. These containers should be buried in the same manner as described above for light, single-trip containers for liquid pesticides. If burning is not possible or feasible for other combustible containers either, all of them should be so buried.

Surplus pesticides.

Pesticides should not be purchased or stocked by the end user in larger quantities than needed for one season. If it nevertheless becomes necessary to carry pesticide stocks over to the next season, they must be stored in the original, labelled container, with the label plainly visible. Never permit storage of pesticides in other containers, especially not in containers such as wine or soft drink bottles whose contents could be mistaken. Partially filled containers should be tightly reclosed, and a notation made on the container or on a tag attached to it indicating the approximate quantity of pesticide remaining. Pesticide storage areas should be kept locked in order to prevent access by unauthorized persons, especially children, theft, etc.

In determining pesticide requirements for the next season, left over

stocks should be taken into consideration, and should be used first at the beginning of the next season.

The best way to dispose of small quantities of unwanted or left over pesticides is to use them up in accordance with the directions and safety precautions on label. Surplus tank mixes of pesticides can best be disposed of in the same manner. If a suitable target crop for which the product is recommended is not available, the material may be sprayed or otherwise distributed in other suitable, safe, protected areas. All safety precautions and limitations on the label must be carefully observed.

PESTICIDE APPLICATION EQUIPMENT.

The success of any pesticide application depends not only on the choice of the right product and the right formulation; equally important is the choice of the right application equipment and its proper use. Most pesticides are applied as sprays, dusts or granules. Application equipment for each of these types of formulation is discussed below.

Spray Equipment.

Types of sprayers.

Sprayers are intended to distribute pesticides dissolved, emulsified or suspended in a liquid carrier, usually water. Availability of an adequate water supply is therefore a prerequisite, especially for use of high-pressure, high volume sprayers.

The basic elements of the sprayer include the tank, one or more nozzles through which the spray is discharged, and a pump generating the necessary pressure. Tanks may be constructed of fiberglass, wood, steel, stainless steel, aluminum, or plastic. All tanks should have a large inlet to allow easy loading and periodic inspection of the inside,

and a large drain to allow fast and complete flushing. Tanks, especially in larger sprayers, should have agitation to prevent separation and settling of emulsions or suspensions. Some sprayers have mechanical agitators, others use the liquid returning from the regulator line to produce agitation.

Filters usually are mounted in the suction line between the tank and the pump, in the main supply line between the pump and the boom, and in each of the spray nozzles.

Pumps used in pesticide spray equipment may be centrifugal, piston or roller pumps. Some sprayers employ a pressurized tank instead of a pump to provide operating pressure. A pressure regulator and a pressure gauge are necessary to set the sprayer at the proper operating pressure, and to maintain constant pressure in the system during operation. The latter is accomplished by allowing liquid to return to the tank when the pressure exceeds its setting.

Several different kinds of nozzles are available which produce different spray patterns and droplet sizes. Each type of nozzle has specific operating pressure requirements which should be ascertained, set before starting, and maintained throughout the spraying operation. Changing the operating pressure changes the spray pattern. When

nozzles become worn, they may deliver excessive amounts of spray and droplets whose size varies over an excessively wide range.

Sprayers for the treatment of row crops should have adjustable boom and nozzle arrangements. On small plants, one nozzle per row, centered over the row and pointing straight down, usually is sufficient. For larger plants, two nozzles per row, one from each side, are used, and for still larger plants, a third nozzle pointing down from over the center of the row may be added to the assembly for each row.

For most sprayers, the volume of spray discharged can be adjusted in a variety of ways, including varying operating pressure, types and numbers of nozzles, and ground speed.

Spray equipment designed to distribute very low volumes of liquid has been developed in recent years. This technique is known as "ultra-low volume (ULV)" spraying. The term is used for operations in which the total volume of liquid applied per acre is ½ gallon or less. Highly concentrated pesticide formulations and certain liquid technical active ingredients can be used in this fashion. Some ULV sprayers work with conventional nozzles, while others are equipped with special, rapidly spinning devices which are intended to produce fine spray droplets of uniform size.

Knapsack or hand sprayers are the smallest kind of sprayers available. They vary considerably in size, shape, and special features. All are carried by the operator. The operating pressure is generated either by a small engine-operated pump, or by a hand pump.

Larger spraying equipment may be mounted on aircraft, or on self-propelled or tractor- or animal- drawn ground rigs.

Pesticide spray applications are made for a variety of different purposes. Small plantings, objects, or the inside of buildings may be treated by hand equipment. Liquid pesticides are applied into the soil by injection, or to the soil surface or into furrows. Crops are treated by power-operated ground rigs, larger fields often by aircraft. Orchards, groves, or other trees may be treated by ground or air. Air application is usually the method of choice for the treatment of larger forest areas.

A considerable variety of spraying machines, representing different combinations of power sources, pumps, and nozzle arrangements are available in a variety of sizes. It is beyond the scope of this manual to discuss each type of machine in detail. The recently issued "Manual of Pesticide Application Equipment" (Ref. 13) describes many types of pesticide application equipment, both large and small, along

with accessories, spare parts, and suppliers.

In situations where pesticide applications are to be undertaken for the first time, starting with the acquisition of the application equipment as well as the pesticide, the contemplated pest control program should be discussed with equipment suppliers as well as with pesticide suppliers, and the most suitable application equipment selected with the assistance of both. Factors such as availability of roads, size and topography of the area, crop or crops to be treated, climatic conditions and availability of water have to be considered. If the application equipment is already available and thus a "given constant", then it is important to select a pesticide whose efficacy, mammalian and environmental toxicity and available formulation meets the control purposes and operating conditions.

Operating problems.

Pesticide formulations for use in spraying equipment include emulsifiable concentrates, liquid or dry soluble formulations, and wettable powders. Regardless of the typ of formulation used, the spray tank should first be fille about half way with the carrier liquid, usually water, then the required amount of pesticide should be added while the agitator is in operation, then the tank should be filled up.

Problems which are commonly encountered with spray equipment include corrosion of tank, pumps, lines or nozzles. Rusting or scaling will generate particles which may clog filters and nozzles. To avoid corrosion, the spray equipment and the pesticide product to be used should be checked for mutual compatibility by consulting the directions for use on both. The spraying equipment must regularly be checked for signs of corrosion.

Some pesticide formulations may cause excessive foaming. This may require the use of an anti-foaming agent, or of a different pesticide formulation.

Clogging of filters or nozzles is probably the most common operating problem and must be corrected as soon as discovered. Spraying must be stopped and the obstruction located and removed. This involves disruption of the spray pattern, loss of time and also, in the case of toxic pesticides, hazards to the operator. Use of clean spraying equipment, clean water, and pesticide formulations meeting specifications are important in avoiding screen and nozzle clogging problems as much as possible. Liquid concentrates should meet prescribed standards of emulsifiability or solubility and freedom from sediment. Wettable powders should meet standards of particle size, wettability and suspendability.

Dust Applicators.

Pesticides in dust form are not used as widely at present as they were in the past. Pesticide dust applications involve considerable drift hazard. Dust particles often do not arrive at, or do not stick where they are needed. Also, pesticide dust formulations may lose active ingredient, cake, lose dustability or otherwise become physically unusable under hot and humid storage and operating conditions. Pesticide dusts are therefore not used nearly as much as sprays. One important advantage of dust application is that no water is required.

Like sprayers, dust applicators are basically available in a variety of different designs, materials, sizes and makes. The basic elements of a dust applicator include the hopper containing the pesticide dust which is usually of rather low concentration (not more than 10% of active ingredient), a device generating an air current into which the dust is introduced and which carries it toward the target by a suitable outlet, and a metering device controlling the dust flow. The air stream is power-generated in large dusting machines. In small machines which are carried by the operator, intermittent air streams may be generated by a bulb or bellows, or hand- or engine- generated rotary action may produce a continuous air stream.

The simplest form of dust applicators are sacks, stockings or other bags of fabric of a suitable mesh structure which emit dust by simple gravity action upon being shaken. These may be used singly, or several of them may be tied to a pole carried across the file by two people.

Pesticide dust applications, especially those from small, hand-operated units, involve a high risk of dermal and inhalation exposure. Therefore, highly toxic pesticides should not be used in dust form, especially not under hot and humid operating conditions.

As with pesticide spraying equipment, larger, power-operated dusting units may be mounted on, and operated from, aircraft or self-propelled or tractor- or animal-drawn ground rigs. Operator protection may be somewhat less of a problem with these larger units, but the problem of drift is made worse.

Granular Applicators.

Granular formulations of pesticides are becoming increasingly popular. This type of formulation and the equipment necessary to apply it offer important advantages, including relative simplicity of the application equipment, and avoidance of drift and operator exposure.

Pesticide granules do not need a water or air stream for transportation to the target, but instead get there simply by gravity. Granular pesticide formulations usually contain low concentrations of active ingredient; rarely over 15, often 5 - 10%.

The basic elements of granular pesticide applicators are the hopper containing the material, a metering device at the bottom of the hopper, and one or more tubes depositing the granules in a row or in a narrow band, or a rotating disc device resulting in a broadcast application pattern. The metering device may consist simply of an adjustable slot, or a rotating mechanism. Several individual granular application units may be mounted on planters, seeders or other agricultural ground machinery.

Smaller granular applicators, for the treatment of one to two rows, may be mounted on a single or a dual wheel frame which is pushed by the operator. The lawn and garden fertilizer spreader is a popular version of this model. Even smaller units resemble rotary hand seeders; they are carried and hand-cranked by the operator and produce a swath whose width depends upon the strength of the centrifugal action generated.

Aircraft Applications.

Fixed wing aircraft as well as helicopters are used for the application of pesticide sprays or dusts. Many more acres are treated by fixed wing aircraft than by helicopters because fixed wing planes are more economical to operate and consequently, pesticide application costs per unit of area are lower. On the other hand, helicopters are more maneuverable and may be used in situations which would be inaccessible to fixed wing aircraft (mountainous areas, fields surrounded by tall obstacles, etc.), or where the degree of target precision required would be unattainable by fixed wing aircraft.

When airplanes are used for pesticide applications to field crops or other row crops, "flagmen" on the ground are needed to direct the plane to the right swath. Flagmen must avoid exposure to the spray or dust as much as possible and attempt to remain up-wind from the application swaths. They must also warn people who may be in the area to stay out of the field and the spray or dust drift.

Piloting a spray or dusting plane is a particularly exacting job. Airplanes often have to be flown within only a few feet of the ground, in the vicinity of obstacles such as power lines, trees, etc. The risks inherent in this are compounded when toxic pesticides are applied. The

pilot must wear suitable protective clothing and respirator if he applies a highly toxic pesticide. Care must be taken to make certain that tanks or hoppers are tightly closed, so that no pesticide material will spill or leak in flight. The entire aircraft, especially the cockpit, and other equipment contaminated by pesticides must be cleaned frequently and thoroughly.

Weather, especially wind conditions must be carefully considered in all aircraft applications of pesticides to avoid drift and possible exposure of people, animals, crops, bodies of water and the environment at large.

Drift.

Drift is one of the major problems associated with the use of pesticide sprays or dusts. Several investigations indicate that quite often, a distressingly high percentage of the pesticide discharged at the spray nozzle or dust outlet never arrives on the target crop. Air applications generally cause a greater drift problem than ground applications, but the latter are by no means trouble-free in this regard.

Drift is wasteful because it reduces the amount of the pesticide arriving on target to control the pest. Furthermore, pesticide drift may cause harm to operators and other

persons or animals in the vicinity, or to non-target crops. Drift may also result in illegal pesticide residues in or on other crops, pastures, livestock, poultry, meat, milk and eggs. Drift is also one of the mechanisms by which pesticides may enter into the atmosphere at greater distances from the ground and be transported far away from the original site of application and, in fact, become a global contaminant.

For all of these reasons, great care must be exercised in avoiding pesticide drift. The following factors will decrease drift and should therefore be adhered to as closely as possible:

1. short distance between spray nozzle and target;
2. larger spray droplets;
3. larger volume of water;
4. wind velocity below 10 mph;
5. low temperature;
6. high humidity (reduces water evaporation in water-based sprays);
7. reduced speed of the application rig.

Consideration of these factors will result in more efficient use of the pesticide, improve pesticide deposit on target, and reduce contamination of the surrounding area and the environment at large.

Good Operating Practices.

For operators of knapsack or other hand-carried pesticide sprayers or dusters, it is practically impossible to avoid close skin and inhalation contact with the spray mist or dust. Under hot and humid conditions as they prevail in warm climates, it is equally impossible for the operator to wear adequate protective clothing including rubber boots, impervious hat, suit or coat, gloves and mask or respirator. Therefore, highly toxic pesticides are not suitable and should not be used with this type of pesticide application equipment.

For operators of larger, power-driven pesticide application equipment, it is more feasible to observe the safety precautions required for the handling of highly toxic materials, but these are still cumbersome and tend to be neglected, especially in hot weather. The use of highly toxic pesticides should generally be discouraged in tropical and subtropical countries. A less toxic product may be more expensive pound for pound, but may still be more economical to use because it provides greater safety and ease of operation for all workers involved, allowing the work to progress more swiftly and smoothly. In addition, less toxic products usually have fewer restrictions regarding safe intervals to harvest, and treated crops, groves or orchards

present a lesser or no safety risk to field workers, fruit pickers and others who need to re-enter the treated area after application.

Proper calibration is another very important step in the operation of any and all pesticide application equipment, regardless of size or type. The procedures to follow vary considerably, depending on the type of machine. Calibration instructions are furnished with every pesticide application device or should be requested from the supplier or manufacturer of the equipment if not available. They should be studied and followed carefully.

The following steps are important at the end of a pesticide application. On the last run, do not load any more dilute pesticide than is necessary to complete the job. The spray tank or hopper should be emptied completely on the last run, and the application equipment cleaned thoroughly immediately afterwards. This will avoid corrosion and, especially, possible harm to workers who may subsequently service or repair the equipment, or to unsuspecting persons, especially children, or pets, livestock, poultry or other animals. This cleaning should be done in such a way that the run-off will not contaminate waterways or wells, or in any other way endanger man, animals or plants.

Fumigation.

In the fumigation process, a pesticide in the vapor or gaseous phase is used to destroy pests in confined spaces such as warehouses, storerooms, mills, factories, shipholds, trucks, or boxcars. Fumigation is also used for desinsectization of public or private human habitations, hotels, prisons, barracks, hospitals, theaters, museums, etc., and for disinfesting a wide range of materials including living plants, fruits, vegetables, stored grains and processed foods. Less volatile fumigants are employed for soil fumigation to destroy insects, nematodes, weeds and microorganisms.

Fumigants should be applied only by professional operators who are trained in their proper use and have the ncessary safety equipment. All fumigants are toxic to man. Some of them are also highly flammable. In all major fumigation projects, the cooperation of local police and public health officals should be engaged.

Rooms or other confined spaces to be fumigated must be made as airtight as possible by closing and sealing all doors windows, cracks, chimney holes, ventilators, etc. The amount of fumigant to be used must be carefully measured depending upon the intended control purpose, time of exposure, temperature, relationship between free air space and load to be

fumigated, and degree of sorption of the fumigant by the commodity under fumigation. The actual concentration of fumigant should be monitored throughout the operation.

Special care is required in the fumigation of living plants such as nursery stock, seeds, trees, greenhouses, etc., where there may only be a narrow safety margin between the amount of exposure necessary to kill the target organism(s) and the amount of exposure which will damage or kill the plants.

Soil fumigants can be applied by a variety of equipment ranging from sprinkling cans to tractor-mounted or tractor-pulled applicators or attachments. The less volatile fumigants may be applied to the soil as liquids, crystalline solids or granulars. Methyl bromide is a gas once released from its container; it must be confined under a gasproof sheet if used for soil fumigation.

HUMAN SAFETY.

General Safety Rules.

All pesticides are toxic to some forms of life and to some biological systems. Many pesticides are highly toxic not only to the target pest(s), but also to many other organisms including man and 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, and access to the equipment necessary to implement these procedures.

The safe use of pesticides always requires three basic steps:

1. Plan ahead. This includes having thorough knowledge of the pesticide to be used, especially being completely familiar with all information, use directions and safety precautions given in 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 clean-up of all equipment, spills, etc., after use, and the protection

of field workers who may be exposed to toxic residues on treated foliage, fruits, vegetables or other plant parts.

2. Prevent exposure. In handling pesticides, exposure to the pesticide must be avoided to the largest possible extent. All persons involved should be trained to 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 fields, groves or other areas, and all other avoidable exposure must be avoided.

3. Protect against unavoidable exposure. Persons directly engaged in mixing, loading and applying pesticides cannot completely avoid breathing spray mist, dusts, or vapors, or skin contamination. Depending upon the toxicity of the pesticide handled, operators have to 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. Where high temperature or humidity make it impossible or impractical to wear such heavy protective clothing and

equipment, highly toxic pesticides should not be used.

Field workers such as fruit or vegetable pickers or scouts should not enter treated fields, orchards or groves until toxic residues have dissipated. If this is not possible, they must wear adequate protective clothing and equipment, depending on the toxicity of the pesticide(s) used and the amount of residue remaining in the treated area.

Acute Pesticide Poisoning.

Pesticides may be poisonous if swallowed, inhaled or absorbed through the skin. They may cause irritation or inflammation of the skin, eyes, or respiratory tract (dermatitis, conjunctivitis, laryngitis, pneumonitis). Some pesticides may cause allergic responses in some or all persons coming in contact with them. In the case of pesticides in the "highly toxic" category, doses as low as a few drops, ingested by mouth or absorbed through the skin, could be fatal to an adult human. Even smaller quantities may be fatal to children.

Pesticide products vary widely in their toxicity to humans, depending on the toxicity of the active ingredient, its concentration in the formulation, other ingredients in the formulation, and other factors. Some products are

highly toxic by mouth, but less toxic by skin contact.

Table 1 summarizes the criteria which determine a pesticide's toxicity classification. "LD-50" is the median lethal dose, that is the milligrams of toxicant per kilogram of bodyweight lethal to 50% of the test animals. "LC-50" is the median lethal concentration, that is the concentration of toxicant in micrograms (µg) per litre (l) of air which kills 50% of the test animals. For each category, the quantity probably lethal to an adult man is given. "Signal words required on label" are those required by U. S. Federal pesticide laws and regulations.

It is the responsibility of the manufacturer of each pesticide product to determine its toxicity, and to give directions to the user, by way of the product label, on how to use the product safely, and what to do in case of accidental poisoning. It cannot be overemphasized that persons planning to use pesticides must be thoroughly familiar with the toxicity and all safety precautions of the product(s) to be used. If the safety precautions set forth on the label cannot be met, or if the necessary protective clothing and equipment as specified on the label are not available, or if their use is not practical or feasible, the product should not be used. A less toxic product or another pest control

Table 1:

TOXICITY AND PRECAUTION CATEGORIES

Group	I	II	III	IV
Description	Highly toxic	Moderately toxic	Slightly toxic	Relatively non-toxic
Acute oral LD-50, mg/kg	Less than 50	Over 50 - 500	Over 500 - 5,000	Over 5,000
Acute dermal LD-50, mg/kg	Less than 200	Over 200 - 2,000	Over 2,000-20,000	Over 20,000
Acute inhalation LC-50, µg/l	Less than 2,000	Over 2,000-20,000		
Dose probably lethal to a 150 lb. man	A few drops to one teaspoonful	One teaspoonful to 1 Oz.	Over 1 oz. to 1 pt. or 1 lb.	Over 1 pt. or 1 lb.
Signal word required on label	Danger -Poison Scull & Cross-bones	Warning	Caution	None required

strategy should be used instead.

Protection of bystanders.

In the United States, the greatest number of accidental poisonings and deaths from pesticides result from carelessness in storage, use and disposal of pesticides among persons not directly involved in the pesticide application itself. Unfortunately, a large percentage of victims in this group are young children.

This experience clearly emphasizes the great importance of preventing exposure of bystanders at all stages of pesticide use. Potential risks which must be avoided include access to stored pesticides, especially half-empty containers not re-closed tightly; contaminated application equipment or containers, especially equipment or containers still containing concentrated or dilute pesticides; and exposure to spills, sprays, dusts, or drift. Children have become poisoned from playing with contaminated wquipment, utensils, measuring cups, dirt, mudpies, etc., or in building or grain bins treated with pesticides, or on heavily contaminated vegetation or bare ground.

Another potentially dangerous situation exists where pesticides are used indoors, especially on floors, along baseboards, floor moldings and in similar areas where children may crawl, play, or lick. Highly toxic pesticides should

never be used for household pest control.

Very serious accidents, several of them involving many deaths, have resulted from the contamination of food, feed, clothing or similar articles with concentrated pesticides. Pesticides, especially highly toxic ones must never be shipped or stored in the same room or compartment with food, feed, or similar items which may become contaminated.

Protection of pesticide applicators and field workers.

Observation of the three basic pesticide safety rules outlined at the beginning of this chapter is important for all workers directly involved in the handling of pesticides, especially those handling toxic organic phosphates or fumigants such as methyl bromide, as well as for persons working in pesticide-treated fields or other areas.

At the operational level planning for safe pesticide use should be a three-step process. First, the person responsible for the contemplated pesticide use must decide which product to use, considering the desired control purpose, available equipment, operating conditions, operator skills, and available alternatives. If the person responsible is not himself technically qualified to make these decisions and weigh alternatives, he should obtain expert advice, preferably from an unbiased source such as a government agency,

rather than from a pesticide salesman or industry representative.

Secondly, after the decision has been made to use a certain pesticide, all persons involved in its handling and use should be thoroughly informed of the properties of the product, of all information and directions on the product label, and instructed in detail on how to use it properly. 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.

Thirdly, potential dangers to field workers from exposure to, or contact with treated crops or animals must be identified and prevented. Workers entering treated fields, orchards, groves or other areas before toxic pesticide residues have dissipated may become ill from skin contact with treated foliage, fruits or other plant parts, from breathing pesticide vapors or dust, or from eating food bearing pesticide residues.

The best way to prevent such exposure of field workers is, of course, to keep them out of treated areas until the toxic residues have dissipated or declined to a safe level. If this is not possible, then field workers must follow the same precautions as required for pesticide applicators,

depending upon the toxicity and persistence of the pesticide(s) employed.

Some states within the U. S. have recently established minimum time periods after treatment which must be observed before treated fields, groves, orchards or other areas may be re-entered by field workers. More states will probably set such "re-entry periods" in the future because there have been several recent episodes of illnesses among fruit pickers from exposure to toxic pesticide residues. The length of required re-entry periods will vary depending on the crop, the pesticide used, the climatic conditions and their effect on the rate of pesticide residue decline. Therefore, it will not be practical to set universally applicable re-entry periods. Instead, these will have to be adapted to regional conditions for each pesticide for which they are required.

Field studies have shown that the greatest hazard to pesticide workers in the field is through skin contact. Many pesticides can readily penetrate into the human body through the intact skin. Adequate protection of all exposed body surfaces in line with the label directions is therefore especially important. Gloves are among the most important personal protective devices. They should be impervious to the chemical being handled, which is best accomplished when they are made of rubber. Gloves should be washed daily,

inside and out. If they become contaminated on the inside during use, they must be removed immediately, and the worker should wash thoroughly with soap and water. Damaged or torn gloves should be discarded.

Leather items including shoes, belts, etc., cannot be effectively decontaminated. They should therefore not be worn during handling of toxic pesticides and must be discarded if they do become contaminated. Rubber boots are recommended.

Rubber gloves, boots and aprons are considered minimal protection for all pesticides. Workers handling highly toxic pesticides should wear a complete rubberized rain suit or long coat, goggles or face shield, impervious hat and respiratory apparatus for complete protection. Field workers exposed to toxic pesticide residues on treated crops must wear clothing suitable to prevent skin contact, including long pants, long-sleeved shirt, hat and gloves.

Close attention to personal hygiene is a must in working with or around pesticides. Clean clothes should be worn daily. If a spill occurs or 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 it will not be endangered. Heavily contaminated clothing should be

discarded by burning or burial; it should be treated in the same manner as emptied combustible pesticide containers (see that section of this manual).

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. For emergency bathing, a tank of fresh water at the edge of the field, or the possibility to use a near-by stream, farm pond, or irrigation ditch are helpful.

If the pesticide to be handled calls for the use of respirators or gas masks, it is very important to use the proper type, fitted with the proper filter, cartridge or cannister effective for protection against the product concerned. In case of uncertainty, a qualified person in the public health or agricultural department should be consulted for selection of the right type of mask or respirator and inserts.

Workers who have not used respirators or gas masks previously should be thoroughly instructed in their proper use and must be warned of the consequences of failure to use them or to follow instructions. Equally important is proper adjustment of respiratory equipment to fit the individual wearer. An adequate supply of filters, cartridges or

cannisters must be available. Washable parts, especially face pieces, should be cleaned at least once daily with a mild soap and water and subsequently air dried. When not in use, the equipment should be carefully stored and protected against outside contamination.

Subacute and Chronic Pesticide Poisoning.

Repeated exposure to sub-disastrous levels of pesticides may have cumulative toxic effects and result in gradual onset of poisoning symptoms. Workers handling pesticides over prolonged periods of time are exposed to this risk, as well as persons such as cotton scouts, fruit and vegetable pickers and others working in pesticide-treated areas.

The potential effects of repeated exposure to pesticides upon people are difficult to predict from animal experiments; therefore, much of the knowledge about these effects develops only slowly from human experience.

Organic phosphate and carbamate insecticides inhibit a vital body enzyme, cholinesterase, and this inhibition can be detected by appropriate tests of small blood samples before more severe poisoning symptoms occur. This offers an opportunity for early detection of low-level exposure of workers to organic phosphates. Workers may be removed from further contact with the pesticide until their cholinesterase level

has returned to normal, and the source of exposure, usually unsafe working condition or practices, can be eliminated.

In the case of DDT and dieldrin, small concentrations of the chemical can be detected in the blood by chemical analysis. These blood levels provide an index of exposure which is useful both as a diagnostic test and as a surveillance tool. Blood levels of DDE, the principal metabolite of DDT, can be determined in the same manner. In studies on DDT, both DDT and DDE should be monitored because DDT is metabolized to DDE in the body. Therefore, readings on DDT only would not give the complete picture.

Enzyme or chemical tests of comparable sensitivity and significance are, unfortunately, not currently available for other pesticides. However, since such tests are available for some of the most widely used pesticides, they should be employed for routine surveillance of workers who are occupationally exposed, such as workers in manufacturing and formulating plants, operators of pesticide application equipment, workers involved in mixing and loading pesticides and, especially, pilots flying pesticide application aircraft.

Chronic pesticide poisoning may result from consumption of food items carrying excessive pesticide residues. In the United States, pesticide residues in food and feed have been subject to strict regulatory controls for many years.

Permissible residue tolerances have been established, or exemptions from the requirement of a tolerance have been granted for most pesticides currently in use. Government agencies routinely monitor pesticide residues in raw agricultural commodities moving in interstate commerce or entering the U. S. from abroad, and in ready-to-eat foods. These extensive regulatory and surveillance activites have been effective in preventing unsafe pesticide residues from getting into the U. S. food supply. There have been no recorded instances of chronic pesticide poisoning from food items obtained through regular channels of trade in the United States. However, poisoning has occurred from misuse of grain treated with toxic seed disinfectants, and from overuse or misuse of pesticides on home-grown fruits, vegetables, etc.

Many other countries do not presently regulate or monitor pesticide residues in food crops. Consequently, very little information is available on the extent of the pesticide residue problem, if any, on a global basis. However, many countries, especially those exporting agricultural commodities, have recently become concerned about pesticide residues in their produce. These countries are currently looking into ways and means of analyzing the problem and taking whatever corrective measures may be required.

Toxic Action of Pesticides.

Many of the pesticides in large scale commercial use at present are either organic phosphates or chlorinated hydrocarbons. The toxicity characteristics of these two types of pesticides are summarized below.

Organic phosphate pesticides.

The phosphate ester group of pesticides includes some of the most toxic pesticides such as parathion, TEPP, mevinphos, phorate, disulfoton, demeton and others. On the other hand, other organic phosphates are only moderately toxic, and some, notably malathion, are among the least toxic insecticides. Parathion has been implicated in more accidental, occupational and epidemic pesticide poisonings than any other pesticide.

The symptoms of organic phosphate poisoning are believed to be caused by the inhibition of cholinesterase, a vital body enzyme. Symptoms of poisoning include headache, nausea, sweating, blurred vision, a sense of tightness in the chest, abdominal pains, vomiting and diarrhea. Onset of symptoms is rapid after heavy exposure. With some organic phosphates, especially if the exposure has not been massive, onset of symptoms may be delayed for several hours, but rarely longer than 12 hours. In more advanced poisoning, difficulty in

breathing, tremors, convulsions, collapse, coma, pulmonary edema and respiratory failure follow.

Fortunately, highly specific antidotes are available for the treatment of organic phosphate poisoning. Timely administration of atropine sulfate, alone or in conjunction with pralidoxime chloride (2-PAM) can save victims who have absorbed several times a fatal dose. Excellent literature is available to physicians concering the proper treatment of organic phosphate poisoning, including Ref. 7.

An important planning step prior to the use of organic phosphate pesticides, therefore, is to inform the physician who would be called in emergencies, asking him to obtain the necessary literature and antidotal drugs. The physician should also be given copies of the label(s) of the product(s) to be used which will contain additional important and specific information.

Chlorinated hydrocarbon pesticides.

Chlorinated hydrocarbon insecticides such as DDT, chlordane, toxaphene, heptachlor, aldrin, dieldrin, endrin and BHC have probably been used in larger quantities than any other group of synthetic pesticides. They are very stable, highly chlorinated, complex organic chemicals. Their mode of action is unknown, even though much research work has been done in efforts to uncover it.

Like the organic phosphates, the chlorinated hydrocarbon insecticides also vary widely in their toxicity. Aldrin, dieldrin and endrin are highly toxic products, whereas DDT, BHC, chlordane and others are less toxic.

The most frequent source of acute poisoning from chlorinated hydrocarbon pesticides has been dermal exposure to massive doses of concentrated liquid formulations from spilling material on the skin or on non-protective clothing. Symptoms of acute poisoning indicate stimulation of the central nervous system and appear usually within a few hours after exposure. Chemical analysis of blood samples may assist in the positive diagnosis of chlorinated hydrocarbon pesticide poisoning. In fatal cases, postmortem findings are non-specific. There are no specific antidotes available. Accordingly, the physician is usually limited to symptomatic treatment of poisoning victims. Fortunately, only relatively few cases of acute pesticide poisoning have resulted from the use of chlorinated hydrocarbon pesticides.

Many pesticides in this group and some of their metabolites are fat-soluble and may accumulate in the adipose tissues of man and animals. Those chlorinated hydrocarbon pesticides and metabolites which combine fat solubility with high stability tend to accumulate through successive trophic levels in aquatic as well as in terrestrial food webs,

resulting in very high residue levels in animals at the top of food chains such as raptorial and fish-eating birds including eagles, hawks, falcons, etc.

Residues of DDT and DDE, its principal metabolite, and of dieldrin, which is an insecticide in its own right and also the principal metabolite of aldrin, have been found in the body fat of the general population in all countries of the world where studies have been conducted. Deposits of DDT and DDE combined, expressed as DDT, of the order of about 5 to 20 ppm in the body fat have been reported from the United States, Canada, Germany, England, France, Hungary, Israel and India. In the United States the average amount of DDT/DDE found in humans is in the neighborhood of 10 to 13 ppm of fat. Comparable dieldrin values are less than 1 ppm.

The significance of these body deposits has yet to be determined. To date, no adverse effects have been proved to be associated with their presence.

Some workers in plants where chlorinated hydrocarbon insecticides are manufactured and formulated carry much higher deposits in their body fat than the general public. The highest level recorded is 1,082 ppm of combined DDT and DDE. Increased cortisone metabolism and liver enzyme induction have been shown to occur in controlled studies at levels of this order of magnitude.

Other pesticides.

Other pesticides belong to many different chemical groups and display wide variations in their acute and chronic toxicity, speed of onset of poisoning symptoms, and other properties pertinent to their toxicity. For most pesticides other than the organic phosphate insecticides, the mechanism of toxic action is not known, and no specific antidotes are available. Symptomatic treatment of poisoning symptoms is therefore usually the only course of action available to the physician.

For each pesticide product, all available information about its toxicity and about what to do in case of poisoning is included in the label which should be consulted in an emergency and, of course, also be made available to the attending physician.

Collection of Information on Pesticide Poisoning.

As pointed out in an earlier chapter of this manual all pesticides undergo extensive testing prior to their registration and commercial use. These investigations include studies on the acute, subacute and chronic toxicity of pesticides to different species of laboratory animals. Through these studies, a large body of information has been

accumulated on the effects of many pesticides on rats, mice, guinea pigs, rabbits, dogs, and other laboratory animals.

By contrast, very little is known about the effects of pesticides on man. Extrapolations from the results of animal experiments to man are of questionable value. Planned and controlled studies on human subjects have been conducted with a few pesticides. Studies on humans are undoubtedly more pertinent in many respects than those on animals, but there is still the problem of extrapolating from a small number of volunteers (usually young men in excellent health, living under rather uniform environmental conditions) to the population at large. The effects of pesticide exposure in conjunction with the many other stresses to which many people are exposed are particularly difficult to assess or predict. Thus, many questions regarding the risks to human health from the use of chemical pesticides have yet to be answered.

Information on the effects of pesticides on humans comes mainly from three sources:

1. research studies involving controlled administration of known amounts of a pesticide;
2. case reports of pesticide poisonings; and
3. epidemiological studies.

In the United States, epidemiological studies on pesticides are conducted by a number of Community Pesticide

Studies Projects which are supported by the Environmental Protection Agency. This program has now been under way for several years and has already contributed much valuable information on the effects of different pesticides on different groups of people in several geographic locations.

Concerning the collection of individual case reports on pesticide poisoning, there is currently no uniform nationwide program in effect in the United States. A number of States have their own programs. A high-level commission (the "Secretary's Commission on Pesticides and their Relationship to Environmental Health", U. S. Department of Health, Education, and Welfare, chaired by Dr. Emil M. Mrak) made a thorough study on the effects of pesticides on man in 1969, and identified a number of urgent research needs in regard to the short term and long term effects of pesticides on man. Many of the Commission's recommendations in this area have not yet been fully implemented. One specific recommendation in this regard, that to establish "pesticide protection teams", deserves special attention not only in the United States, but also in other countries where chemical pesticides are used on an increasing scale. Pesticide protection teams are envisaged as multidisciplinary teams whose responsibilities are to include the exploration, investigation and documentation of episodes of pesticide poisoning, and the dissemination

of information on the safe use of pesticides.

In the training and operating instructions for these pesticide protection teams, the importance of timely collection and reporting of all incidents of pesticide poisoning should be stressed. The training or sponsoring agency should provide these teams with uniform reporting procedures and forms. Pesticide poisoning data should be exchanged between all teams, and all data summarized and published at regular intervals. Such an information network on pesticide poisoning cases will greatly contribute to a better understanding of the effects of pesticides on humans, and also pinpoint especially dangerous products or use practices which should be eliminated or corrected.

JUDICIOUS USE OF PESTICIDES.

The production of food through plant and animal agriculture is a very complex process in which man has been engaged since the beginning of time. Pests are among the many factors which may adversely affect the quality and/or quantity of crops or livestock, and their control has been an integral part of agriculture for centuries.

Prior to the advent of the synthetic organic pesticides in the 1930's, the principal tools of pest control included the use of resistant varieties of plants; mechanical removal of weed seeds from crop seeds; selection of fertilizer types and application dates, and timing of plowing, planting, tilling, and harvesting so as to favor the crop and disrupt pests' life cycles; cultivation; removal of weeds or insects by hand labor; removal of intermediate host plants harboring pests; crop rotation; flooding; and other cultural methods. Pests affecting man were controlled by screens, sticky bands, fly swatters, rodent traps, cats, etc.

Also included in this set of pest control tools were some of the early pesticides such as sulfur, lime sulfur, copper, mercury and other metal salts, and "Bordeaux" mixture (copper sulfate and lime) for the control of plant diseases caused by fungi; various inorganic salts and nitrophenols for

weed control; and arsenicals, spray oils, nicotine, pyrethrum, ryania, derris, etc., for the control of insects.

When the synthetic organic pesticides became available in rapid succession beginning in the 1930's, they brought about drastic changes in the ways in which agricultural pests were controlled, especially in the area of insect and mite control. In many instances, the "old" pest control measures were abandoned. Initially, the new insecticides provided spectacular control of target pests. However, fairly soon, undesirable results also appeared, including the development of pest populations resistant to pesticides; increasingly rapid resurgence of target pest populations following treatment; outbreaks of secondary pests which did not cause economic damage previously; undesirable residue levels on food crops and in many other elements of the environment including man himself; and adverse effects on wildlife.

Many growers of different crops in many countries went through the same experience. At first, results of the use of chemical insecticides ranged all the way from satisfactory to near-miraculous. Next, regular rates of application failed to give control. The same or different chemical insecticides were used at ever higher rates and shorter intervals. Finally, control failed completely from an economic as well as from a biological standpoint. In all of these situations,

the net benefits from the use of chemical insecticides diminished steadily, while the monetary cost of control increased, and unanticipated ecological risks became more and more apparent.

These developments, especially the increasingly unfavorable benefit:risk ratio, have led to the realization that sole reliance on chemicals for the control of insect and mite pests is not a good strategy. Instead, it is now believed that chemical insecticides will work best from the economic as well as from the ecological standpoint if they are employed as only one tool of crop protection, along with many or all of the other tools mentioned above. This concept is known as "integrated pest control" or "pest management".

In principle, these considerations are equally applicable to the use of other chemical pesticides. However, it seems that plant pathologists, weed scientists, agronomists and others have not relied on chemicals as intensively and as exclusively as some entomologists. Other tools and strategies of crop protection were never abandoned in weed control and plant disease control to the extent that they were abandoned temporarily in insect and mite control.

In areas where the basic ecosystem of major crops has been thoroughly disturbed through prolonged heavy use of chemical pesticides, reestablishment of a more diversified

ecosystem including natural control agents, and development of economically and biologically successful "integrated control" systems may take several years. In areas where such upsets have not as yet occurred, there is at present a great opportunity to develop sound crop protection from an ecologically undisturbed base. In many of the tropical and subtropical areas of the world, biotic elements of pest population regulation have been demonstrated, and they are operating successfully on a number of pests and potential pests of important crops including coconut, citrus, tea, rubber, oil palm, and cotton. Every effort should be made to use chemical pesticides prudently so as to augment, rather than disrupt or destroy natural and other non-chemical pest population regulation factors.

To implement these concepts at the grower level is not an easy task and will require a major educational effort. One problem in some situations may be that at present, representatives of pesticide manufacturers and pesticide sales agencies are a major, sometimes the dominant source of expertise and advice on pest control. Not all chemical companies have as yet decided to sell crop protection rather than chemicals, although many constructive moves are being made in this direction by an increasing number of commercial interests.

Another obstacle may exist where so-called "wash-day"-type pesticide application patterns or fixed spray schedules are popular. In these schemes, one or more pesticides are routinely applied at pre-set times, regardless of need. On the surface, these predetermined application schedules are attractive because of their seeming simplicity. However, experience has shown that such schemes will work only in the very short run, and that they are unsound and impractical in the long run, both economically and ecologically.

Chemical pesticides in an ecologically sound integrated crop protection or pest management system should be used only if and when needed, and only in the amount necessary to provide economic control of the pest. If this is done, selectio of resistant populations will be avoided or delayed, the possibility of resurgence of treated populations is decreased, adverse affects on non-target organisms and environmental contamination are minimized, and the cost of control is kept low.

To accomplish this, answers to the following questions must be available:

1. What crop, animal or material is being attacked?
2. What pest is causing the problem? What is its life cycle?
3. At what infestation level will the pest damage crop

yield or quality (economic damage threshold)?

4. Are there natural control factors (such as predators or parasites) and if so, will they control the pest sufficiently to prevent economic damage?

5. If natural control will not suffice, what options are available to control the pest?

6. If a pesticide is the tool of choice, how will it affect predators, parasites, pollinating insects, or other beneficial ecological factors? Will it result in the build-up of other pests which are not now a problem?

7. Will the benefits from the use of the chemical pesticide be worth the cost? Economically? Ecologically?

8. If so, what pesticide is most suitable and offers the most favorable benefit:risk ratio?

9. What is the lowest rate of application required to do the job?

10. And, afterwards: What was right, and what was wrong about the course of action taken?

Obviously, it will often be difficult to find the right answers to all of these questions. However, development of the expertise required to do so at the regional as well as at the local level is an urgent requirement in many

countries at all levels of development.

Of all methods of crop protection and pest control which have been tried in different parts of the world ov the centuries and in the very recent past, the pest management approach today represents the best strategy for achieving two different, seemingly incompatible sets of objectives, i.e., (1) production of foods, feeds, fibers and forest products in increasing quality and quantity, and high standards of living, public health and human comfort; and (2) preservation and improvement of the quality of the local, regional and global environment.

Pesticides will be an important tool in accomplishing all of these objectives if they are used judiciously, which means that the following must be avoided:

- Misuse
- Overuse
- Unnecessary use
- Accidents.

MONITORING PESTICIDE RESIDUES IN FOOD AND IN THE ENVIRONMENT.

The proper handling and management of pesticides is not completed when the application has been made, the equipment cleaned and the emptied containers disposed of. It must include consideration of the fate and effects of the pesticide residues on the target crop, on all other elements of the environment, and on man himself. These effects reach much beyond the bounds of the farms or other locations where pesticides are used and are therefore properly the concern of government or other public agencies.

Pesticide Residues in Food.

In the United States, pesticide residues in raw agricultural commodities and in food and feed have been regulated and monitored for many years. Permissible residue tolerances have been set, or exemptions from the requirement of a tolerance have been allowed for all registered pesticides. Government agencies, food processors and others regularly monitor pesticide residue levels in crops, produce, livestock, animal products, animal feeds, finished foods and, to some extent, wildlife and fish. The U. S. Food and Drug Administration monitors pesticide residues in ready-to-eat

foods in about 30 different cities in its "total diet study" program. The pesticide residue levels in the general diet of people in the United States are thus being monitored continuously, and the findings are published from time to time. From the beginning of this program in the early 1960's to the present, there have been no reports or indication of unsafe pesticide residues in the U. S. food supply.

At the international level, several committees have concerned themselves with pesticide residues in food, including residue analysis methods, toxicological significance of residues, and the levels of pesticide residues in the diet which should be permitted.

The Expert Committee on Pesticide Residues of the World Health Organization (WHO) and the Panel of Experts on the Use of Pesticides in Agriculture of the Food and Agriculture Organization (FAO) of the United Nations have held annual separate and joint meetings for the last decade or more. So-called "allowable daily intake" (ADI) levels have been established for a number of different pesticides, based on extensive consideration of the acute and chronic toxicity of the products concerned, their use patterns, and other factors. "Practical residue limits" for different pesticides on a number of commodities were also established in these joint meetings.

The Commission on Pesticide Residue Analysis of the International Union of Pure and Applied Chemistry (IUPAC) is studying the complex problems associated with pesticide residue analysis.

These committees have generated much valuable background information and many principles and guidelines, and their efforts continue. However, not much information is available to date on the actual level of pesticide residues in raw agricultural commodities and in the food and feed supplies of countries outside of the United States because not many countries are collecting such data systematically, and those who do cover only a few of the pesticides currently in use.

The increasing world-wide attention to pesticide problems has recently brought about greater concern about pesticide residues, especially in countries exporting agricultural commodities. Consequently, more and more developing countries are becoming interested in training personnel, and in setting up laboratory and other facilities necessary to the establishment of pesticide residue regulation and monitoring systems.

The United States and other countries currently explore different avenues of providing assistance in this regard, including the training of analysts and furnishing analytical

equipment and supplies. The United States is probably in the best position to provide guidance in this field because it currently has the most extensive system of pesticide residue analysis and surveillance in foods and feeds, and the greatest background of experience. Besides, the United States exports many of the pesticide chemicals used overseas, and it imports many agricultural products including live animals, meat, foods, vegetables, fruits and many other commodities from other countries. The U. S., therefore, has a natural self-interest in the development of pesticide residue analysis and surveillance programs in these countries.

Many practical problems associated with the establishment of pesticide residue regulation and surveillance systems in countries without prior experience in this field are not fully resolved at present. For instance, many of the residue analysis methods developed and used in the United States require highly complex and sensitive equipment, accessories and supplies and do not work well under conditions of high temperature and high humidity. Pesticide residue analysis methods and equipment which will operate satisfactorily under tropical and subtropical working conditions will therefore be needed. This is just one example; many similar practical problems remain to be resolved.

Efforts are currently being initiated to identify these

needs in terms of training and education, facilities, equipment, library resources, and organizational and administrative support. Cooperation is being established between U. S. government agencies and scientists concerned about pesticide residues, and their counterparts in developing countries. It is anticipated that through these efforts, coupled with the continued public concern about pesticides, programs to monitor and regulate pesticide residues in food will evolve in an increasing number of countries.

Pesticide Residues in Man.

As pointed out above in the discussion on the toxic action of chlorinated hydrocarbon pesticides, residues of DDT, its metabolites and dieldrin have been found in the body fat of the population of all countries where this problem has been studied to date. It was first believed that the primary source of these deposits was dietary intake of the pesticides as food residues, particularly in meat and eggs. However, recent studies have revealed striking differences in the human body burden of DDT between different segments of the population in the U. S. These differences could not be accounted for by differences in dietary intake of DDT. These findings have led to the conclusion that for

people living in warmer climates, as much as 50% of the total DDT body burden may come from non-dietary sources. Household dust appears to be one important contributant. This is consistent with the fact that flies, mosquitoes, roaches and other household pests are more prevalent in warmer regions, and that more pesticides are used in and around homes for their control. However, this may not be the only non-dietary source of this ubiquitous contamination.

These observations emphasize the need to include humans in future pesticide residue monitoring studies, especially in tropical and subtropical regions where pesticide residues in food would represent only a fraction of the total pesticide burden to which the population may be exposed.

Pesticide Residues in the Environment.

Concern about the fate and effects of pesticides and their residues and degradation products in the environment is of relatively recent origin. It is presently greater in the United States than in other countries. This is not surprising in view of the fact that larger quantities of chemical pesticides have been produced and dispensed into the environment in the United States than in any other country in the world.

In recent years, several U. S. Federal and State agencies have initiated programs to monitor pesticide residues in soil, water, air, wildlife, and other environmental samples. These efforts may eventually permit an assessment of the total pesticide burden on the environment, although no systematic, nationwide collection and evaluation of environmental pesticide residue data from all sources has been made to date.

Other countries have noted with concern reports from the United States on actual or potential environmental damage from chemical pesticides. While our knowledge on the extent and level of pesticide residues in the environment in the United States is far from complete, much less information is available from other parts of the world.

Our knowledge about the pathways of degradation and "disappearance" of pesticides in the environment and about the short term or long term effects of these chemicals on aquatic or terrestrial ecosystems is likewise incomplete. The analytical problems associated with the determination of pesticide residues in food and feed discussed in the previous section apply to an even greater extent to the determination of pesticide residues in environmental samples. Considerable knowledge is available on the metabolism and rate of decline and excretion of pesticide residues in laboratory animals,

plants, and livestock. By contrast, much less is known at present about the fate of pesticides in the environment, including the rates and pathways of their degradation. As long as the degradation products of pesticides in the environment have not been identified, it is, of course, not possible to analyze for them. Data on pesticide residues in environmental media do not indicate the presence or absence of metabolites or degradation products for which the analytical method employed is not sensitive. Furthermore, chemical analysis results, no matter how many degradation products they may or may not include, still leave unanswered the question of the ecological significance of the residues found.

This suggests that increased attention should be placed in the future on more comprehensive methods for monitoring pesticide residues and their effects in the environment. Efforts should not be limited to chemical methods alone, but should include biological methods both on a field and on a laboratory scale. Chemical analysis of environmental samples might very profitably be complemented by laboratory bioassays on suitable isolated organisms or families of organisms. Field observations on the effects of pesticides on individual plant or animal species or on entire ecosystems or subsystems should support and complement the chemical and biological laboratory studies. Such observations should cover sufficient

periods of time and numbers of species so as to insure detection of change, not merely normal periodic fluctuations of populations.

Such a holistic approach may be especially worthwhile in situations where the use of chemical pesticides has not as yet profoundly disturbed the ecosystem. Thus, biological and chemical baseline parameters could be established, and the ecological impact of the use of pesticides and the extent and duration of these effects could be studied and ever better defined, described and understood. This approach will likely be a more useful and effective way of obtaining information on the fate and effects of pesticides and their metabolites and degradation products in the environment than chemical analyses alone.

The number of bioassays or field survey procedures specifically developed for this purpose are limited. However, many potentially useful biological methods, field scale as well as laboratory scale, are available and could easily be adapted. It is suggested that this area should receive priority attention in the training of pest management and pesticide protection personnel in the future.

It is obvious from this discussion as well as from the previous section that the judicious use of pesticides will depend a great deal on the skills and expertise of scientists

well trained in all of the scientific, especially the biological disciplines involved in crop production and pest management. The education and training of such "all round" scientists is an urgent requirement.

IMPORTANT PEST PROBLEMS AND PESTICIDES IN TROPICAL AND SUBTROPICAL COUNTRIES

Land Use, Crops and Livestock.

The Food and Agriculture Organization (FAO) of the United Nations has divided the world into seven regions for purposes of statistical studies on agriculture. Almost all tropical and subtropical countries of the world are in four of these regions, namely Latin America, Near East, Far East, and Africa. The following discussion on the important pest problems in tropical and subtropical countries will therefore be presented geographically in terms of these four world regions.

In comparing agricultural statistics for these four "regions" to comparable statistics for continents, the regional totals for Africa are usually smaller than those for the African continent. This is due to the fact that Libya, Sudan and the United Arab Republic are included in the Near East region, not in the African region. The Far East region does not include the Peoples' Republic of China (Mainland China).

Weights and measures in the following discussion are given primarily in metric units. One hectare (ha), the

main agricultural area measurement unit in the metric system, is equivalent to 2.47 U. S. acres. One kilogram (kg) in the metric system is equivalent to 2.2 U. S. pounds. One metric ton is equivalent to 1,000 kilograms or 1.1 short tons. One short ton is equivalent to 2,000 lbs., or 0.91 metric tons. For further details on conversion factors for weights, measures and rates of application, refer to the conversion tables, page 145 - 159.

Table 2 summarizes total land use in the four regions and includes a comparison with world totals. The four regions contain 51.5% of the world's total land area, 47% of the world's cultivated agricultural area, 54% of permanent grasslands, 52.5% of forest lands. The agricultural area under cultivation is about 9.7% of the total land area in the four regions.

Table 3 lists the major agricultural crops grown in these regions. These figures are given in millions of hectares for most crops; in millions or thousands of metric tons of production for vegetables, citrus fruits, coffee, cocoa, and natural rubber. For comparison, world totals for these crops are also included in table 3.

For several of the major crop groups, i.e. cereals, pulses, oilseeds, citrus fruits, and stimulant crops, figures for one or more major individual crop(s) in the group are also

Table 2: Land Use in Tropical and Subtropical Regions of the World (in Millions of Hectares)

Region	Total Area	Agricultural Area		Forest Land	Other Areas
		Under Cultivation	Permanent Grasslands		
Latin America	2,057	123	502	1,003	429
Near East	1,207	77	187	138	805
Far East	1,117	274	110	448	285
Africa	2,503	192	817	555	939
Four Regions	6,884	666	1,616	2,144	2,458
World	13,392	1,424	3,001	4,091	4,876
Regions/World	51.5%	47%	54%	52.5%	50.5%

Table 3: Major Tropical and Subtropical Crops.

Crop	Region				World	Unit
	Latin America	Near East	Far East	Africa		
Cereals:						
All	48.8	33.9	174.6	58.1	703.8	1,000,000
Wheat	7.6	20.1	24.1	7.9	210.3	hectares
Barley	1.4	6.5	4.4	5.0	78.1	unless
Rice	6.4	1.2	89.8	3.4	135.5	otherwise
Corn	28.2	2.0	14.6	15.5	110.8	noted
Millet & sorghum	3.8	2.9	41.4	25.9	112.3	
Pulses:						
All	7.8	1.4	25.7	7.9	63.1	
Dry beans	6.9	0.2	8.5	1.4	23.2	
Oilseeds:						
All	10.4	4.1	30.3	9.9	119.2	
Peanuts (groundnuts)	1.1	0.4	9.6	5.4	19.1	
Cotton	4.6	2.6	10.0	3.5	33.2	
Sugar Cane	5.4	0.1	4.3	0.6	11.3	
Vegetables	10.9	20.3	56.9	6.7	242.7	) 1,000,000
Citrus fruit:						) metric
All	7.7	3.4	5.2	2.4	37.1	) tons
Oranges & tangerines	6.8	2.6	4.5	2.2	30.3	)
Bananas	0.9	negl.	0.6	0.1	1.7	1,000,000 hectares
Stimulants:						
Coffee	2,324	negl.	294	1,318	3,971	) 1,000
Cocoa	358	--	negl.	955	1.353	) metric tons
Tea	0.04	0.05	0.87	0.12	1.3	) 1,000,000
Tobacco	0.5	0.3	1.1	0.3	4.0	) hectares
Rubber trees	30	--	2,691	190	2,917	1,000 metric tons

given. In addition to the crops shown individually in table 3, the cereals group includes rye, oats, and several minor cereals. The pulses group includes dry peas, lentils, vetch, lupins and several other, minor pulses. The oilseeds group includes soybeans, linseed, rapeseed, sesame seed, sunflower seed, castor beans, etc. The vegetable group includes onions, tomatoes, cabbages, cauliflower, green beans, green peas, cucumbers, cantaloups and other melons, and a variety of minor vegetables. The citrus fruits include grapefruits, lemons, limes and others.

Table 4 summarizes the livestock population in the four tropical and subtropical regions, in millions of animals. Again, world totals are included for comparison.

The four regions contain almost all of the world's camels, a high proportion of all mules and buffaloes, more than 50% of the world's horses, asses, cattle and goats, and less than half of the world's pigs and sheep.

Table 4: Livestock in Tropical and Subtropical Regions of the World (in Millions of Animals)

Livestock	Region				World
	Latin America	Near East	Far East	Africa	
Horses	24.3	2.2	5.3	3.6	67.2
Mules	9.3	0.6	0.2	2.1	15.0
Asses	9.1	8.7	1.9	8.8	42.7
Cattle	241.9	42.3	261.7	135.6	1,118.2
Pigs	99.3	0.1	47.9	6.5	626.6
Sheep	130.1	145.8	77.0	131.7	1,072.6
Goats	41.6	54.8	103.2	106.9	384.4
Buffaloes	0.1	3.4	90.9	--	124.5
Camels	--	4.8	2.7	5.6	13.4
Poultry	n.a.	n.a.	n.a.	n.a.	n.a.

Insects and Diseases, and Pesticides Used for Their Control.

In this section, the most important insect pests and diseases of tropical and subtropical crops are discussed by major crops, and under each crop in order of economic importance. If on a given crop one or more insect pests are economically most important, then these are discussed before diseases, and vice versa.

Weed problems and their control are discussed in a separate section.

Very little, if any reliable, quantitative data are currently available on the crop losses caused by pests in the tropical and subtropical regions of the world. Recognizing the need for this type of information, the FAO developed a Manual on "Crop Loss Assessment Methods" (Ref. 12) which is intended to provide plant protection workers with sound methods and guidelines for the measurement of crop losses through field experiments. It is hoped that this FAO publication will facilitate and stimulate the development of such data in the future.

Small grains (wheat, barley, oats, rye).

Small grains are the predominant cereals of the temperate zones of the world, but sizeable acreages of wheat are also

grown in the Near East and Far East (India), and some in Latin America and Africa.

Diseases affecting small grains include three important rusts. These are black stem rust (Puccinia graminis Pers.), yellow rust (P. striiformis Westend.), and brown rust (P. recondita Desm.). Chemical fungicides are rarely if ever used against these diseases because the cost of treatment is too high in relation to the value of the potential yield increase. Use of resistant varieties and campaigns to destroy the intermediate hosts of the rust fungi are the most common control practices.

Small grains are also affected by head smuts caused by a group of closely related fungi including several species of Tilletia causing bunt, and several species of Ustilago causing covered and loose smuts of wheat, oats, and barley. Bunts, covered smuts and loose smut of oats can be controlled by treating the seeds with an appropriate seed disinfectant. Loose smuts of wheat and barley are not susceptible to seed disinfectant treatments because the mycelium of the causative fungus is on the inside of the seed. Neither bunts nor smuts are controllable by foliar fungicidal treatments.

The most important insect pest of small grains is the wireworm, Agriotes spp. It occurs primarily in the temperate zones and is seldom, if ever, found in the subtropical wheat

growing areas. In the Near and Middle East, Eurygaster integriceps Put., also known as the "Sunni pest", a hemipterous species, may be very damaging to wheat by feeding on young leaves and grains in the milky stage. Formerly, hand picking of the rather large adult bugs (about 15 mm long) was the only form of control in severe infestations. Recently, organic phosphate and chlorinated hydrocarbon insecticide dusts and sprays have been used successfully.

Rice.

The most important insects affecting rice are the Pyralid stem borers, including the rice borer or yellow stem borer, Schoenobius incertellus Wlk., and the striped stem borer, Chilotraea suppressalis Wlk. These lepidopterous insects usually have two generations per year. Female moths lay eggs in several clusters from which larvae hatch which bore into the main stem of the rice plant. This damage causes the central shoot to turn yellow and die.

Chemical control measures against rice stem borers have been developed primarily in Japan. Parathion was widely used at first, but more recently, it has been completely replaced by less toxic organic phosphate insecticides. The use of chemical insecticides against rice stem borers is not nearly as widespread in other rice growing countries as it is

in Japan.

Several jassids including the green leafhopper, Nephotettix spp., and the rice leaf bug, N. bipunctatus Fab., occur in India, Pakistan, Burma, Southeast Asia and the Philippines. The nymphs and adults of these leafhoppers suck the cell sap, thus causing direct damage to the plant, but they are probably even more important as vectors of a rice virus disease causing dwarfing. The use of rice varieties resistant against these insects is promising. Where such varieties are not available or in case of serious outbreaks, chlorinated hydrocarbon insecticides have been used.

Fungus diseases are generally less damaging to rice than insects. A ubiquitous fungus disease found wherever rice is grown is brown spot, Cochliobolus miyabeanus, syn. Helminthosporium oryzae. This fungus attacks the germinating seed, young seedlings and mature grain. Treatment of the seed with an effective seed disinfectant is the best method of control.

Rice blast, also known as rotten neck, caused by Pyricularia oryzae Cav., occurs in most areas of the world where rice is grown. It is particularly important in Japan. This fungus occurs on rice foliage and later damages the stem, particularly the neck just below the head. This results in diseased, bleached-looking panicles and bending

over of the stem at the point of infection. Foliage fungicides have been used successfully for the control of rice blast in Japan. Rice varieties resistant to the disease have been developed in India and Japan.

Corn.

Next to wheat and rice, corn (known as "maize" in most countries outside of the United States) is the third most important cereal crop in the world. Corn is used extensively in the human diet in Latin America and Africa. Large quantities are also used for animal feed all over the world. Approximately 75% of the world's corn is produced in the United States.

In the subtropical and tropical regions of the world, corn is grown predominantly as a subsistence rather than a cash crop and, fortunately, it is generally a very healthy plant under these growing conditions. Its yields are not affected by any major insects or diseases. Chemical insecticides or fungicides are not used to any significant extent on corn in Latin America, Africa or the Near or Far East.

Millet and sorghum.

Millet includes five main varieties which are of dietary importance in Asia and Africa. These are cattail millet, *Pennisetum glaucum*, also known as pearl millet or as

"bajra" in India; finger millet, Eleusine coracana, known as "ragi" in India; bread millet, Panicum millaceum, also called "proso"; foxtail millet or Italian millet, Setaria italica; and barnyard millet, Echinochloa crusgalli, also known as Japanese millet. Sorghum, Sorghum vulgare, includes many varieties such as kafir or kafircorn, milo, feterita, durra, and sorgo.

Statistics are often given together for millets and sorghums because many countries do not make distinction between these two types of grains. This practice is followed in this section.

Millets and sorghums have remarkable powers of drought resistance and are the outstanding cereals in the dryer parts of the tropical and subtropical regions of the world. They are widely grown as subsistence crops and mainly eaten in porridge form because the grain does not lend itself to making good bread.

Some plant diseases affect millets and sorghums. Of these, covered smut, Sphacelotheca sorghi Link, is the most important, especially in Africa. Fungicidal seed disinfectants are effective against the spores of this fungus which are seed-borne. However, seed treatment of millets and sorghums is not widely practicded at this time.

Insects found on millets and sorghums are in most cases

the same as those found on corn. As in the case of corn, insects do not appear to be a limiting factor to the production of sorghums and millets in Latin America, Africa or the Near or Far East under present growing conditions, and there is no significant use of chemical insecticides on these crops.

Pulses.

The group of crops referred to as "pulses" includes dry beans (*Phaseolus vulgaris*, *P. lunatus*, *P. aureus*, *P. radiatus*, *P. mungo*, and *P. angularis*); dry peas (*Pisum sativum* and *P. arvense*); lentils (*Lens esculenta*); dry broad beans (*Vicia faba*); vetch (*V. sativa*); lupins (*Lupinus* spp.); and several additional leguminous plants. These crops are important sources of protein. They are primarily grown as subsistence crops in Latin America, Africa, and in the Near and Far East. They are relatively free of major diseases and insect pests which would affect yields, and there is no major use of chemical pesticides on these crops.

Oilseeds.

Oilseed crops include soybeans, peanuts (known as "groundnuts" in most countries outside of the United States), linseed, rapeseed, sesame seed, sunflower seed, and castor beans. Cottonseed is also included in production figures on oilseeds, but agronomically, cotton is a different crop

and is treated separately in this manual.

World-wide, the soybean is the most important oilseed crop, being grown on 35 million hectares. Of this soybean area, 17 million hectares are grown in North America, and almost 14 million hectares in the Peoples' Republic of China. The soybean acreage in Latin America, Africa and the Near and Far East (except Mainland China) is very small. In these four regions, peanuts or groundnuts are the most important oilseed crop.

Peanuts as well as the other oilseed crops mentioned above are relatively free of major insects and diseases in the tropical and subtropical countries of the world, and there is no significant use of chemical pesticides on these crops at the present time.

Cotton.

Of the world's 33 million hectares of cotton, about two-thirds are grown in the tropical/subtropical regions. Cotton is the world's most important fiber crop, and it is an important cash and export commodity for many tropical and subtropical countries. For some of these, it is the dominant crop and the country's greatest source of revenue.

Cotton requires a warm climate and a minimum of about 200 frost-free days.

Cotton is afflicted by a large number of insect pests.

Each major cotton growing region has its own pest spectrum. It is therefore not surprising that cotton has created a greater demand for chemical insecticides than any other single crop.

In the Near and Middle East, important lepidopterous insects on cotton include the spiny bollworm, Earias insulana Boisd.; the Egyptian leafworm, Prodenia litura F.; and the pink bollworm, Pectinophora (Platyhedra) gossypiella Saund. In addition, at least two Hemiptera occur in this area, especially in the Sudan, namely the cotton jassid, Empoasca lybica de Berg.; and the cotton whitefly, Bemisia tabaci Genn.

In India, the spiny bollworm and the cotton jassid damage cotton, along with another lepidopterous insect, the cotton bollworm, Heliothis zea Boddie, also called the "American bollworm" outside the Western Hemisphere.

In Central and East Africa, two hemipterous species are predominant on cotton, i.e., the lygus bug, Lygus vosseleri Popp., and the cotton stainer, Dysdercus spp.

In Latin America the cotton boll weevil, Anthonomus grandis Boh.; several species of the cotton bollworm, Heliothis spp.; the pink bollworm; and the cotton leafworm, Alabama argillacea Hubn., are important cotton insects. The cotton aphid, Aphis gossypii Glover, certain species of thrips,

and spider mites are damaging to cotton in the United States, but appear to be less injurious in other cotton areas of the world.

The boll weevil, the only Coleoptera species of economic importance on cotton, is controlled primarily by organic phosphate insecticides. The lepidopterous insects affecting cotton, including the cotton bollworms, the spiny bollworm, the pink bollworm, the Egyptian leafworm and the cotton leafworm account for the largest use of chlorinated hydrocarbon insecticides on cotton. DDT, BHC, endrin and toxaphene are widely used. More recently, carbaryl and some organic phosphates have also been used successfully on these insects.

The hemipterous insects affecting cotton, including the cotton jassid, the cotton whitefly and the cotton stainer are susceptible to a number of organic phosphate and chlorinated hydrocarbon insecticides.

No single chemical insecticide controls all of the economically important insects occurring on cotton in any one region of the world. Consequently, chemical control of these insects requires the use of two or more different insecticides. Unfortunately, insecticides used for the control of one insect often result in subsequent outbreaks of other insects because the insecticide first used destroyed not only the target insect, but also natural enemies of other cotton

pests which then in turn quickly build up to damaging proportions. These intricate and complex interrelationships were often not recognized and understood in the early enthusiasm about the benefits of chemical insecticides. In some areas, the destruction of natural control factors through the injudicious use of chemicals, combined with increasing development of resistance in target insect species, has resulted in complete failure of chemical cotton insect control programs.

Much effort is presently being devoted to the development of integrated control programs for cotton insects, combining all control tools, including resistant varieties; cultural practices; prudent selection of planting and harvesting dates; early destruction of crop residues; chemical defoliation; use of traps baited with live boll weevils or synthetic attractants; natural predators and parasites; biological insecticides such as Bacillus thuringiensis or polyhedrosis virus; and chemical insecticides.

The economically and ecologically most successful combinations of these various tools will have to be developed on site for each major cotton growing region because, as pointed out above, each region has its own complex of economically important cotton insects.

In contrast to the insect situation, there are few

diseases of economic importance on cotton. The use of chemical fungicides on cotton is limited to the use of seed dressings for protection against seedling diseases. There is no significant use of foliar fungicides on cotton anywhere in the world.

Sugar cane.

The great majority of the world's sugar cane is grown in the four tropical/subtropical regions of the world. Sugar cane supplies about half the world's sugar requirements, the balance being derived from sugar beets. Sugar cane is grown principally in Central and South America, and in India, Pakistan, Taiwan, the Philippines and Indonesia. Very little sugar cane is grown in the Near East or in Africa.

In the Western Hemisphere, the sugar cane borer, *Diatraea saccharalis* Fab., a member of the Pyralid family, is the economically most important insect on cane. While *Diatraea* is not found outside of the Americas, another pyralid, *Scirpophaga nivella* Fab., the top borer, is important in India. Both insects have similar life cycles. The economically important stage is the larva which enters the stem, killing the central growing shoot. Affected canes mature early and produce low weight. The mechanical injury of the stalk may cause it to break in wind storms.

The use of insecticides against sugar cane borers has

not been promising. While chemical insecticides are used to some extent on cane in the United States, they are seldom used in other parts of the world on this crop.

There are no major economically important diseases on sugar cane, and no significant quantities of chemical fungicides are used.

Vegetables.

Vegetable crops include a considerable variety of different plant species such as onions, tomatoes, green beans, green peas, cole crops and cucurbits. According to the FAO (Table 3), about one-third of the world's vegetables are produced in the tropical/subtropical regions. Many of these crops mature to the desired edible stage in a very short time in the tropics and subtropics, and many of them are grown primarily for local consumption, without processing or preservation.

As a result of these factors, there is currently no widespread use of chemical insecticides or fungicides on vegetable crops in the tropical and subtropical regions. The only exception are some fertile areas in the immediate vicinity of the large cities where the transportation situation and economic incentives invite commercial vegetable growing practices. One such example is the intensive vegetable growing area serving Bangkok, Thailand, and there are several others.

Chemical insecticides have been used rather extensively in these limited areas. Several insects affecting vegetable crops, including the diamond-back moth, Plutella maculipennis Curtis, and other lepidoptera have developed a high degree of resistance against almost all currently available insecticides. High quantities of insecticides are used at frequent intervals, and there have been reports of high insecticide residues on the vegetables and fruits produced under these circumstances.

Chemical fungicides are also used to some extent on tropical and subtropical vegetables where they are grown as cash crops.

Citrus fruits.

The FAO (Table 3) reports that about 50% of the world's citrus fruits are produced in Latin America, Africa and the Near and Far East. Included in this group are oranges, tangerines, grapefruits, lemons, limes, and several minor citrus fruits. Oranges and tangerines are by far the most important, accounting for more than 80% of the world's citrus production, and 86% of the production of citrus fruits in Latin America, Africa and the Near and Far East.

Citrus is grown mainly in the subtropical regions in a broad belt 35 degrees on either side of the equator. The

world's principal commercial citrus production areas are the Mediterranean region and the United States. In other parts of the world, citrus fruits are also grown extensively, but the production is not commercialized to the same extent, and the fruit is largely home-consumed.

Homopterous insects, especially scales, mealybugs and whiteflies are among the most important insect pests of citrus. These include the red scale, Aonidiella aurantii Mask. (South Africa, Near East); the yellow scale, A. citrina Coq. (Central America); the black scale, Chrysomphalus aonidium L. (Near East); the purple scale, Lepidosaphes beckii Newn. (Latin America, Near East);and the soft brown scale, Coccus hesperidum L. (Near and Middle East, South Africa).

Special grade petroleum oils have been used for many years against citrus scales. Chlorinated hydrocarbon insecticides are almost completely ineffective against these insects. Parathion was the first synthetic insecticide found to be effective. More recently, it has been replaced to a large extent by less toxic organic phosphate insecticides such as malathion and others.

Several species of mealybugs occur on citrus, including Pseudococcus gahani Green and P. citri Risso. At least two species of the family Aleyrodidae are also important on citrus, including the citrus blackfly, Aleurocanthus woglumi Ashby, which is an important pest in India and the Far East,

and the citrus whitefly, Dialeurodes citri R. & H., which occurs primarily in North America and is of lesser importance in the Near East.

Citrus mealybugs and whiteflies are quite susceptible to the insecticides used against scales and therefore, usually do not require separate control measures.

Several species of aphids, thrips and spider mites also occur on citrus, but they do not appear to be as important in Latin America, Africa and the Near and Far East as they are in the United States' citrus growing regions.

The citrus rust mite, Phyllocoptruta oleivora Ashm., is an important citrus pest in the Near East. This mite is very minute and invisible to the naked eye. There can be as many as thirty generations in a single year. The mites puncture the cells of the leaves and fruit, causing them to dry out which results in a blemish on the fruit known as russeting.

Organic phosphate insecticides are ineffective against the citrus rust mite, but it is readily controlled by sulfur sprays or dusts. The fungicide zineb has also been used successfully.

There are two important dipterous species affecting citrus, i.e., the Mediterranean fruit fly, Ceratitis capitata Wied., and the Mexican fruit fly, Anastrepha ludens Loew. The Mediterranean fruit fly is an insect of great importance,

affecting many deciduous and other tropical and subtropical fruits. It occurs principally in the countries around the Mediterranean Sea, but is also found in Africa, Australia and the West Coast of South America. It is absent from India, the Far East and the United States. The Mexican fruit fly occurs in Central and South America and has a much more limited range of hosts than the Mediterranean fruit fly. Among the citrus fruits, oranges are much more susceptible to these two fruit flies than the other species.

Fruit flies have a tremendous reproductive potential. The female is equipped with an ovipositor with which it deposits eggs under the surface of fruits. Larvae hatch in a few days which bore into and devour the flesh of the fruit. Many generations can occur in a single season.

The most effective method of controlling fruit flies is by poisoned baits. Baits consisting of malathion, protein hydrolysate and water have been highly successful.

There are several diseases affecting citrus fruits, including brown rot gummosis, or fruit rot, caused by several species of Phytophthora; melanose, Diaporthe citri Fawc.; citrus canker, Xanthomonas citri; and fruit storage rots caused by several species of Penicillium. A virus disease, known as citrus "tristeza" or "quick decline" has been described as injurious to citrus primarily in South America.

Chemical fungicides are not used to any significant extent in Latin America, Africa, the Near or Far East on any of these citrus diseases.

Bananas.

The banana is a tropical plant which can be grown successfully only in areas which are frost-free. According to the FAO (Table 3), the total world banana growing area is about 1.7 million hectares. Of these, 900,000 hectares are grown in Latin America, 600,000 in the Far East. There are no significant banana plantings in the Near East, and only a small acreage in Africa.

Two diseases are of great economic importance on bananas, i.e., the Panama disease, or banana wilt, caused by *Fusarium oxysporum* Schl. *f. cubense*, and the leaf spot or Sigatoka disease, caused by *Mycosphaerella musicola* Leach.

The fungus causing Panama disease or banana wilt is soil-borne, enters the plant through the roots and from there invades the rhizome. It spreads rapidly throughout the plant and induces it to wilt, primarily by the production of toxic substances. The infection will eventually kill all the aerial parts of the plant. Chemical fungicides are largely ineffective. The use of disease-free suckers for planting stock is an important control measure. The development of resistant banana varieties is difficult for two reasons.

Firstly, banana is a seedless fruit which poses considerable obstacles to the plant breeder. Secondly, it has thus far not been possible to develop a resistant commercial variety with the same high qualities as "Gros Michel", by far the most popular commercial banana variety.

The leaf spot or Sigatoka disease is caused by a fungus specific to banana foliage. The fungus initially causes light yellowish spots on leaves which enlarge into oval spots whose centers eventually die. Spots then coalesce, destroying ever larger leaf areas with the result that the fruit bunches cannot grow and ripen normally.

In contrast to banana wilt, the Sigatoka disease can be controlled by chemical fungicides. Copper fungicides with or without refined mineral oils are used with good results. The low volume spraying technique has been introduced successfully, and volumes required per acre have been reduced from 100 to 150 gallons down to 8 to 10 gallons.

Compared to these two fungus diseases, insects are of relatively minor economic importance on bananas in general. One insect worth mentioning is the banana borer, Cosmopolites sordidus Germ., a weevil of the order Coleoptera. The adult bores into the base of the banana stem and deposits eggs from which larvae hatch that tunnel further into the stem. Large numbers of these insects can weaken the mechanical

structure of the plant, causing it to break down under stress. However, banana borers are not believed to be of major economic importance generally, and no significant amounts of chemical insecticides are used in their control.

In some areas nematodes, primarily the burrowing nematode, Radopholus similis, are reported to reach economically damaging infestation levels on bananas. Chemical nematicides are sometimes used to control these pathogens.

Coffee.

Almost 4 million metric tons of coffee are produced in the world annually at the present time. The Latin American region produces almost 60% of this total, Africa another 33%. Brazil is the world's largest coffee producing country, it alone accounts for about 40% of the world production.

Other major coffee producing countries include Costa Rica, El Salvador, Nicaragua and Guatemala. The most important African coffee producing countries are Ivory Coast, Kenya, Uganda, The Congo and Angola.

The most important disease of coffee is a leaf rust, Hemileia vastatrix Berk. and Br. Like other members of the rust family, this fungus attacks the foliage, causing eventual defoliation and loss of crop. Of the two principal species

of coffee, Coffea arabica and C. robusta, the Robusta varieties are more resistant to leaf rust. However, about 90% of the world's coffee currently is C. arabica because this species yields the finest and most desired type of coffee. Copper fungicides have been effective in the control of coffee leaf rust in Kenya and also in India but, surprisingly, spraying with coppers or other fungicides has been largely ineffective in other parts of the world. It is believed that this is due to the absence of a dry season in the countries where the fungicides were unsatisfactory. In continuously humid climates, the fungus maintains a high level of infestation the year around. Accordingly, successful use of fungicides for leaf rust control is limited to those areas where an annual dry season occurs.

It is interesting to note that Hemileia vastatrix, the coffee leaf rust fungus, does not appear to have a sexual stage, making it unlikely that as many different races will arise as with the cereal rusts.

A second economically important disease of coffee is the coffee berry disease, caused by Colletotrichum coffeanum Noack. This fungus also primarily attacks the Arabica coffee varieties and is a major problem in Kenya. Attempts at protecting the berries with copper fungicide sprays proved difficult, but in a thorough study of the life cycle of the

fungus, it was found that most of the fungus spores are produced on the freshly formed bark of young shoots. Copper fungicide sprays were then directed toward the inoculum on these shoots which proved to be highly successful.

There are no other disease problems on coffee requiring routine fungicide treatments.

Few important insect pests occur on coffee. The coffee leaf miner, Leucoptera coffeella Guer, a lepidopterous insect, is found in Latin America as well as in Africa. Larvae of this insect mine coffee leaves. Severe infestations cause such a high percentage of the leaves to drop that the coffee yield is affected by loss of assimilating leaf surface. The coffee leaf miner is attacked by many parasites and, therefore, often does not require chemical control. In Brazil and East Africa, organic phosphate insecticides have been employed.

The coffee berry borer, Stephanoderes hampei Ferr., of the order Coleoptera, is a tiny beetle which occurs in all coffee growing areas of the world. The larval stage attacks the coffee berry. Reportedly, Brazil is the only country where chemical insecticides are used against this insect. Chlorinated hydrocarbon insecticides are the materials of choice. According to reports from Kenya, BHC and lindane have caused off-flavor in the more sensitive Coffea arabica varieties. This does not seem to be a problem in Brazil;

possibly the C. robusta varieties more prevalent there are less susceptible to off-flavors.

Several other insects have been recorded on the coffee plant, but none of them account for significant uses of chemical insecticides.

Cocoa.

Current world production of cocoa is approximately 1.3 million metric tons. Almost all of this quantity comes from two regions. Africa produces about 955,000 metric tons, Latin America about 358,000 metric tons. West Africa alone grows about 60% of the world's crop. Ghana is the foremost cocoa producer.

In West Africa, a group of capsid bugs of the family Miridae, order Hemiptera, are the most important pests of cocoa. All four species in this complex have toxic saliva which they inject into plant tissues when feeding. Both nymphs and adults feed on young shoots, damaging young cocoa trees, causing defoliation, die-back of shoots and lack of pods. In Ghana and in neighboring countries, these capsid bugs have been successfully controlled with sprays or dusts of BHC. Capsid bugs are not a problem in the Latin American cocoa growing areas.

The most serious disease problem of cocoa in West Africa

in recent times has been the swollen shoot disease, caused by a complex of viruses. Symptoms of this disease include swelling of shoots, roots, foliage and pods. The disease kills trees in three to six years. No method is known of curing an infected cocoa tree, but it was discovered that the disease is transmitted by several species of mealybugs. More than a dozen mealybug species have been found capable of transmitting one or more of the swollen shoot disease viruses. Pseudococcus njalensis Laing is the most important vector in Ghana. The mealybugs cause little direct damage by their feeding, but their economic importance is based on their role in transmitting the virus disease.

The use of systemic organic phosphate insecticides has been tried to control these mealybug vectors. Some treatments gave good mealybug reduction, but did not halt the progress of the disease itself. Foliar sprays with non-systemic organic phosphates, especially parathion, were likewise largely ineffective. Another approach tried was the use of massive dosages of chlorinated hydrocarbon insecticides against ants which live in a symbiotic relationship with the mealybugs. It was hoped that the mealybugs could not survive without the ants. This insecticide use was not only ineffective against ants, mealybugs and the spread of the swollen shoot disease, but resulted in a severe outbreak of the shoot borer

Eulophonotus myrmeleon Feld. which had not previously been of major economic importance.

The most effective, although slow and difficult method to control the swollen shoot disease has been to prevent infection by the cutting out of diseased trees, along with destruction of an indigenous West African small forest tree, Cola chlamydantha, which is a carrier of swollen shoot viruses. Starting in 1941, more than 70 million trees were cut down in West Africa. The possibility of using improved varieties of cocoa immune or tolerant to the disease is also being pursued.

The swollen shoot disease is not a problem in the Latin American cocoa growing regions.

Several insects of minor importance affect cocoa in Latin America, but insecticides are not usually required for their control.

The only disease of cocoa in Latin America is known as "witches' broom", caused by Marasmius perniciosus Stahel. This fungus induces hypertrophy of the shoots, causing them to become stubby and almost leafless. Fungicides have not been effective in controlling this disease. Again, it is hoped that plant breeders may be able to solve the problem by resistant or tolerant varieties.

Tea.

Tea is grown on approximately 1.3 million hectares in the world; the largest percentage of these, 870,000 hectares, are located in the Far Eastern region.

The most important disease of tea is blister blight, *Exobasidium vexans* Massee. The fungus attacks the foliage, causing the development of blisters which increase until most of the young foliage is affected. Copper fungicides are quite effective against this disease and are widely used on all tea plantations affected by it.

There are no other major diseases of tea requiring significant fungicide treatments.

Insect pests of tea include the "tea mosquito bug", *Helopeltis theivora* Wlk., order Hemiptera. In severe attacks, the feeding of the adults suppresses the development of new growth and damages young shoots and leaves to the extent that almost no leaves remain to be picked. Sprays or dusts of chlorinated hydrocarbon insecticides including DDT, BHC and others have been used to control this insect.

Several species of mites are found on tea. The red spider mite, *Oligonychus coffeae* Nietn. is considered the most important of these. Spider mites occur on tea throughout the year, causing infested bushes to turn first red and later coppery in color. During the rainy season, the bushes recover,

but infestations recur as soon as the dry season begins again. Chemical acaricide treatments at the beginning of an attack cycle have been successful, but some of these have caused problems for tea exporters if residue tolerances for the product used had not previously been established in the receiving country.

Tobacco.

About 4 million acres of tobacco are currently grown in the world, approximately half of these in the tropical and subtropical regions.

Several different insect pests affect tobacco in different parts of the world. In India and the Far East (as well as in the United States), large lepidopterous caterpillars feeding on foliage or buds predominate. Whiteflies and aphids are important on tobacco in Africa. Most insects attacking tobacco are not specific to the tobacco plant, but are also found on other crops.

Lepidoptera important on tobacco include *Heliothis armigera* Hb. in the Far East; *Prodenia litura* Fab. in the Near and Middle East and India; tobacco hornworms, *Protoparce sexta* John. and *P. quinquemaculata* Haw.; and several other species. DDT has been the most widely used insecticide against all of these.

The whitefly affecting tobacco in Africa and the Far

East is Bemisia tabaci Genn. This insect is damaging to tobacco in its own right but more importantly, it is one of the vectors of the leaf curl virus disease of tobacco. Insecticide treatments have been somewhat effective but first of all, weeds on which Bemisia overwinters as an adult and which also harbor the leaf curl virus should be destroyed along with volunteer tobacco which may also be a virus reservoir.

The most important aphid species found on tobacco is Myzus persicae Sulz. It is important in Rhodesia where it transmits another important tobacco virus disease. It is also found on Far Eastern tobacco, but does not appear to be a virus vector there. Several organic phosphate insecticides are very effective in controlling this aphid on tobacco.

Tobacco is one of the few major tropical/subtropical crops on which nematodes are so important that they may endanger production. The rootknot nematode, Meloidogyne spp., is the most important species, occurring in all major tobacco countries. In most tropical and subtropical tobacco growing areas, use of chemical nematicides over entire fields is usually not economically feasible. Crop rotation and seedbed treatment are practiced instead.

Various fungus diseases affect tobacco and/or tobacco seedbeds. These include blue mold, Peronospora tabacina Adam,

several bacterial wilts caused by Pseudomonas species, and several virus diseases including tobacco mosaic and leaf curl. No chemical pesticides are employed in significant amounts against these diseases in Latin America, Africa or the Near or Far East.

Rubber trees.

Approximately 2.9 million metric tons of natural rubber are produced in the world; almost 2.7 million metric tons in the Far East. Malaysia is currently the foremost rubber producing country of the world.

Several different root diseases caused by fungi, and a condition known as "secondary leaf fall", caused by a complex of fungi, insects and mites, cause problems to the rubber planter. Insect pests are not a serious problem on rubber trees.

No significant amounts of chemical fungicides or insecticides are used on this crop. The use of plant growth regulators has shown promise in tests to increase the latex flow from rubber trees. This practice is now used on a commercial scale, especially in Malaysia.

Nematodes.

Nematodes, sometimes called eelworms, are roundworms which abound everywhere. Most nematode species are microscopic in size, much too small to be seen with the naked eye. Many plants and higher animals have nematode parasites. Many soil-inhabiting nematode species feed on other microorganisms or on decaying organic matter; these are called "free-living" species. Others feed only on higher plants; they are called "parasitic" species. Some of these cause damage to, and reduce yields of food and fiber crops.

Practically every crop has its complement of nematode parasites. Most plant-parasitic species live either in the roots or in the soil around the roots of host plants, or in both. These soil nematodes affect the host plant's root system and cause damage by limiting uptake and utilization of water and nutrients. Affected plants wilt more readily and may be more susceptible to frost injury. Other nematode species live in stems, leaves or buds of plants. Some nematodes are vectors for other plant pathogenic organisms, make the host plant more susceptible to fungal diseases, or provide entry routes for secondary disease organisms.

Plant diseases caused by nematodes have been found almost everywhere where nematological investigations have been conducted thus far. However, nematodes have been studied

more extensively only during the last 30 years. A number of chemical nematicides have been developed, but their use to date is largely limited to countries with an advanced agricultural technology.

Very little information is currently available on the economic significance of nematodes to the major agricultural crops in subtropical and tropical countries. The use of chemical nematicides in these regions is very limited at the present time. The relatively small quantities of nematicides which are used go primarily on tobacco, bananas and pineapples.

Weeds and the Use of Herbicides on Tropical and Subtropical Crops.

While weeds are considered "pests" of agricultural crops, along with insects, diseases and other organisms, as detailed in the introduction to this manual, they differ from insect pests and plant diseases in important ways. Weeds are not specific to one or a few crops, and they do not usually live in a host-parasite relationship with the affected crop. Many weeds can be controlled very satisfactorily by a variety of methods other than the use of chemicals.

The use of chemical herbicides for weed control has become an established practice in the United States, in

Europe, and in other countries where agriculture is highly mechanized. Chemical weed control is not employed as widely in the tropical and subtropical countries of the world at the present time.

Weeds probably cause just as great or greater losses in potential production in the warmer regions of the world than they do in the temperate zones. At the higher temperatures and light intensities of the tropics, weeds also grow more vigorously and regenerate more quickly, competing with the crop for air, light, water and nutrients.

According to a recent publication, the worst weeds of the warm regions of the world are as follows:

Purple nutsedge, *Cyperus rotundus* L.

Bermudagrass, *Cynodon dactylon* L.

Barnyardgrass, *Echinochloa crusgalli* L.

Junglerice, *Echinochloa colonum* L.

Goosegrass, *Eleusine indica* L.

Johnsongrass, *Sorghum halepense* L.

Guineagrass, *Tanicum maximum* Jacq.

Waterhyacinth, *Eichhornia crassipes* Mart.

Cogongrass, *Imperata cylindrica* L.

Lantana, *Lantana camara* L.

Eight of these are grasses or sedges, five are perennial grasses.

As pointed out above, the current volume of chemical herbicides used in Latin America, Africa and the Near and Far East is much smaller than that of insecticides and fungicides. However, herbicide use will probably increase substantially in the future with increasing mechanization of agriculture, parallel to the experience in the U. S. and Europe.

The current status of chemical weed control by major crops and products in the four tropical/subtropical regions is as follows.

Rice.

The use of herbicides on rice has developed slowly because in many tropical and subtropical countries, the crop is grown with little mechanization. In addition, the traditional method of growing rice by transplanting allows time for weed control by flooding and cultivation. Broadleaf weeds in rice in some countries are controlled by 2,4-D or MCPA. The rice herbicide propanil is used in the Latin American rice growing areas, and its use is also expanding in the Far East.

Corn (maize).

As pointed out earlier, corn is to a large extent grown as a subsistence crop in the tropical/subtropical regions of the world, and no major quantities of herbicides are used. Where chemical weed control is practiced, 2,4-D, MCPA or

atrazine are the products of choice.

Sugar cane.

The growing of sugar cane has been increasingly mechanized and consequently, the use of chemical herbicides on this crop is growing. 2,4-D products were used at first, but more recently, triazine herbicides, primarily simazine and atrazine were found to selectively control grass weeds in sugar cane without damage to the crop. Substituted urea herbicides including diuron and monuron, and paraquat have also been shown to be effective for weed control in sugar cane.

Citrus fruits.

Residual soil herbicides are used in citrus groves to kill weeds at the base of the trees or in or between the rows. Even though some weed specialists question the need for killing weeds in such permanent crops, the practice appears to be on the increase and may in time also become more widely accepted in the citrus growing areas of the tropical and subtropical world regions.

Herbicides which have been used successfully in this manner include the triazines, substituted ureas, dalapon and paraquat.

Plantation crops.

As in citrus groves, the use of chemical weed killers in tropical plantation crops such as rubber, coffee, cocoa, tea, bananas and others is relatively new, but it is developing rapidly.

In Malaysian rubber plantations, sodium arsenite has been an effective and inexpensive contact herbicide, although it is highly toxic to man and animals and causes skin damage. Paraquat and triazines have been successful from the weed control standpoint, but are more expensive than sodium arsenite.

In coffee and banana plantations, chemical weed control is also on the increase. Promising herbicides include dalapon and paraquat.

Paraquat has also been tried successfully on tea, although tea bushes are often so densely planted that little weed growth occurs between them.

Livestock Insects.

As summarized in table 4 in the first part of this chapter, a sizeable portion of the world's livestock population is found in the four tropical and subtropical regions. A variety of insect pests affect these domestic animals,

including several species of flies, ticks, lice, keds, fleas, mites, mange, maggots, bots, and grubs.

Several livestock insecticides are available for the control of these pests, but these chemicals are not used to a significant extent on livestock in developing countries at the present time. It is anticipated that a demand for livestock insecticides will develop and grow in the future as animal husbandry changes from the present subsistence level into commercial systems. This is beginning to occur in some countries, and this development will probably accelerate before too long.

Pest Resistance to Pesticides.

"Resistance" of pests to pesticides is present when populations of a formerly susceptible pest species can no longer be controlled by a given pesticide at the rate which was previously effective. Such resistance is an inheritable characteristic which develops in populations that already have the factors for resistance, following Darwin's principle of the survival of the fittest. It should be expected to develop wherever pest populations are exposed for prolonged periods of time to levels of a pesticide that causes less than 100% mortality.

Over 200 species of insects and mites have been reported as being resistant to one or more pesticides in various parts of the world. These include some 130 agricultural pests and about 100 pests of medical or veterinary importance. Insect and mite strains have developed resistance to all types of chemicals employed against them. Many strains are resistant to more than one pesticide. The number of cases of confirmed resistance is steadily increasing.

There have also been reports of resistance of plant pathogenic fungi to chemical fungicides, and of resistance of weeds to chemical herbicides. However, these are relatively few in number compared to the situation with insects and mites. The latter pests have many more generations per year and therefore a much greater potential for resistance development in a given period of time.

The resistance phenomenon poses a threat for the future for three reasons:

-- Firstly, as pointed out above, the number of cases of resistance continues to increase.

-- Secondly, when a pest strain has become resistant to a particular pesticide, no way has yet been found to restore the original effectiveness of the pesticide. Even when the use of that pesticide is discontinued for many years, resistance rapidly reappears when it is reapplied.

-- Thirdly, the full effects of pest resistance have not yet been felt because world-wide, the areas involved are still limited, and in most cases, effective alternative chemical pesticides are still available. However, these are usually more expensive than the chemicals previously used.

For these reasons, every effort must be made to prolong the useful life of available pesticides and to delay resistance. Important steps in this direction are discussed above in the chapter on "Judicious Use of Pesticides.

CONVERSION TABLES FOR MEASURES, WEIGHTS AND RATES OF APPLICATION

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Leverkusen, Germany, 1968

Linear Measures

U.S./Great Britain/South Africa/Australia/New Zealand

1 inch = 2.54 cm.	1 cm.= 0.39 in.
1 foot = 12 in. = 30.48 cm.	1 m. = 3.28 ft.
1 yard = 3 ft. = 0.91 m.	1 m. = 1.09 yds.
1 stat. mile = 1760 yds.=1.609km.	1 km.= 0.621 st.mi.

Brazil

1 polegada	= 2.75 cm.	1 cm.= 0.36 polegada
1 palmo = 8 polegadas	= 0.22 m.	1 m. = 4.55 palmos
1 pe = 1½ palmos	= 0.33 m.	1 m. = 3.03 pes
1 vara	= 1.10 m.	1 m. = 0.91 vara
1 braca = 2 varas	= 2.20 m.	1 m. = 0.45 braca
1 milha = 1000 bracas	= 2.20 km.	1 km.= 0.455 milha
1 legua = 3000 bracas	= 6.60 km.	1 km.= 0.152 legua

Iran

1 farsach = 6.72 km.	1 km.= 0.149 farsach

Japan

1 shaku kane = 0.30 m.	1 m. = 3.03 shaku kane
1 ken = 6 shaku = 1.82 m.	1 m. = 0.55 ken
1 cho = 60 ken = 109.09 m.	1 km.= 9.17 cho
1 ri = 36 cho = 3.93 km.	1 km.= 0.25 ri

South and Central America

1 vara = 0.84 m.	1 m. = 1.20 varas
1 vara (Colombia) = 0.80 m.	1 m. = 1.25 varas
1 vara (Ecuador) = 0.85 m.	1 m. = 1.18 varas
1 yarda = 0.91 m.	1 m. = 1.09 yardas
1 legua = 5.572 km.	1 km.= 0.179 legua
1 legua (Colombia) = 5.0 km.	1 km.= 0.20 legua
1 legua (Uruguay) = 5.154 km.	1 km.= 0.194 legua
1 legua (Bolivia) = 5.196 km.	1 km.= 0.192 legua
1 legua (Guatemala)= 4.444 km.	1 km.= 0.225 legua

Thailand (Siam)

1 keup = 0.25 m.	1 m. = 4 keup
1 sauk = 0.50 m.	1 m. = 2 sauk
1 wah = 2.0 m.	1 m. = 0.5 wah
1 sen = 40.0 m.	1 km.= 25 sen

Square Measures

U.S./Great Britain/South Africa/Australia/New Zealand

1 square inch = 6.65 cm^2

1 cm^2 = 0.16 sq.in.

1 square foot = 144 sq.in. = 0.093 m^2

1 m^2 = 10.76 sq.ft.

1 square yard = 9 sq.ft. = 0.836 m^2

1 m^2 = 1.20 sq.yds.

1 acre = 4840 sq.yds. = 0.4047 ha.

1 ha. = 2.47 acres

1 rood (Great Britain) = 0.25 acre = 1011.71 m^2

1 ha. = 9.88 roods

1 square mile = 640 acres = 259 ha.

1 ha. = 0.0039 sq. miles

1 morgen (South Africa) = 2.166 acres = 0.8565 ha.

1 ha. = 1.17 morgen

Brazil

1 alqueire paulista = 100 x 50 bracas = 2.42 ha.

1 ha. = 0.41 alq. paul.

1 alqueire mineiro = 100 x 100 bracas = 4.84 ha.

1 ha. = 0.21 alq. min. (quadra)

1 braca quadrada = 4.84 m^2

1 m^2 = 0.21 brac. qu.

1 tarefa baiana = 30 x 30 bracas = 0.4356 ha.

1 ha. = 2.30 tarefas baianas

1 quadra quadrada = 132 x 132 m. = 1.742 ha.

1 ha. = 0.57 quadra quad.

1 quadra de Sesmaria = 60 bracas x 1 legua = 87.12 ha.

1 ha. = 0.011 quadra de Sesm.

India/Ceylon

1 cent = 40 m^2 100 m^2 = 2.5 cent

Indonesia

1 bahu = 0.7096 ha. 1 ha. = 1.41 bahu

Iran

1 qu-ser = 1.10 m^2 1 m^2 = 0.91 qu-ser

1 jerib = 1000-1066 qu-ser = 1082-1153 m^2

1 tanab = 4400-4500 m^2

Iraq/Lebanon

1 donum = 0.25 ha. 1 ha. = 4 donum

Japan

1 tsubo = 3.3 m^2	1 m^2 = 0.30 tsubo
1 se = 30 tsubo = 99 m^2	100 m^2 = 1.01 se
1 tan = 10 se = 992 m^2	1 ha.= 10.10 se
1 cho = 10 tan = 0.99 ha.	1 ha.= 1.01 cho

South and Central America

1 cuerda (Venezuela) = 7.14 m^2

1 m^2 = 0.14 cuerda

1 cuerda (Guatemala) = 437.0 m^2

100 m^2 = 0.23 cuerda

1 fanegada (plaza) = 0.64 ha.

1 ha. = 1.56 fanegadas

South and Central America, continued

1 fanegada (Venezuela) = 0.6987 ha.

1 ha. = 1.43 fanegadas

1 fanegada espanola (Peru) = 2.8978 ha.

1 ha. = 0.35 fanegada espanola

1 manzana = 0.699 ha.

1 ha. = 1.43 manzanas

1 caballeria (Costa Rica) = 40.07 ha.

1 ha. = 0.025 caballeria

1 caballeria (El Salvador, Honduras, Guatemala)

= 64 manzanas = 44.736 ha.

1 ha. = 0.022 caballeria

1 cuadra (Chile) = 125.4 m^2

100 m^2 = 0.80 cuadra

1 cuadra (Peru) = 0.7244 ha.

1 ha. = 1.38 cuadras

1 cuadra (Uruguay) = 0.7378 ha.

1 ha. = 1.36 cuadras

1 topo (Peru) = 0.3494 ha.

1 ha. = 2.86 topos

1 tarea (Dom.Rep.) = 0.0625 ha.

1 ha. = 16 tareas

Thailand

1 dalang wah = 4 m^2

1 m^2 = 0.25 dalang wah

1 ngan = 400 m^2

1 ha. = 25 ngan

1 rai = 1600 m^2

1 ha = 6.25 rai

Turkey

1 dekar = 1000 m^2

1 ha. = 10 dekar

United Arab Republic

1 feddan = 0.4201 ha

1 ha. = 2.38 feddan

Cubic Measures and Capacities

U.S.

1 cubic inch = 16.39 cm^3 1 cm^3 = 0.061 cub. in

1 cubic foot = 1728 cub. in. = 28.32 dm^3

1 dm^3 = 0.035 cub. ft.

1 cubic yard = 27 cub. ft. = 0.7645 m^3

1 m^3 = 1.31 cub. yds.

1 register ton = 100 cub. ft. = 2.832 m^3

1 m^3 = 0.35 reg. ton

1 fluid ounce = 29.57 cm^3 1 litre = 33.82 fl. ozs.

1 pint (liquid) = 16 fl. ozs. = 0.473 litre

1 litre = 2.11 pints

1 quart = 2 pints = 0.946 litre 1 litre = 1.06 quarts

1 gallon = 4 quarts = 3.785 litres

1 litre = 0.26 gal.

Great Britain/South Africa/Australia/New Zealand

1 cubic inch = 16.39 cm^3 1 cm^3 = 0.061 cub. in.

1 cubic foot = 1728 cub. in. = 28.32 dm^3

1 dm^3 = 0.035 cub. ft.

1 cubic yard = 27 cub. ft. = 0.7645 m^3

1 m^3 = 1.31 cub. yds.

Great Britain/So. Africa/Australia/New Zealand, continued

1 register ton = 100 cub. ft. = 2.832 m^3

1 m^3 = 0.35 reg. ton

1 fluid ounce = 28.41 cm^3 1 litre = 35.2 fl. ozs.

1 pint = 20 fl. ozs. = 0.57 litre 1 litre = 1.76 pints

1 quart = 2 pints = 1.14 litres 1 litre = 0.88 quart

1 imp. gallon = 4 quarts = 4.546 litres

1 litre = 0.22 imp. gal.

Japan

1 sho = 1.804 litres 1 litre = 0.55 sho

1 koku = 100 sho = 180.4 litres 100 litres = 0.55 koku

1 tate tsubo = 6.01 m^3 1 m^3 = 0.17 tate tsubo

South and Central America

1 botella (Colombia) = 0.7 litre 1 litre = 1.43 botellas

1 botella (Guatemala)= 0.75 litre 1 litre = 1.33 botellas

1 galon -aceite- (Colombia) = 3.78 litres

1 litre = 0.26 galon

1 arroba -aguardiente- (Peru) = 11.5 litres

1 litre = 0.087 arroba -aguardiente-

1 arroba -vino- (Chile) = 40.0 litres

1 litre = 0.025 arroba

South and Central America, continued

1 cantara = 16.33 litres	1 litre = 0.06 cantara
1 fanega espanola (Bolivia) = 1.372 hl.	
100 litres = 0.73 fanega espanola	
1 moyo = 2.583 hl.	100 litres = 0.39 moyo
1 pipa = 4.357 hl.	100 litres = 0.23 pipa
1 bota = 4.841 hl.	100 litres = 0.21 bota
1 cahiz = 6.66 hl.	100 litres = 0.15 cahiz

Thailand

1 tanan = 1 litre	
1 thang = 10 litres	1 litre = 0.1 thang
1 sat = 20 litres	1 litre = 0.05 sat
1 ban = 1000 litres	100 litres = 0.1 ban
1 kwien = 2000 litres	100 litres = 0.05 kwien

<u>Weights</u>

U.S./Great Britain/South Africa/Australia/New Zealand

1 grain = 0.065 g.	1 g. = 15.43 grains
1 ounce = 28.35 g.	100 g. = 3.53 ozs.
1 pound = 16 ozs. = 0.454 kg.	1 kg. = 2.20 lbs.

U.S./Great Britain/So. Africa/Australia/New Zealand, cont.

1 stone = 14 lbs. = 6.35 kg. 1 kg. = 0.16 stone

1 quarter = 28 lbs. = 12.70 kg. 100 kg. = 7.87 quarters

1 hundredweight)
1 cental (So. Africa)) = 112 lbs. = 50.802 kg.
1 cwt. long (U.S.))

100 kg. = 1.97 cwts.

1 cwt. short (U.S.) = 100 lbs. = 45.36 kg.

100 kg. = 2.20 cwts. short

1 long ton = 2240 lbs. = 20 cwts. long = 1016.05 kg.

1000 kg. = 0.98 long ton

1 short ton (U.S.))
)= 2000 lbs. = 20 cwts. short = 907.2 kg.
1 cape ton (So. Africa))

1000 kg. = 1.10 short tons

1 metric ton = 1000 kg.

Brazil

1 arroba = 15 kg. 1 kg. = 0.067 arroba

1 quintal = 4 arrobas = 60 kg. 100 kg. = 1.67 quintales

1 quilate = 0.2 g. 1 g. = 5 quilates

1 onca = 28.7 g. 100 g. = 3.48 oncas

Indonesia

1 pikul	= 61.76 kg.	100 kg. = 1.62 pikuls
1 quintal	= 100 kg.	

Iran

1 meskal	= 4.54 g.	1 g. = 0.22 meskal
1 kharwar	= 294.41 kg.	100 kg. = 0.34 kharwar
1 man	= 2 kg.	1 kg. = 0.5 man
1 batman	= 3 kg.	1 kg. = 0.33 batman
1 pud	= 16.5 kg.	100 kg. = 6.06 pud

Japan

1 momme(me)	= 3.75 g.	1 g. = 0.27 momme(me)
1 kin	= 0.6 kg.	1 kg. = 1.67 kin
1 kwan	= 3.75 kg.	1 kg. = 0.27 kwan

South and Central America

1 libra = 0.454 kg. 1 kg. = 2.20 libras

1 libra (Cuba/Mexico/Peru) = 0.46 kg.

1 kg. = 2.17 libras

1 arroba (Peru/Guatemala) = 25 libras = 11.5 kg.

100 kg. = 8.70 arrobas

South and Central America, continued

1 arroba (Honduras) = 25 libras = 11.34 kg.

100 kg. = 8.82 arrobas

1 quintal (Cuba/Mexico/Peru/Bolivia/Guatemala)

= 100 libras = 4 arrobas = 46.01 kg.

100 kg. = 2.17 quintales

1 quintal (Central America))
) = 100 libras = 45.36 kg.
1 tercio (Honduras))

100 kg. = 2.20 quintales

1 quintal (Colombia) = 50 kg. 100 kg. = 2 quintales

1 carga (Bolivia) = 69.01 kg. 100 kg. = 1.45 cargas

1 carga (Colombia) = 125 kg. 100 kg. = 0.8 carga

1 carga algodon (Peru) = 167.44 kg.

1000 kg. = 5.97 cargas algod.

1 cajon (Chile) = 2941 kg. 1000 kg. = 0.34 cajon

1 tonelada = 920 kg. 1000 kg. = 1.09 toneladas

1 tonelada (Uruguay/Colombia) = 1000 kg.

Rates of Application

U.S.

1 pint/100 gals. = 125 ml./100 litres

100 ml./100 litres = 0.8 pint/100 gals.

1 oz./100 gals. = 7.81 g./100 litres

100 g./100 litres = 12.8 ozs./100 gals.

1 lb./100 gals. = 120 g./100 litres

100 g./100 litres = 0.835 lb./100 gals

1 oz./sq.ft. = 318 g./m^2

100 g./m^2 = 0.314 oz./sq.ft.

1 oz./acre = 73 g./ha.

100 g./ha. = 1.37 ozs./acre

1 cwt./acre = 112.080 kg./ha.

100 kg./ha. = 0.891 cwt./acre

1 gal./acre = 9.352 litres/ha.

10 litres/ha. = 1.068 gals./acre

Great Britain

1 pint/100 gals. = 124 ml./100 litres

100 ml./100 litres = 0.8 pint/100 gals.

1 oz./100 gals. = 6.2 g./100 litres

100 g./100 litres = 16 ozs./100 gals.

Great Britain, continued

1 lb./100 gals. = 100 g./100 litres

100 g./100 litres = 1 lb./100 gals.

1 oz./sq.ft = 305 g./m^2

100 g./m^2 = 0.327 oz/sq.ft.

1 oz./acre = 70 g./ha.

100 g./ha. = 1.43 ozs./acre

1 cwt./acre = 125.530 kg./ha.

100 kg./ha. = 0.796 cwt./acre

1 gal./acre = 11.233 litres/ha.

10 litres/ha. = 0.890 gal./acre

U.S. and Great Britain

1 lb./100 sq.ft. = 488 kg./ha.

1 kg./m^2 = 0.204 lb./sq.ft.

1 lb./sq.yd. = 543 g./m^2

1 kg./m^2 = 1.842 lbs./sq.yd.

1 lb./acre = 1.122 kg./ha.

1 kg./ha. 0.892 lb./acre

LITERATURE.

The following publications are recommended for more detailed information on pests and the use of pesticides. These publications are not available from AID. Sources from where they may be ordered are listed below, p. 162.

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(13) "Manual of Pesticide Application Equipment", edited by A. E. Deutsch and A. P. Poole, International Plant Protection Center, Oregon State University, Corvallis, Oregon 97331, USA

Sources from which these publications may be ordered are as follows:

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Ref. 7	The American Public Health Association, Inc. 1740 Broadway New York, N. Y. 10019 USA
Ref. 8	Superintendent of Documents U. S. Government Printing Office Washington, D. C. 20402 USA (Request Stock Number 4106-0029)
Ref. 9	W. Heffer & Sons Ltd. Cambridge, Great Britain
Ref. 10 - 12	UNIPUB, Inc. 650 First Avenue, P. O. Box 433 New York, N. Y. 10016 USA (Also available from sales agents and booksellers for FAO Publications in many other countries. Ref. 10 and 11 also available in several languages other than English.)
Ref. 13	Address included in reference.