BEFORE USING ANY PESTICIDE

STOP

READ THE LABEL

HANDBOOK FOR PESTICIDE APPLICATORS AND DISPENSERS

BRITISH COLUMBIA
The Best Place on Earth

Ministry of Environment

HANDBOOK FOR PESTICIDE APPLICATORS AND DISPENSERS

Fifth Edition

compiled and edited by
Robert W. Adams

Environmental Management Branch
2975 Jutland Road
Victoria, BC

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Name Change

The Ministry of Water, Land and Air Protection mentioned in this handbook is now the Ministry of Environment

Health Canada's Pest Management Regulatory Agency (PMRA) is now responsible for registering pesticides

PREFACE

This Handbook is intended for use in training courses, or in home-study kits, by individuals who require certification as a pesticide applicator or dispenser. The Handbook may also be useful as a reference manual for pesticide applicators and others who require basic information on pesticides or safe pesticide use.

The Handbook has evolved from a booklet entitled "Pesticide Handbook for Pesticide Dealers", published in 1966 by the (then) British Columbia Department of Agriculture. It was revised in 1972 to include information for pesticide applicators. In April, 1977, the Pesticide Control Branch was transferred from the Ministry of Agriculture to the Ministry of Environment. Another Handbook edition was published by the Ministry of Environment in 1979.

This 1987 edition was required to update many sections of text. New standards for safe pesticide transport, storage and disposal are included. Legislation regulating pesticide use is updated. More information is provided on pesticide properties, pest control objectives and integrated pest management. A new chapter is included on equipment calibration. The reference lists of pesticides have been revised to include new pesticides and to identify or exclude pesticides no longer in use. A chapter quiz is included at the end of most chapters to help students determine whether they can answer basic questions about the information covered.

The new Handbook edition is divided into five sections which are:

I Introduction to Pesticides; Their Classification and Regulation
II Human Safety Considerations
III Pests, Pesticide Uses and Properties
IV Pesticide Application Techniques
V Protecting the Environment

It is anticipated that most candidates for certification will study all Chapters in Sections I and II and those Chapters or parts of Chapters in Sections III, IV and V which pertain to their type of pest control work or pesticide sales.

Sections I and II provide core information on pesticide properties and handling practices. These Sections review the chemical and physical characteristics of pesticides, government regulations regarding their use, recommended procedures for safe handling of pesticides and first aid for pesticide poisoning.

In Section III, each chapter covers a separate category of pests and their control. Candidates for pesticide applicator and dispenser certification should have a basic knowledge of the pests encountered in their line of work. These chapters provide background information on life-cycles, habitat requirements and characteristics used to identify major categories of pests. This text does not, however, contain detailed information on the biology or identification of specific pests. A number of publications with such information are listed in each chapter.

Also included in each chapter of Section III are reference lists of pesticides used in British Columbia. The lists contain summaries of each pesticide's classification, use, persistence and toxicity to humans, fish and wildlife. These lists provide applicators with a preliminary source of information when selecting pesticides or identifying pesticide hazards.

No recommendations are given in this Handbook for the use of specific pesticides to control a particular pest. Such information requires regular revision as new products or better application techniques are developed. Applicators and dispensers should consult the most recent pest control recommendations such as the current Crop Production Guides of the B.C. Ministry of Agriculture and Fisheries. As a final check, a product label is the legal aurthority which describes the pests for which a product can be used.

Section IV includes a chapter on application equipment and a chapter on calibration methods and pesticide dilution calculations.

Section V describes potential undesirable effects of pesticides on the environment. The toxicity of various pesticides to bees, cultivated plants and fish and wildlife are reviewed. Guidelines are presented on ways to protect the environment during various types of pesticide applications.

Definitions of pest control terms are included in a Glossary at the end of this text.

Pesticides must be used with caution and good judgement. This Handbook is meant to provide readers with a basic understanding of pesticides and their proper use.

ACKNOWLEDGEMENTS

Much of the format of this Handbook is derived from contributors to former editions. A list of contributing authors to the previous (1979) edition is given in Appendix I.

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The Workers' Compensation Board manual entitled **"Standard Practices for Pesticide Applicators"** *(1985) was used extensively in revising chapters on safe handling of pesticides, protective clothing and safety equipment in this Handbook. The W.C.B. manual can be consulted for additional details about safety on the job site when using pesticides.*

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CONTENTS

SECTION I

INTRODUCTION TO PESTICIDES; THEIR CLASSIFICATION AND REGULATION

Chapter 1

INTRODUCTION

People's efforts to control pests have been responsible for major advances in agricultural production and human health protection. Pests are living organisms which cause harm to people or their property. Pests may be plant-parasitic viruses, bacteria, nematodes and fungi as well as certain insects, weeds, rodents, birds and vertebrate predators. Man and his cultivated plants and domesticated animals share a complex environment in competition with the pests he tries to control. The bacteria and fungi cause more than 1,500 plant diseases. Over 1,800 species of weeds cause serious economic losses. More than 1,500 nematode species attack crop plants and cause significant damage. More than 8,000 insect species are responsible for spread of disease and destruction of food, fibres and structures. Numerous rodent species are vectors for human and animal diseases and cause damage to standing and stored crops.

Many techniques are employed in an effort to control such pests. In crop production, for example, such techniques include the development and use of resistant plant varieties, improved plant nutrition, improved drainage and irrigation practices, timely and appropriate cultivation, crop rotation, exclusion of pest infested material, field sanitation, biological controls and the use of pesticides.

All of the above pest control methods may be useful alone or in some combination, depending on circumstances. The contents of this Handbook deal primarily with the use of pesticides. However, some nonchemical pest control methods are described. It is important to consider nonchemical alternatives to ensure that a pest control operation is as safe, economical and effective as possible.

A pesticide is a substance or mixture of substances used to control pests. Pesticides are not new. The ancient Romans found that they could control insects by burning sulphur. In early Chinese civilization, arsenic and pyrethrum were used to control insect pests of crops. Ground tobacco was used for aphid control, and the Bordeaux mixture of copper and lime was used to control mildew on crops in 19th Century France.

In the early part of the 20th Century, pesticides were primarily of two classes - botanicals and inorganic salts. The botanical pesticides are derived from plant materials and include pyrethrum, rotenone and nicotine insecticides and red squill and strychnine for rodent control. The inorganic pesticides include lime sulphur, arsenicals, borate salts, and various salts of such heavy metals as chromium, copper, iron, lead, mercury, thallium and zinc. These inorganic pesticides were used widely as fungicides, herbicides and insecticides.

Before World War II, only a few synthetically produced pesticides were used. These included the dinitrophenols, hydrogen cyanide, methyl bromide and naphthalene. In the early 1940's, the insecticidal properties of the organochlorine-type insecticide, DDT were recognized. It was also during the war that the weed-killing properties of the herbicide 2,4-D and the insecticidal properties of the organophosphorous-type pesticides, such as parathion, were discovered.

Since World War II, a large number of synthetic organic pesticides have been developed. There are now over 600 basic pesticide chemicals incorporated in over 5,000 brand name products registered for use in Canada. Some of the most recently developed pesticides are the pyrethroids, man-made derivatives of pyrethrins obtained from flowers. They have rapid insect knock-down effects. Research also continues on insect growth regulators and insect sex attractants which are used to disrupt insect development and behavior.

In response to concerns about pesticide contamination of the environment there is a continuing effort to develop pesticides which are as specific as possible to the pests treated and which break down into harmless chemicals. There is also a greater desire to use pesticides only when essential. The need for some pesticides can be reduced by monitoring pest populations and applying pesticides only when the pests cause economic damage. The concept of integrated pest management, which is the combination of mechanical, cultural, biological and pesticide use now forms the basis of many pest control programs.

In past decades, there has been a growing awareness of the undesirable effects of some pesticides on human health and the environment. The accumulation of the chlorinated hydrocarbons such as DDT in food chains, and effects of DDT on fish and bird populations, have promoted the use of less persistent pesticides. Accidental spills of toxic pesticides which contaminated drinking water and caused fish kills have emphasized the need to develop and use safe handling techniques. Accidental human poisonings from pesticide misuse, or pesticides accessible to children, have demonstrated the need for secure storage and handling by responsible people. Health effects suffered by some applicators have emphasized the need for protective clothing and safety equipment for applicators. It is essential that pesticide applicators are knowledgeable about pesticide toxicities and they should understand the reasons for pesticide product label precautions.

The need to improve the safety record of pesticides has promoted the concept of user training which is now

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required for certain pesticide uses in many Canadian provinces and the United States. This text is meant to provide a core of information on pesticide regulations, toxicity and hazards, proper methods of handling pesticides and pest control objectives basic to training needs in British Columbia. Pesticide applicators and dispensers will need to supplement this material with information from other sources on pest identification and pest control recommendations.

Pesticides must be used with care and respect. Safe and efficient use requires knowledge about pesticide properties and the pests they control.

Chapter 2

PESTICIDES: WHAT ARE THEY?

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CONTENTS

PESTICIDE NAMES

The term pesticide is broadly defined by provincial legislation to include all materials that are used to prevent, destroy, repel, attract or reduce pest organisms. Insecticides, herbicides, fungicides and rodenticides are some of the more well-known pesticides. Less well-known pesticides include growth regulators, plant defoliants, surface disinfectants and some swimming pool chemicals. Under federal legislation, all pesticides used in Canada must be registered by Heath Canada.

Pesticides can be named in three ways: by trade or brand name, by common name and by chemical name. For example:

Roundup = trade name of a herbicide product
glyphosate = common name of the active ingredient in *Roundup*
N-(phosphonomethyl)glycine = chemical name of the active ingredient in *Roundup*

Trade names (capitalized) are given by the manufacturer or formulator. The trade-named product is usually a mixture containing one or more pesticide active ingredients (a.i.) and several additives. The **active ingredient** is the chemical which controls the target pest. The additives usually make the product safer, more convenient to handle and easier to apply.

Common names (not capitalized) are assigned to pesticide active ingredients. A common name is used when referring to an active ingredient rather than a product.

Chemical names are used by chemists to describe the chemical structure of the active ingredient. Chemical names are not used in this Handbook.

TYPES OF PESTICIDES

There are about 5,000 pesticide products on the Canadian market. These can be grouped or classified according to the pests they control, their chemical structure, or the way they control or affect the target pest species.

CLASSIFICATION BY TARGET PEST SPECIES

Most pesticides may be classified according to the pests they kill. The word ending or suffix — cide means to kill. Thus, the word pesticide means to kill pests and the following types of pesticides are used to kill specific kinds of pests:

Pesticide	Target pest
algicide	algae
avicide	birds
bactericide	bacteria
fungicide	fungi
herbicide	weeds
insecticide	insects
miticide	mites
molluscicide	snails, slugs
nematicide	nematodes
piscicide	fish
rodenticide	rodents

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CLASSIFICATION BY CHEMICAL STRUCTURE

Most pesticide active ingredients can be grouped into two chemical types: inorganic and organic pesticides.

Type A: Inorganic pesticides. Inorganic pesticides do not contain carbon and are usually derived from mineral ores extracted from the earth. Inorganic compounds such as sulphur were some of the first pesticides used by man. Inorganic pesticides in use today contain salts such as copper sulphate, sodium chlorate, ferrous sulphate and sodium tetraborate or elements such as copper and sulphur.

Type B: Organic pesticides. The organic pesticides contain carbon in their chemical structure. Most organic compounds are synthesized or manufactured from petroleum derived chemical components, although some are extracted from plant material and are called 'botanicals'. Chemists have classified organic pesticides into groups or families of chemicals with similar molecular structures. Organic pesticides of a particular group often have similar properties. The most important groups of organic pesticides are as follows:

- **Organophosphorous pesticides.** Most pesticides in this group are insecticides; a few are also miticides. Organophosphorous pesticides (commonly called OP's) typically have a short persistence in soil, food and feed for animals. This group contains some of the most toxic pesticides used in Canada, e.g. parathion and phosdrin. Even the least toxic of this group is easily capable of poisoning humans if used improperly. Commonly-used pesticides in this group are dimethoate, acephate, malathion and diazinon.
- **Carbamate pesticides.** The carbamate group includes insecticides such as carbaryl, carbofuran and propoxur; fungicides (dithiocarbamates) such as zineb, ferbam and maneb; and herbicides (thiocarbamates) such as barban, EPTC and triallate. Most have a short persistence in the environment. The toxic hazard to humans and animals is generally low for the fungicides and herbicides, but high for the insecticides.
- **Organochlorine pesticides.** Few of the organochlorine pesticides (OC's) are now in use because most have a relatively long persistence in the environment and some have a tendency to accumulate in the fatty tissues of humans and animals. Several organochlorine compounds that have a shorter persistence and a relatively low mammalian toxicity are commonly-used insecticides. Examples are endosulfan and methoxychlor.
- **Dinitrophenol pesticides.** These compounds are used as insecticides, miticides, fungicides and herbicides. They are very toxic. They belong to a family of chemicals used as dyes and have a strong yellow colour. Examples are dinoseb and dinitro-orthocresol (DNOC).
- **Triazine pesticides.** The compounds in this group are all herbicides of mild toxicity to humans and include amitrole, atrazine, prometryne and simazine. They are taken up by plant roots and some may also be absorbed through foliage. Residues from these compounds are noted for their persistence in the soil.
- **Phenoxy pesticides.** These herbicides are widely used for weed control in grain crops. They are selective because grasses and some other crop species are resistant to them. The most commonly used members of this group are 2,4-D and MCPA. They have low to moderate toxicity to humans and animals.

CLASSIFICATION BY MODE OF ACTION

Pesticides can also be classified according to the way they enter or affect the target pest species. Some examples of pesticide groups in this type of classification include the following:

Contact pesticides generally control a pest as a result of direct contact. Insects are killed when sprayed directly with a lethal dose of contact insecticide. Insects may also be killed when they touch surfaces treated with a residual contact insecticide. Weed foliage is killed when sufficient surface area is covered with a contact herbicide.

Systemic pesticides are pesticides which are absorbed by plants or animals and are transported to untreated tissues. Systemic herbicides pass through the plant to untreated areas of leaves, stems or roots, and may be effective in killing weeds with only partial spray coverage. In the case of a systemic insecticide, sucking pests such as aphids on roses or horn flies on beef cattle are affected beyond the area of pesticide treatment.

Foliar pesticides are applied to plant leaves, stems and branches. They may be **contact herbicides** which kill only plant parts covered with spray or **systemic herbicides** which are translocated inside the plant.

Soil-applied pesticides are applied to the soil. Some are taken up by roots and translocated inside the plant. Other soil-applied herbicides kill weed seedlings by contact with young shoots or leaves as they break through the soil.

Fumigants are chemicals that are applied as a toxic gas or as a solid or liquid which generate a toxic gas. The gas will penetrate cracks and crevices of structures or soil or the spaces between products stored in various containers.

PESTICIDE FORMULATIONS

TYPES OF FORMULATIONS

When a pesticide active ingredient is manufactured, it is known as technical grade material. This technical grade material must usually be incorporated into a formulation in order to produce a useful pest control product. The technical grade material may be formulated into a product by the basic manufacturer or may be sold to a formulator.

During the formulation process, the active ingredient is mixed with other materials to make the product safer to handle, easier to apply, more effective or more suitable for storage. For example, carriers such as water or oil, solvents, inert powders or gas propellants are often added to dilute the active ingredient or to provide a medium in which it can be applied. Adjuvants are often added to improve the properties of the formulation. They may improve the way a product will mix with a diluent, improve its efficacy or reduce non-target damage.

Some pesticide formulations are ready-to-use, e.g. aerosols and various dusts, baits, pastes, gels, pellets and granules, with 1 to 5% active ingredient. Other formulations must be diluted with water or oil before use.

Pesticide formulations can be divided into three main types: solids, liquids or gases. They may also be categorized according to the way they are to be applied or diluted. Some active ingredients are incorporated in several different kinds of formulations. Applicators must select the formulation that will be best for their particular needs. The most commonly used formulations include the following. Note that the formulation of many products is indicated by an abbreviation on the pesticide label — as shown below in parentheses.

Solids

Some solid (dry) formulations are ready-to-use while others must be mixed with a diluent. Solid formulations may be easily stored, transported and handled. They are not absorbed by the skin as readily as liquid formulations.

Dusts (D or DU) consist of the pesticide active ingredient mixed with finely-ground particles of inert materials such as talc, clay or volcanic ashes. They are used dry and are usually marketed ready-for-use. The concentration of active ingredient is usually low, i.e. 1 to 10%. Dusts are rarely used for large-scale field applications because they easily drift into non-target areas.

Granules (G or GR) consist of the active ingredient adsorbed onto particles of inert materials such as clay. The particles are typically about 2 to 6 mm in diameter. Like dusts, granules are used without further mixing. The concentration of active ingredient is usually between 2 and 25%. A number of advantages when using granules include minimal drift and clean, simple application. Where residual action is required, granules may provide slow release of the pesticide. Unsightly dust deposits on foliage may be avoided and drift to non-target areas is usually minimal. Granular formulations are usually applied to the soil.

Pellets (PE), like granules, are small particles of inert materials containing a pesticide, but the particles are generally larger and may have a more uniform shape and weight than granules.

Baits are a mixture of pesticide and food material to attract and control pests. Although some may be formulated as liquids or pastes; most baits are solid formulations. Baits are commonly used for rodent and bird control and may also be used to control insect pests such as weevils, ants and earwigs, as well as slugs and snails. The amount of active ingredient in most baits is quite low, usually less than 5%. Baiting, if properly done, is a good method of delivering the minimum required pesticide dosage to the target species.

Soluble powders (SP) are dry formulations of finely-ground active and inert ingredients which are dissolved in water to make a spray solution. No agitation is needed once the pesticide is dissolved. The active ingredient in soluble powders ranges from 15 to 95%, but is usually over 50%. They may be hazardous to the applicator if inhaled while mixing.

Wettable powders (WP), like soluble powders, consist of finely- ground active and inert ingredients. Wettable powders must be added to water and kept in suspension through constant agitation. They settle out quickly without agitation. Wettable powders usually contain 50% or more active ingredient. Like soluble powders, wettable powders are not readily absorbed through the skin, but may be hazardous to the applicator if inhaled.

Dry flowables (DF) consist of active ingredient mixed with inert ingredients to form granule-size particles. To prepare a spray mix, the particles are added to water, producing a suspension just like a wettable powder. The spray mixture must be continuously agitated. However, dry flowables are easier to pour than powders and are less of an inhalation hazard during mixing.

Capsules consist of a pesticide with a coating of a material such as gelatin which dissolves or disintegrates in water, releasing the pesticide, e.g. pyrethrin capsules for mosquito control.

Blocks, crystals, flakes, balls and tablets are other solid formulations, usually of ready-to-use material, which may be applied in a variety of ways.

Liquids

Liquid pesticides may be formulated with water or petroleum solvents and may be ready-to-use or require further dilution with water or oil prior to use. Liquid pesticides which must be diluted before use can be very hazardous when the concentrate is handled during the mixing process.

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Emulsifiable concentrates (EC) usually contain an active ingredient, one or more petroleum-based solvents and an emulsifier which allows the formulation to be mixed with water. When the spray mixture is prepared, the pesticide is suspended as minute droplets in the mixture. Emulsifiable concentrates should remain suspended without further agitation for at least one day following dilution with water. The petroleum-based solvents in some emulsifiable concentrates can cause foliage burning even at moderate concentrations if used when temperatures are high.

Water-soluble concentrates or solutions (WS or SN) are liquid formulations which mix completely in water. They form solutions which will not settle out or separate and do not require agitation after mixing. Few pesticides are available in this type of formulation because most active ingredients are not soluble in water.

Liquid flowables or suspensions (SU) are formulations where the finely-ground active ingredient is mixed in a liquid along with inert ingredients to form a thick suspension. The formulation is diluted with water for application as a spray mixture. Constant agitation of the spray tank is necessary as liquid flowables have the same tank-settling characteristics as wettable powders.

Microencapsulated suspensions are formulations in which the active ingredient is contained in microscopic-size polymer film capsules. The capsules (15 to 50 μ in diameter) are suspended in a liquid which is diluted before application. When applied, the microscopic capsules slowly release the active ingredient, thus prolonging the persistence of the pesticide. These formulations must be well agitated during application. They are usually safer to handle than other formulations because the capsules cannot be absorbed through the skin and pass through the digestive tract if ingested. Care must be taken to ensure that any screens or filters within the spray equipment will permit the passage of the capsules.

Ultra low volume concentrates (ULV) contain mostly active ingredient. They are designed to be used as is or to be diluted with only small quantities of specified solvents. These special-purpose formulations must be applied with highly specialized equipment that produce a very fine spray.

Aerosols (A) usually contain small amounts of active ingredient and a petroleum solvent. There are two types of these formulations, the ready-to-use type and those made for use in fog-generators. Ready-to-use aerosols are usually under pressure in small containers. When the nozzle valve is triggered, the pesticide is driven through a small opening, creating fine droplets. The fog-generators are not under pressure. They are used in machines which break the liquid formulation into a fine mist or fog using a rapidly spinning disc or heated surface. These formulations are used mainly in structures such as greenhouses and for mosquito control outdoors. The fine droplets produced by ready-to-use aerosols and fog generators may represent an inhalation hazard.

Gases

Fumigants are pesticides applied as a gas or applied as a liquid or solid which release toxic gases to control pests in enclosed spaces. Fumigants are used in stored grains, in structural pest control, and as soil treatments to control insects, weeds, fungi or nematodes. They are hazardous to work with because they are highly toxic and applicators must take considerable precautions to avoid exposure to the gas.

ADJUVANTS

Adjuvants are materials added to a pesticide formulation or tank mix to increase the effectiveness of the active ingredient. They may help the pesticide spread more evenly or penetrate into or stick on the target. They are either incorporated into the formulation by the manufacturer or may be added to the spray by the pesticide applicator. Caution should be used when adding adjuvants to a pesticide spray because pesticide residue levels or plant sensitivity to the pesticide may increase.

The following adjuvants are sometimes used:

Wetting agents — allow wettable powders to mix with water.
Emulsifiers — allow oil-based pesticides (EC's) to mix with water.
Invert emulsifiers — allow water-based pesticides to mix with oil-based carriers.
Spreaders — allow the pesticide to form a uniform coating over the treated surface.
Stickers — allow the pesticide to stay on the treated surface.
Penetrants — allow the pesticide to get through the outer layer of a treated surface.
Thickeners — reduce drift by increasing droplet size.
Foaming agents — reduce drift.
Anti-foaming agents — reduce foaming of spray mixtures that require vigorous agitation.

MIXING PESTICIDES

It is often desirable to combine two or more pesticides to improve the control of a single pest species, or to control several different pest species with one application. Pesticides that cannot be mixed together because of adverse reactions are called 'incompatible'.

Incompatibilities may be chemical or physical. A chemical incompatibility results in a chemical reaction between any of the constituents being mixed. A chemical incompatibility may destroy the effectiveness or increase the toxicity of one or more active ingredients. A physical incompatibility results in a change in the physical characteristics of a pesticide. A physical incompatibility may cause the formation of a precipitate which clogs the sprayer screens and nozzles or may cause the separation of an emulsifier from the active ingredient. The resulting spray could be mostly carrier or highly concentrated active ingredient. Excessive human exposure, high residues, or various types of plant injury may occur.

Some general guidelines to prevent incompatibilities include the following:

- Formulations containing lime, such as Bordeaux mixture, lime sulphur and other materials that are highly alkaline, are incompatible with many synthetic organic chemicals. Organophosphorous pesticides, carbamates and some organochlorines and dinitro pesticides are generally degraded into nontoxic chemicals in alkaline solutions.
- Combinations of oil-based solvents with organic pesticides are often injurious to plants. The mixture can cause severe burning of the fruit or foliage. This will occur with most carbamate and dinitro pesticides and some organophosphorous pesticides. Many emulsifiable concentrates are formulated with oil-based solvents.
- When two emulsifiable concentrates are combined, the active ingredients may be compatible, but the solvents or the emulsifying agents may be incompatible.
- Often there is incompatibility when emulsifiable concentrates and wettable powders are combined. One of the pesticides may precipitate out of the mixture and plant injury may result.
- Granular formulations of pesticides should not be combined with liquid pesticides or liquid fertilizers.

Many pesticide formulations can be combined safely. A good rule to follow, particularly with combinations of wettable powders and emulsifiable concentrates, is to use formulations produced by the same manufacturer. The pesticide labels should be checked for any specific precautions about mixing. **When mixing pesticides for agricultural use, refer to the compatibility charts available from the Ministry of Agriculture and Fisheries. These charts are included in Production Guides for various crops.**

PRODUCT LABELS

Every pesticide product must be registered by Heath Canada before it can be sold or used in Canada. In order to obtain registration, the manufacturer must supply data on product safety and efficacy. This data is used to produce a product label with use directions, safety precautions and first aid information. This label must be attached to every package or container of pesticide for sale.

There are four times when a label should be read:

- **Before the pesticide is purchased,** make certain the product is registered for the intended use, determine if special application techniques are required and determine how much pesticide is required.
- **Before mixing and applying the pesticide,** determine how it should be mixed, check on requirements for protective clothing, learn what first aid procedures may be required in case of an accident. Also determine when and how to apply the pesticide and any residue and re-entry restrictions.
- **Before storing the pesticide,** determine if there are special storage precautions which must be followed.
- **Before disposing of unwanted pesticides or the container,** check the label for instructions to avoid health risks or environmental contamination.

Examples of labels for three pesticides with different hazard ratings are given in Figures 1, 2 and 3. The important information on these labels is numbered and defined as follows:

1. **Trade Name.** This is the manufacturer or selling agent's assigned name for the product.

2. **Use and Classification.** The type of pest controlled by the product is stated, i.e. herbicide, fungicide, insecticide, etc. The product is assigned to one of three use categories: Domestic, Commercial or Restricted.

   Domestic products are considered to be sufficiently safe to use in or around the home. Accidental exposure is unlikely to cause severe effects and the environmental consequences of their use is considered slight (Figure 1).

   Commercial products include the more toxic pesticides or moderately toxic pesticides sold in large containers, as well as pesticides for special uses or requiring special application techniques. They are to be used by commercial applicators who have knowledge about safe use practices. Products in this class may also be more specifically labelled as **Agricultural, Horticultural** or **Industrial** (Figure 2).

   Restricted products are pesticides which require a notice to alert users to particular hazards or special requirements involved in their use (Figure 3).

   Neither commercial nor restricted class products should be used by people with limited knowledge about pesticides.

3. **Formulation.** The type of formulation is described in one or two words or as an abbreviation (e.g. emulsifiable concentrate or EC).

4. **Precautionary Symbol.** This symbol is placed on the label if the product may be hazardous to use or handle. The kind of symbol illustrates how dangerous the pesticide is with respect to toxicity, flammability, explosiveness or corrosiveness. The degree of hazard is indicated by the shape surrounding the symbol (see Tables 1 and 2).

5. **Guarantee.** This important part of the label identifies the active ingredient by its common name and indicates how much this chemical is diluted by other materials in the product. The amount of active ingredient in the product is given as a percent of total weight (e.g. 20%), or the weight of active ingredient per volume of product (e.g. 200 grams per litre).

6. **Registration Number.** The Pest Control Products Act (PCP Act) Registration number must be shown

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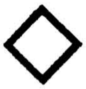
and is proof that the product has been registered for use by Health Canada. The more recently registered products have registration numbers over 18,000, while older products have registration numbers less than 5,000. There are only about 5,000 products currently registered for use which means many formerly-registered products have been withdrawn. Products may be withdrawn as better pesticides are developed or because of health or environmental concerns, lack of demand, etc.

Table 1. Pesticide label precautionary shapes and signal words.

Shape	Signal Word	Hazard Rating
	DANGER	extreme or high
	WARNING	moderate
	CAUTION	low or slight

The nature of the hazard is represented by the symbol within the shape as follows:

The **"skull and crossbones"** symbol warns that the chemical is **poisonous** if taken into the body. See Chapter 4 for an interpretation of the poisonous hazard ratings.

The **"fire"** symbol is a warning that the pesticide is **flammable** or easily ignited. Non-pressurized products with a 'Danger Flammable' symbol have a flashpoint less than -6.7°C; the 'Warning Flammable' symbol means a flashpoint of -6.7° to 10°C; the 'Caution Flammable' symbol means a flashpoint of 10° to 26.7°C.

The **"exploding grenade"** symbol indicates that the pesticide represents an **explosion** hazard. Aerosols and pressurized products represent such a hazard.

The **"corroded hand in liquid"** *symbol indicates the pesticide is* **corrosive** to the skin. The chemical is either acidic or alkaline (caustic) and can burn the skin if mishandled.

The label may contain none, one or several of the shape and symbol combinations shown in Table 2. Where more than one symbol is required, only the most severe signal word is used on the label.

7. **Net Contents.** This information gives the total contents of the pesticide formulation in the container, usually as a weight (g or kg) or as volume (mL or L).

8. **Directions for Use, Use Area and Limitations.** These sections of the label identify where the pesticide may be used, which pests will be controlled and specific rates of application. The directions state how the user can obtain desired results while avoiding undesirable effects. Instructions may be given on the minimum number of days between pesticide application and harvesting of specified crops to ensure there is no hazard from pesticide residues. It is important that these directions are followed completely. They have been developed specifically for the product to ensure safety and efficacy.

9. **Precautions.** This section describes how the pesticide must be used or not used to prevent user exposure or environmental contamination. The precautions vary according to the properties and intended use of the product.

10. **First Aid.** Instructions are given for treating a victim of accidental poisoning. No information is given if the product is of such low toxicity that first aid is not needed after accidental exposure.

11. **Toxicological Information.** This section includes symptoms of poisoning and other information important to medical staff for treatment of poisoned victims.

12. **Disposal.** Information is provided regarding the disposal of empty containers to prevent accidental poisonings or environmental contamination.

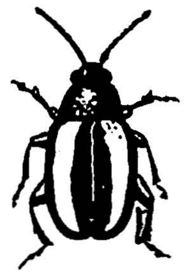
13. **Pesticide Company's Name and Address.** On request, many companies will provide Material Safety Data Sheets which give additional detailed information on how to use a particular pesticide safely.

Table 2. Precautionary shape and symbol combinations used on pesticide labels.

	Danger	Warning	Caution
Poison			
Flammable			
Explosive			
Corrosive			

→ 1 **Diazinon**

→ 3 **Pressurized Insect Spray**



For ORNAMENTALS, FLOWERS, and AROUND HOMES.

→ 2 Domestic

→ 13

Later Chemicals Ltd.,
12080 Horseshoe Way,
Richmond, B.C.
V7A 4V5

→ 4 WARNING

POISON FLAMMABLE EXPLOSIVE

READ THE LABEL BEFORE USING.
→ 6 REG. NO. 13287 P.C.P. ACT.
→ 5 GUARANTEE: diazinon 0.5%
→ 7 Net Content: 310 g

→ 8 DIRECTIONS FOR USE:

Remove the protective cap. Do not point the valve opening to the face. Press down on valve tip, spray with a slow sweeping motion. Do not spray when temperature is over 25 °C.

ORNAMENTALS: To control Ants, Aphids, Flea beetles, Leafhoppers, Mites, Tent caterpillars, White flies: Spray 45 cm away from foliage with slow sweeping motion, to upper and lower surfaces. Spot treat larger plants to control localized infestations.

LIMITATIONS:
1) For outdoor use only.
2) Do not use on certain ferns, poinsettias, hibiscus, papaya, pilea, gardenia, orchids.
3) Do not use as a space spray.

ARBORVITAE: To control Leafminers and Scale insects (crawlers), spray when insects first appear. Repeat as necessary.

APPLE, CHERRY, PEAR: To control Aphids, Fruit tree leafrollers, Leafhoppers, Mealy bugs, Mites and Scale insects (crawlers): Spray at the rate of 1 m² per 10 seconds. Do not use within 14 days on apple or pear; within 10 days on cherry — before harvest.

→ 9 PRECAUTIONS: KEEP OUT OF REACH OF CHILDREN. Avoid inhaling and contact with skin and eyes. Bury empty container. Avoid contamination of
→ 12 food, and drinking water. May be absorbed through the skin. Do not burn or puncture container. Do not use in presence of open flame or spark.

→ 10 FIRST AID: In case of accident, call a doctor.

→ 11 TOXICOLOGICAL INFORMATION: Diazinon is a cholinesterase inhibitor. Atropine is antidotal.

Seller's guarantee shall be limited to the terms set out on the lable and subject thereto, the buyer assumes the risk to persons or property arising from the use or handling of this product and accepts the product on that condition.

Figure 1. Pesticide label from a Domestic product (Index numbers refer to definitions in text).

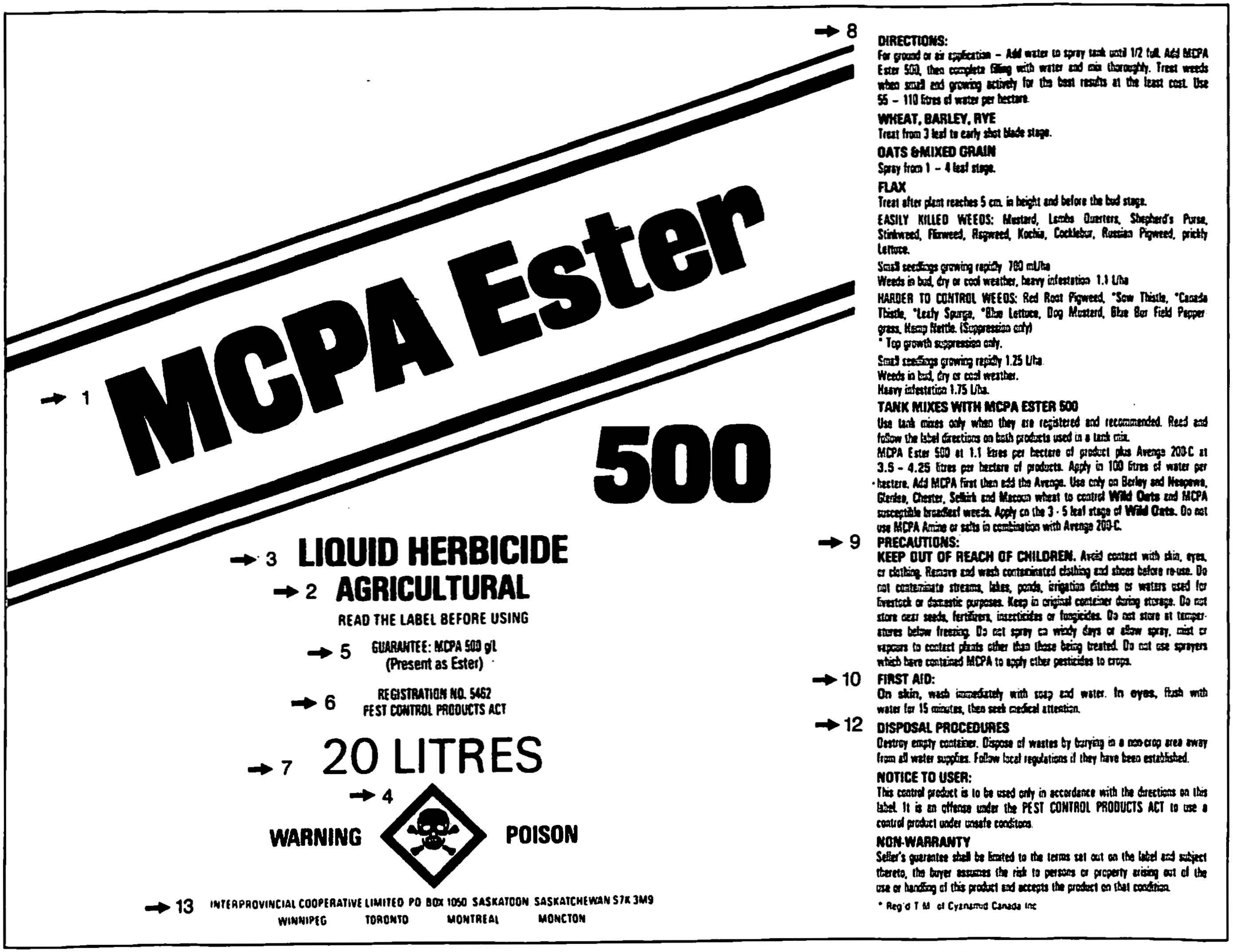


Figure 2. Pesticide label from an Agricultural product (index numbers refer to definitions in text; note that item 11, toxicological information was not present on this label example).

→1 # MONITOR 480[REG. TM] →8

→3 # Liquid Insecticide

→2 # RESTRICTED

For Insect Control on Cole Crops, Potatoes, Head Lettuce and Rapeseed

→5 GUARANTEE:
Methamidophos* .... 480 g/L
*U.S. Patent No. 3,309,266; 3,689,604; 3,676,555

→6 Registration No. 12,434 Pest Control Products Act

→4

DANGER  **POISON**

READ THE LABEL BEFORE USING
KEEP OUT OF REACH OF CHILDREN
CALL A DOCTOR IN CASE OF ACCIDENT
(See side panel for First Aid and Danger Statements)
STORE IN A COOL DRY PLACE
PROTECT FROM HEAT

WARNING:

Safety data and registration of this product are under review. Directions for use and cautionary statements should be carefully followed. Read the label before using.

→7 **10 L**

NOTICE TO USER: This control product is to be used only in accordance with the directions on this label. It is an offence under the **Pest Control Products Act** to use a control product under unsafe conditions.
NATURE OF RESTRICTION: This product is to be stored and displayed apart from food or feed.

RESTRICTED USES

READ ENTIRE LABEL. USE STRICTLY IN ACCORDANCE WITH LABEL CAUTIONS, WARNINGS AND DIRECTIONS.
DIRECTIONS: Use the designated amount of product in the following litres of water per hectare unless otherwise noted
Ground Application: 200 to 1000 Litres of Water

RECOMMENDED APPLICATIONS

CROP	INSECT	DOSAGE LITRES MONITOR 480	REMARKS
Broccoli Brussels Sprouts Cabbage Cauliflower	Cabbage looper Imported cabbageworm Diamondback moth larvae Aphids	1.1–2.3 L	Apply 1.1 L on a 7 day schedule beginning when insects or their damage first appears. For severe infestations 1.85–2.3 L applied at 7 to 14 day intervals may be necessary. Do not apply to cauliflower, or cabbage later than 7 days before the first harvest, or to broccoli and Brussels spouts later than 14 days before the first harvest.
Head lettuce (Field grown)	Cabbage looper Aphids	1.1–2.3 L	Apply 1.1 L on a 7 day schedule beginning when insects or their damage first appears. For severe infestations 1.85–2.3 L applied at 7 to 14 day intervals may be necessary. Do not apply to head lettuce later than 14 days before the first harvest.
Potatoes	Aphids Colorado potato beetle Potato flea beetle Potato leafhopper Tarnished plant bug (Ontario only)	1.85–2.3 L	Use 1.85–2.3 L per hectare. Apply in a 10 to 14 day program or as necessary. Do not apply later than 14 days before harvest.
Rapeseed	Bertha army worm	575 mL–1.25 L	Use 575 mL–1.25 L per hectare. Applications by air* or ground equipment should begin when small larvae are present or when damage first appears. Two applications may be made. Do not apply within 10 days of harvest.
	Grasshoppers	1.25 L	Use 1.25 L per hectare. Applications by ground or air* equipment should begin when migration of grasshoppers from ditches and field borders becomes apparent. Two applications may be made. Do not apply within 10 days of harvest.

*FOR AIRCRAFT APPLICATION ON RAPESEED, USE NOT LESS THAN 10 LITRES OF WATER PER HECTARE

→9 **PRECAUTIONS:** Do not apply under conditions involving possible drift to food, forage or other plantings that might be damaged or the crops thereof rendered unfit for sale, use or consumption.
FISH AND WILDLIFE CAUTIONS: Toxic to Fish and Wildlife. Keep out of lakes, streams and ponds. Fish will be killed if their waters are contaminated with this product. Wildlife in contact with treated areas may be harmed. This product is highly toxic to bees exposed to direct treatment or residues on crops. Avoid use during flowering and pollination periods.

→12 **CONTAINER DISPOSAL:** Keep pesticide in original container. Do not put concentrate or dilute into food or drink containers. Wash and destroy container when empty. Never reuse.

KEEP OUT OF REACH OF CHILDREN

DO NOT INHALE — DO NOT GET ON SKIN — DO NOT TAKE INTERNALLY

Poisonous if swallowed, inhaled or absorbed through skin. Rapidly absorbed through skin. Do not get in eyes, on skin or on clothing. Wear a mask or respirator of a type suitable for protection against organic phosphate insecticides. Wear natural rubber gloves, protective clothing and goggles. Wash hands, arms and face thoroughly with soap and water before eating or smoking. Wash all contaminated clothing with soap and hot water before reuse. Keep all unprotected persons out of operating areas or vicinity where there may be danger of drift. Vacated areas should not be reentered until drifting insecticide and volatile residues have dissipated. Do not store or transport with feed or food.

→10 **FIRST AID INSTRUCTIONS:** In case of **Contact with Skin** remove contaminated clothing and wash immediately with soap and water. **If in Eyes** flush with large amounts of water for at least 15 minutes and get medical attention. **If Swallowed**, give 15 mL of salt in a glass of warm water and repeat until the vomit fluid is clear. Have victim lie down and keep quiet. **CALL A PHYSICIAN IMMEDIATELY.**

→11 **TOXICOLOGICAL INFORMATION: Note to Physicians:** Emergency Information—call (415) 233-3737. The compound inhibits cholinesterase resulting in stimulation of the central nervous system. This results in a sense of "tightness" in the chest, sweating, contracted pupils, stomach pains, vomiting and diarrhea. The antidote is atropine sulfate administered in large therapeutic doses repeated as necessary to the point of tolerance. 2-PAM is also antidotal and may be administered in conjunction with atropine. Do not give morphine. Watch for pulmonary edema, which may develop in serious cases of poisoning even after 12 hours. At first sign of pulmonary edema, the patient should be placed in an oxygen tent and treated symptomatically.

LIMITATION OF WARRANTY: Seller's guarantee shall be limited to the terms set out on the label and subject thereto, the buyer assumes the risk to persons or property arising from the use or handling of this product and accepts the product on that condition.

MONITOR is a Reg. TM of Chevron Chemical Company.

→13 **Chevron Chemical (Canada) Limited** © 1985
3228 South Service Road
Burlington, Ontario L7N 3H8
R Form C-10018-D

Figure 3. Pesticide label from a Restricted product (index numbers refer to definitions in text).

Chapt. 2

ACTIVE INGREDIENT CONCENTRATION

When pesticides are applied, they usually consist of the active ingredient together with diluents and adjuvants. It is sometimes important to know how to calculate the amount of active ingredient in a pesticide product or spray mix. The concentration of active ingredient is used to assess the toxicity of the pesticide (reviewed in Chapter 4). It may be necessary to compare the amount of active ingredient applied per unit area when using different products or to compare the cost of different products based on their active ingredient. It may also be necessary to maintain records of pesticide use in terms of active ingredient. A method for calculating active ingredient quantities in pesticide products and pesticide mixtures is outlined below.

The examples given here are in metric units because all labels on pesticide products now sold in Canada have directions which use the metric system. Some labels may contain both metric and imperial units of measurement but we do not recommend the use of imperial units (pounds or gallons) because the calculations are more difficult. Applicators should be familiar with the following metric units and their abbreviations. (See Appendix II for conversion factors.)

METRIC UNITS

Weight is measured in grams (g)
one kilogram (kg) = 1,000 grams
one milligram (mg) = 1/1,000 or 0.001 gram

Volume is measured in litres (L)
one millilitre (mL) = 1/1,000 or 0.001 litre

Note the relation of these units as follows:

1.0 kg	=	1,000 g	1.0 L	=	1,000 mL
0.1 kg	=	100 g	0.1 L	=	100 mL
0.01 kg	=	10 g	0.01 L	=	10 mL
0.001 kg	=	1 g	0.001 L	=	1 mL

The concentration of the active ingredient (a.i.) in the formulated product is stated under the heading "Guarantee" on the label of pesticide containers. On dry formulations, the concentration of active ingredient is normally listed as a percent of the total weight. If the guarantee on a dry formulation was 20% a.i., there would be 200 grams of active ingredient in every kilogram of product. The remaining 800 grams would consist of inert ingredients such as clay.

Example 1. Suppose it is necessary to determine the amount of active ingredient in a 5 kg package of granular pesticide with a guarantee of 5%. Use the formula:

$$\begin{aligned}\text{active ingredient} &= \text{percent guarantee} \times \text{total product}\\ &= 5\% \times 5\text{ kg}\\ &= \frac{5}{100} \times 5\text{ kg}\\ &= 0.25\text{ kg}\\ &= 250\text{ g a.i.}\end{aligned}$$

There would be 250 g a.i. in a 5 kg package containing 5% a.i.

On the label of liquid formulations the concentration of active ingredient may be listed as a percent of the total product weight, a percent of the total product volume (e.g. 20%), or as a weight of active ingredient per volume of product (e.g. 200 g/L). If the guarantee on a liquid formulation was 20% of the product volume, there would be 200 mL of active ingredient in every litre of product. The remaining 800 mL would be inert ingredients.

Example 2. Suppose it is necessary to determine the amount of active ingredient in a 5 L container of liquid with 35% active ingredient. Use the formula:

$$\begin{aligned}\text{active ingredient} &= \text{percent guarantee} \times \text{total product}\\ &= 35\% \times 5\text{ L}\\ &= \frac{35}{100} \times 5\text{ L}\\ &= 1.75\text{ L a.i.}\end{aligned}$$

There would be 1.75 L a.i. in a 5 L container with a guarantee of 35% a.i.

The calculations are a little different if the guarantee is expressed as a weight of active ingredient per volume of product.

Example 3. Suppose it is necessary to determine how much active ingredient is in a 5 L container with a guarantee of 350 g per L of product? The guarantee is a ratio of 350 g/L.

$$\begin{aligned}\text{active ingredient} &= \text{ratio} \times \text{total product}\\ &= \frac{350\text{ g}}{1\text{ L}} \times 5\text{ L}\\ &= 1{,}750\text{ g}\\ &= 1.75\text{ kg}\end{aligned}$$

There would be 1.75 kg a.i. in a 5 L container with a guarantee of 350 g/L.

CHAPTER QUIZ

Questions / **Answers**

1. What is the difference between the trade name and the common name of a pesticide?

   Answer: A trade name is given to a pesticide product by a manufacturer. A common name refers to an active ingredient which may be incorporated in a number of products with different trade names.

2. What are the following pesticides used for: avicides, bactericides, miticides, molluscicides, rodenticides?

   Answer: avicides — birds; bactericides — bacteria; miticides — mites; molluscicides — snails, slugs; rodenticides — rodents.

3. Match the following types of pesticides with the most appropriate characteristics: organophosphorous pesticides, carbamate pesticides, organochlorine pesticides, triazine pesticides, phenoxy pesticides
   a) most are herbicides of low to moderate toxicity used for weed control in grain crops.
   b) fungicides and herbicides have fairly low toxicity, insecticides have greater toxicity, most have short persistence.
   c) most are insecticides, some are very toxic, typically have a short persistence.
   d) some accumulate in fatty tissues and have a long persistence.
   e) all are herbicides of mild toxicity, taken up by plant roots, residues from some have a long persistence in soil.

   Answer: organophosphorous — c; carbamate — b; organochlorine — d; triazine — e; phenoxy — a.

4. Name three types of pesticides, classified according to the way they affect pest species.

   Answer: Contact pesticides, systemic pesticides, foliar pesticides, soil-applied herbicides, fumigants.

5. What is the difference between a contact pesticide and a systemic pesticide?

   Answer: Contact pesticides produce an effect by direct contact; systemic pesticides are absorbed and moved around inside the plant or animal treated.

6. Name three types of solid pesticide formulations and three types of liquid pesticide formulations.

   Answer: Solid formulations = dusts, granules, pellets, baits, soluble powders, wettable powders, dry flowables, capsules, flakes or tablets; liquid formulations = emulsifiable concentrates, water soluble concentrates, flowables, microencapsulated suspensions, ultra low volume concentrates, aerosols.

7. What is the name of the material incorporated in some pesticides so they will spread more evenly, penetrate into or stick to target pests? Adjuvants

   Answer: adjuvant

8. Name two types of physical incompatibilites from mixing pesticides and describe the resulting problems.
   Precipitate and Separation of emulsifier effecting mixture

   Answer: precipitate formation — plugs screens, nozzles; break in emulsion — can cause spray injury

9. Where would you find information on the compatibility of pesticides used for agriculture?
   Ministry of Agriculture & Fisheries

   Answer: Ministry of Agriculture and Fisheries Crop Production Guides

10. What are the three categories of pesticide use classifications indicated on product labels?

    Answer: Domestic, Commercial, Restricted

11. What would the following symbols represent on a label?

    Answer: There is a high hazard due to the poisonous nature of the chemical and it is slightly corrosive to the skin.

Chapt. 2

12. How much active ingredient is there in a 5 L container of insecticide with a guarantee of 22%?

12. active ingredient = percent guarantee x total product

$$= 22\% \times 5\ L = \frac{22}{100} \times 5\ L = 1.1\ L$$

13. How much active ingredient is there in a 2.26 kg package of wettable powder herbicide with a guarantee of 80%?

13. active ingredient = percent guarantee x total product

$$= 80\% \times 2.26\ kg = \frac{80}{100} \times 2.26\ kg = 1.808\ kg$$

14. How much active ingredient is there in a 10 L container of insecticide with a guarantee of 215 g/L?

14. active ingredient = ratio x total product

$$= \frac{215\ g}{1L} \times 10\ L = 2{,}150\ g = 2.15\ kg$$

Chapt. 3

Chapter 3

PESTICIDE LEGISLATION

CONTENTS

There is a considerable amount of legislation in Canada that deals with pesticides. It has been developed to protect human health, non-target plants and animals and environmental quality.

In this chapter the more important aspects of this legislation are briefly described.

FEDERAL LEGISLATION

PEST CONTROL PRODUCTS ACT

The Pest Control Products Act requires that every pesticide product is registered by Health Canada's Pest Management Regulatory Agency (PMRA) before it can be sold or used in Canada.

In applying to the PMRA for registration of a pesticide, a company must submit the following kinds of data:

- physical and chemical properties of active ingredient(s);
- toxicology data including:
  - acute oral, dermal, inhalation, skin and eye irritation test;
  - long-term oral toxicity studies on rodents and possibly non-rodents; and
  - studies to assess effects on reproduction and potential for teratogenicity, mutagenicity and carcinogenicity;
- residue on food crops including analytical methodology and animal metabolism studies;
- environmental data on persistence and degradation as well as effects on birds, mammals, aquatic organisms, predators, parasites and honeybees; and
- efficacy data.

These data are reviewed by specialists who assess many things including: efficacy; toxicology and residue data; occupational, environmental and public health concerns; and the pesticide's persistence and fate in the environment.

If all data submissions are acceptable, and the pesticide is approved for use in Canada, it is assigned a Pest Control Products Registration Number (P.C.P. No. or Registration No.) which must appear on every label. No pesticides without a P.C.P. No. may be sold or used in Canada.

No pesticide may be used for any purpose or in any ways other than those described on the label.

"Chapt. 3"

FISHERIES ACT

Two sections in the Fisheries Act can be used to prosecute persons responsible for damage to fish or fish habitat as a result of improper pesticide use.

One section of the Fisheries Act specifies that it is an offence to harmfully alter, disrupt or destroy fish habitat. Fish habitat includes spawning grounds, nursery, rearing, food supply and migration areas on which fish depend directly or indirectly. Thus, care must be taken to not kill streamside vegetation which provides a source of food (e.g. terrestrial insects) and shade, and preserves bank stability and fish habitat.

Another section specifies that it is an offence to deposit or permit the deposition of a deleterious substance into waters frequented by fish. Deleterious substances are those materials which may directly or indirectly harm fish or fish habitat. This section thus prohibits the unauthorized introduction of pesticides into fish frequented waters, either directly or indirectly, through airborne drift or surface runoff.

MIGRATORY BIRDS CONVENTION ACT

Under this Act, the Migratory Birds Regulations may be used to prosecute pesticide applicators for causing harm to migratory birds. It is an offence to allow the release of any substance harmful to migratory birds into waters or areas frequented by migratory birds. Pesticide applicators must be careful to not apply pesticides toxic to birds on land or water where exposure to migratory birds is possible.

FOOD AND DRUGS ACT

Under authority of this Act, the Health Protection Branch of Health Canada establishes maximum residue limits (legally permissible amounts of pesticide) that are considered to be safe levels of pesticide residues in or on foods intended for human use. The residues of pesticides remaining in foods depend on many factors, including the type of pesticide, amount applied, number of applications, climatic conditions, soil type and the interval between last application and harvest.

The Pest Management Regulatory Agency specifies the minimum number of days between pesticide application and harvest of food crops. This pre-harvest interval is based on application rates specified on the product label. Residues should remain below the maximum permissible levels if pesticides are applied according to current label recommendations and the appropriate pre-harvest interval is used. If applicators use higher rates of application, or harvest before the minimum harvest interval, excessive residue levels may be present in the harvested crop. Harvested crops that carry pesticide residue in excess of the maximum residue limit are subject to seizure by the Health Protection Branch.

PESTICIDE RESIDUE COMPENSTATION ACT

Farmers whose crops have been seized by the Health Protection Branch may be compensated under the Pesticide Residue Compensation Act. Compensation would only be granted if the pesticide application and the pre-harvest interval were in accordance with label directions.

PLANT PROTECTION ACT

This Act is the responsibility of Agriculture and Agri-Food Canada. The purpose of the legislations is to prevent the introduction or spread of insects, nematodes, plant diseases or other pests which may be destructive to Canadian agricultural of forestry crops. Agriculture and Agri-Food Canada can require the treatment of a serious pest outbreak with a specific pesticide.

BRITISH COLUMBIA'S LEGISLATION

INTEGRATED PEST MANAGEMENT ACT

The Integrated Pest Management Act (IPM Act) and Regulations establish conditions for the sale and use of pesticides in British Columbia through a pesticide classification system and regulatory provisions for licences, certification, permits, pesticide use notices and pesticide use notice confirmations. It also specifies reporting, monitoring and enforcement requirements.

The IPM Act and Regulations were brought into effect in December 2004 to replace the Pesticide Control Act. The main changes in the new Act are requirements for the use of integrated pest management (IPM) and for the development of pest management plans for large-scale commercial uses of pesticides.

Under the IPM Act, all pesticides used on public land, private land used for forestry, public utilities, transportation or pipelines, and all pesticides used by pest control service companies must be used as part of an IPM program. The IPM Act also requires that a person not sell, use, handle, release, transport, store, or dispose of a pesticide in a manner that causes or is likely to cause an unreasonable adverse effect.

Following is a summary of the IPM Act and Regulations, provided here for training purposes. The entire IPM Act and Regulations and related information can be accessed through the website http://wlapwww.gov.bc.ca/epd/epdpa/ipmp/index.html.

IPM Definition

The Integrated Pest Management Act defines Integrated Pest Management (IPM) as a process for managing pest populations that includes the following elements:

- planning and managing ecosystems to prevent organisms from becoming pests;
- identifying pest problems and potential pest problems;
- monitoring populations of pests and beneficial organisms, damage caused by pests and environmental conditions;
- using injury thresholds in making treatment decisions;
- suppressing pest populations to acceptable levels using strategies based on considerations of:
  - biological, physical, cultural, mechanical, behavioural and chemical controls in appropriate combinations, and
  - environmental and health protection; and
- evaluating the effectiveness of pest management treatments.

IPM Use

A licensee, permittee or pesticide use notice confirmation holder is required to conduct the following IPM activities as part of the process of using pesticides:

- attempt to prevent pest problems through non-chemical means where appropriate;
- correctly identify pest species or pest complexes to be managed;
- monitor to determine the presence and location of pests;
- determine treatment thresholds for each pest or pest complex, and use of these thresholds to determine when a pesticide may be used;
- select pest treatment methods based on consideration of practical alternatives to pesticides and the protection of human health and the environment; and
- evaluate the effectiveness of pesticide use.

Classification of Pesticides

The IPM Act and Regulations establish **classes** of pesticides, and requirements for licences, certification, permits and pesticide use notice confirmation for each class. The classification system utilizes definitions, labelling and other standards for sale and use of pesticides set out in the federal Pest Control Products Act.

Pesticide classes under the IPM Act are:

- **Permit Restricted**: most strictly controlled, requiring a permit for purchase or application;
- **Restricted**: requiring a pesticide applicator certificate for purchase or use;
- **Commercial**: labelled for commercial use, all sales and use must be recorded;
- **Domestic**: intended for use by non-professionals in or around private homes and gardens; and
- **Excluded**: specified pesticides are assigned to this class if the Administrator considers that there will be no significant increase in risk to human health or the environment by not requiring certification, licencing, permits or pesticide use notice confirmation for their use or sale.

See the table on the following page for a summary of requirements for each class of pesticide.

Pesticide Storage and Transportation

Pesticides must be stored in their original containers, or in properly labelled containers designed for pesticide storage. If a pesticide is not labelled by individual package, any drum or tank used for storage or transport must have a conspicuously displayed label that shows the active ingredient common name, the trade name, the pesticide concentration and the name of the manufacturer or owner.

All pesticides – other than domestic pesticides – must be stored separately from food intended for human or animal consumption in a facility with ventilation to remove vapours to the outside atmosphere, signage, access and security measures. A sign must be posted on the outside of each door giving access to the storage facility that states: "*Warning:* Chemical Storage – Authorized Persons Only" in clearly visible block letters.

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Fumigants, and other pesticides that release vapours with a high inhalation hazard (i.e., with a "danger poison" symbol on their label), are not to be stored in a facility that is within or attached to a building where people reside.

Domestic pesticides must be displayed or stored in a manner that separates the pesticides from food or drink intended for human or animal consumption.

Pesticides must be transported in a manner: that is sufficient to prevent escape, discharge or unauthorized removal of the pesticide from the transport vehicle; and that prevents contamination of food or drink intended for human or animal consumption, or of household items such as furnishings, clothes, toiletries, or bedding.

Summary of Requirements for each Class of Pesticide Under the IPM Act and Regulations

Requirements	Pesticide Classes				
	Permit-Restricted	Restricted	Commercial	Domestic	Excluded
Permit required for purchase and all uses	Yes	No	No	No	No
Applicator certificate required for purchase and all uses	Yes	Yes	No	No	No
Purchase must be recorded by Vendor	Yes	Yes	Yes	No	No
Pesticide use **licence** required for use on public land to manage pests of forests, structures, landscapes, or vegetation on industrial sites *	Yes	Yes	Yes	Yes	No
Pesticide use **licence** required for use on private forest land, in rooms occupied as living accommodation, or to the common area, in a multi-resident building	Yes	Yes	Yes	Yes	No
Pesticide Use Notice and confirmation of receipt of pesticide use notice required for specified pesticide use on public land (greater than 20 ha per yr) or private land used for transportation or public utilities	Yes	Yes	Yes	Yes	No
Service licence required for fee-for-service applications	Yes	Yes	Yes	Yes	No
Applicator certificate required to supervise applications to public land or on fee-for-service basis	Yes	Yes	Yes	Yes	No
Vendor licence required for selling	Yes	Yes	Yes	Yes	No
Dispenser certificate required for selling	Yes	Yes	Yes	Yes	No
Pesticide use **permit** required for uses of high concern (e.g., aerial application over urban areas)	Yes	Yes	Yes	Yes	Yes
Use must not cause an unreasonable adverse effect	Yes	Yes	Yes	Yes	Yes

Licences for Sale or Use of Pesticides

A **vendor licence** is required for the sale of any non-Excluded pesticides labelled or designated for domestic, commercial or restricted use.

A **pesticide use licence** is required for:

- any person or company who provides a service using pesticides;
- pesticide use on public land to manage:
  - pests of structures, or landscapes;
  - mosquito larvae using Bt on less than 1 ha/year;
  - invasive plants (noxious weeds) on less than 50 ha/year;
  - vegetation on industrial land on less than 20 ha/year;
  - forest pests on less than 20 ha/year of land used for timber production or that is forested;
  - to preserve less than 1000 wooden poles a year on highway or public utility rights-of-way;
- pesticide use on private land:
  - effective January 7, 2007, in rooms occupied as living accommodation, or to "common areas"[1] in

[1] an indoor area that may be accessed by all occupants, inside a private or publicly owned multi-residence building and outdoors, on a multi-residence property, within 5 m of a residence, or in areas used for recreation or resident passage.

a "multi-resident" building with four or more residences;
- to manage vegetation on less than 20 ha per year of land used for public utilities, transportation or pipelines; or
- to manage forest pests.

To be eligible for a licence, an applicant must:

- hold appropriate certification[2], or have one or more employees who hold such certification;
- have an office for conducting business with an address in BC; and
- identify the location where pesticides are stored, business is conducted and records kept.

The Administrator may suspend or revoke a licence for failure to comply with regulations. A licence is not transferable without the written authorization of the Administrator and a licensee may only sell pesticides at the place of business identified on the licence application. The Administrator is to be informed of a change of address in the licensee's place of business within 30 days of the change.

Certification for the Sale or Use of Pesticides

A **certificate** is required for any person:

- selling any pesticide other than excluded pesticides;
- using permit restricted or restricted pesticides;
- supervising the application of any pesticide, other than excluded pesticides, used by the holder of a licence, pesticide use notice confirmation or permit (information on pesticide use notice confirmation and permits is in following sections of this chapter).

To be eligible for certification or recertification, a person must be at least 16 years of age and have successfully passed a designated examination or completed specified continuing education requirements.

The main dispenser certificate categories are:

- domestic pesticides – to sell domestic pesticides;
- commercial pesticides – to sell any pesticides including those with commercial and restricted, and permit restricted classification.

The main applicator certificate categories are:

- agriculture – to manage pests and diseases of agricultural crops;
- forestry – to manage forest pests ;
- industrial vegetation and noxious weed – to manage weeds on highway, powerline, pipeline, public utility or railway rights-of-way and on industrial lands and to manage weeds designated as noxious under the Weed Control Act;
- landscape – to manage pests on and around ornamental plantings;
- mosquito and biting fly – to manage mosquitoes or biting flies;
- product fumigation – to manage pests of structures or stored products using fumigants; and
- structural - to manage insects, rodents and birds which invade or damage structures.

The sale or use of a pesticide classed as excluded does not require a certificate.

Licensees, pesticide use notice confirmation holders and permittees must ensure that pesticides are used or supervised by certified applicators who are certified in the appropriate category. A certified applicator may supervise no more than four uncertified staff and must be within visual or auditory contact and no more than 500 m away from the applicators being supervised. A copy of the certified individual's certificate must be available for inspection at the place and time of pesticide sale or use.

Pesticide Sales, Purchases and Use

A licensee must not sell a pesticide to a person who is under 16 years of age. Only a certified applicator or their agent may purchase a permit restricted or restricted pesticide.

Any licensee selling pesticides must ensure that a certified individual is available on the licensee's premises to:

- assist with pesticide handling, storage and emergency response;
- advise purchasers that pesticides can only be lawfully used to manage pests listed on the pesticide label and that label directions must be followed; and
- provide advice to purchasers regarding the use of IPM and safe use of a pesticide.

Pesticide Use Notices and Confirmation

The following uses of pesticides will require filing a pesticide use notice (PUN) with the Ministry of Water, Land and Air Protection and receiving back a confirmation of the notification prior to any pesticide use:

[2] see "Certification for the Sale or Use of Pesticides"

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- to manage forest pests for the production of timber on public lands where pesticides are applied to more than 20 ha per year;
- for managing mosquitoes using a bacterial pesticide on more than 1 ha of land per year;
- the management of mosquitoes other than with a bacterial pesticide;
- to manage invasive plants (noxious weed control) where the area of use is greater than 50 ha per year;
- to manage vegetation on railway rights-of-way, yards and associated facilities on more than 20 ha/year;
- to manage vegetation on road, power transmission, and pipeline rights-of-way on more than 20 ha/year; and
- to manage vegetation on other industrial sites on public land where the area to which pesticide is applied is greater than 20 ha per year;
- to preserve more than 1000 wood poles per year on highway or public utility rights-of-way.

A **PUN** must include the following information:

- name and contact information of the applicant;
- category of pest management;
- a description of the geographic area where pesticide use is proposed;
- a list of the active ingredients of the pesticides proposed for use;
- whether aerial application of a pesticide is proposed as a treatment method;
- the location(s) where detailed pest management plans (see below) may be viewed and copied;
- the maximum area, or the maximum number of poles, on which pesticide is to be used within any one calendar year;
- the fee appropriate to the maximum area, or maximum number of poles, on which pesticide is to be used within any one calendar year; and
- a declaration, signed by the applicant, that the pest management plan was prepared according to regulations, that pesticide use will be conducted according to regulations, and that IPM will be practiced.

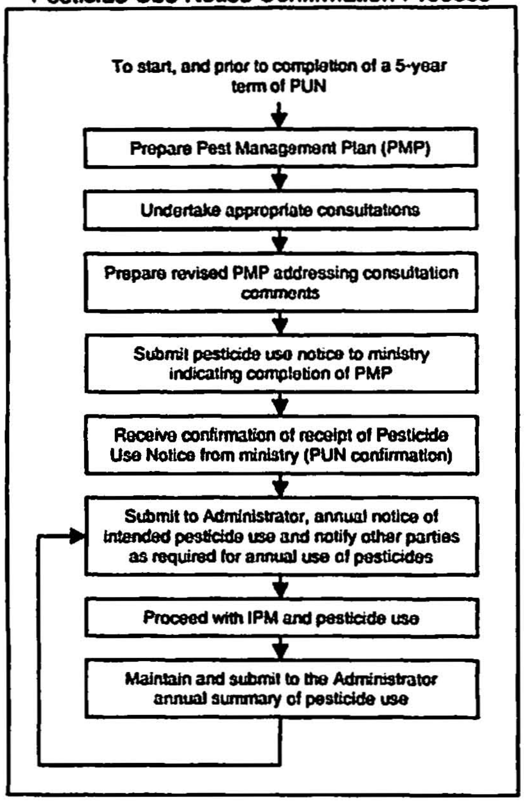
Pest Management Plans (PMP) required for a PUN must include details on the following:

- the geographic boundaries within which pest management will take place;
- maps of proposed pesticide use areas;
- the name of the person or legal entity responsible for managing the pests in the land area, principle contact and contact information;
- a description of the planning and management activities that will be used to prevent pest problems;
- the names of correctly identified targeted pest species or pest complexes;
- a description of the monitoring strategy (including methods, frequency of monitoring, and data to be collected);
- the specified thresholds to be used in deciding whether a pesticide treatment is warranted (including an explanation of how thresholds were determined and how they will be used);
- the treatment options (including a description of the pesticide and non-pesticide controls that may be used, the rationale for the selected control methods, the benefits and limitations of each control method, and a description of the decision making process for using differing treatment methods in different circumstances);
- a description of the monitoring strategy (including the data to be collected to evaluate the effectiveness in preventing pest damage and the extent of undesirable impacts);
- pesticide handling practices (including: transportation methods and precautions; safe storage, practices for mixing, loading and applying pesticides; procedures for the disposal of empty pesticide containers and residual products or mixed pesticide; and pesticide spill procedures);
- environmental protection practices (including: the strategy to protect community watersheds, and domestic and agricultural water sources, from pesticide contamination; the strategy to protect fish and wildlife, wildlife habitat and riparian areas from the effects of pesticides; the strategy to protect humans from consuming food or water contaminated by pesticide within the PUN area; procedures for maintenance and calibration of pesticide application equipment; and procedures to monitor weather conditions and how pesticide application will be modified in relation to weather conditions); and
- application procedures for each pesticide (including the application method to be used, and the type of application equipment and its deployment).

A PUN confirmation holder is required to submit to the Administrator an **annual notification** of intended pesticide use indicating proposed treatment(s) and location(s) of treatment, at least 21 days prior to the commencement of pesticide use for each calendar year of the term of the PUN confirmation. The notification must include diagrams, maps or map references of an appropriate scale to identify the locations of proposed pesticide use, and be consistent with the information in the associated PUN and confirmation.

The process of preparing and confirming a PUN is summarized in the chart on the following page.

Pesticide Use Notice Confirmation Process



Pesticide Use Permits

A **permit** for use of pesticides is required for:

- use of a permit restricted pesticide;
- aerial application of a pesticide[3];
- pesticide application on public land, or on a body of water that is not human-made and self-contained, other than those uses requiring a licence or PUN confirmation[4]; or
- pesticide use that requires a licence or PUN confirmation for which a deviation is requested from requirements for preparation of a PUN, consultation, notification or pesticide use[5].

[3] Except for aerial application on land used for agriculture or application of a pesticide whose main active ingredient is a biological organism, or glyphosate (if applied in accordance with requirements set out in a Pesticide Use Notice and PMP registration, or a licence). Aerial application of any pesticide over urban areas, however, does require a permit.

[4] This includes pesticide uses on public land for which no standards have been prescribed, unless the use is research that follows requirements under the federal Pest Control Products Act.

[5] The permit required in this case is for the deviation and would be in addition to the requirement for a licence or a PMP and PMP registration.

Permit applicants must:

- have an office with an address in B.C.;
- submit to the Administrator, proof that required consultation has been provided for;
- submit to the Administrator, a description of any proposed actions in response to comments received during consultation; and
- if required by the Administrator, submit a pre-treatment evaluation.

Public Consultation Requirements

Consultation with the public in regard to use of pesticides is required:

- by a **permit applicant**;
- as part of preparing a **PUN**; and
- by a licensee applying pesticides to more than 20 ha of land used for timber production, managed by a single entity.

These consultation requirements include:

- placing advertisements with specified information in newspapers in the vicinity of the proposed pesticide use area;
- making all reasonable efforts to contact and consult with individuals and organizations who may potentially be significantly impacted by the pesticide use activities proposed in the PMP;
- making the proposed and revised PMP available to any individual or organization that requests it from the proponent.
- allowing at least 30 days for individuals to respond to information provided to them;
- evaluating comments prior to finalization of plans or proposed actions;
- retaining records of: the newspaper advertisements used to publicize the proposed PMP; efforts made to contact relevant representative organizations; all public comments made in response to the proposed PMP; and the proponent's response to public comments;
- for private forest land, if pesticide is to be applied within 150 m of an adjacent property, notification must be given to the adjacent property owner, occupant or manager at least 14 days prior to pesticide use and must include a request for information concerning the location of any wells, water intakes or land uses that may require protection.

Note: It is anticipated that specific requirements to consult First Nations will be added to the *Integrated Pest Management Act* Regulations in 2005.

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Public Notification Requirements

The *Integrated Pest Management Act* regulations include requirements for notification of the public, property owners and residents prior to pesticide use by licensees, permittees, and PUN confirmation holders. The regulations also include specific requirements for notification of people who may enter the following treated areas:

- living accommodations;
- common areas[6] of multiple residence buildings; or
- outdoor landscaped public use areas[7].

Posted treatment notices for these areas are to have the following characteristics:

- signs posted in outdoor areas must be at least 550 cm^2 in size (i.e. letter size);
- signs posted in indoor areas be at least 200 cm^2 in size;
- be constructed of water-resistant material where exposed to potential rain or sprinklers;
- use type or letters of sufficient size and clarity to be clearly legible prior to entry into areas of pesticide use;
- contain a cautionary symbol (such as a stop sign or raised hand) that draws the attention of people that may enter the treatment area; and
- in bold letters state the words "NOTICE OF PESTICIDE USE" (or alternatively, the category of pesticide (e.g., "insecticide, "herbicide") in place of the word "pesticide").

Treatment notices for these areas must contain the following information:

- a description of the area to be treated;
- the name of the target pest;
- names of pesticides to be used including active ingredients and *Pest Control Products Act* registration number;
- date and start time of the proposed application;
- alternative dates and times of proposed application (if necessary);
- name and licence number of the service licensee and the phone number at which the licensee or an employee can be reached to obtain more information;
- precautions, including a statement that indicates the period of time following treatment during which people should not enter the treated area and any additional precautions needed to minimize exposure to the pesticides or residues; and
- days-to-harvest information where food crops are treated.

Specific notification requirements for other pesticide uses include:

a. PUN Confirmation Holders

- prior to pesticide use, clearly visible and legible signs are to be posted at each treatment area approach that is maintained for public access;
- the signs must not be removed for a minimum of 14 days following treatment;
- treatment notices must include:
  - the trade name or active ingredient of the pesticide that will be used;
  - the date and time of pesticide use;
  - precautions to be taken to prevent harm to people entering the treatment area;
  - the PUN confirmation number;
  - how to contact the PUN confirmation holder;
- notification must be given to those individuals or agencies who were offered direct notification during the consultation to finalize the PUN;
- prior to pesticide use for adult mosquito control the registrant must notify the public of the intended pesticide use by means of an advertisement in a newspaper circulated in the treatment area, radio broadcast, and/or direct notification of appropriate residents and property owners or managers.

b. Licensee use in living accommodations

- notices must be given in writing to the occupant and to the building owner or manager, or their representative at least 72 hours prior to the pesticide use;
- where an occupant cannot read English, notices must be written in a language that the occupant can read, or conveyed verbally in a manner understandable to the occupant;
- the time between treatment notice and treatment may be reduced, if agreed to by the occupant and building manager;
- for living accommodation that is unoccupied when treatment occurs, a treatment notice must be posted or notice given to any person who becomes an occupant within 48 hours after treatment.

c. Multi-residence common areas[9]

- the building manager, must been given a treatment notice at least 48 hours prior to pesticide use;

[6] "Common areas" include hallways and utility rooms in apartments and condominiums, outdoor areas within 5 m of a multi- residence building and trailers or campsites in trailer parks or campgrounds, and play areas or walkways of such properties.
[7] an outdoor landscaped area of public land that is maintained use for recreation or public passage.
[9] An indoor area that may be accessed by all occupants of a building with two or more residences, or an outdoor area of such a property that is within 5 m of a residence, or an area maintained for recreation or resident passage.

- each person with access to the common area must be given a treatment notice, or a treatment notice must be posted at each entrance to an indoor treated area and at all gates or openings leading to outdoor treated areas at least 48 hours prior to, and 48 hours following, pesticide application;
- if agreed to by all persons with access to the area, the time before treatment that a treatment notice must be provided may be reduced.

d. Multi-residence restricted access areas[10]

- the building manager must been given a treatment notice immediately following pesticide use; and
- a treatment notice must be posted immediately following pesticide use or a treatment notice must be given, prior to access, to anyone who may enter the treated area within 48 hours after the treatment.

e. Pesticide use under permit

- a copy of the permit and any relevant maps must be available for inspection by the public within the vicinity of the location where the pesticide is to be used;
- the permittee may also be required (under direction of the Administrator) to issue or publish a notice of the relevant details of the permit to those people who may be affected by the use of the pesticide;
- direct notification of specified groups or individuals may also be required.

Record Keeping Requirements

A. Sales Records

Licensees are required to maintain a **record of sales** of all pesticides except those pesticides classed as domestic or excluded. The record must include:

- the date of purchase;
- the purchaser's name, address and telephone number;
- for restricted or permit restricted pesticides, the purchaser's applicator certificate number;
- the certified dispenser's name and certificate number; and
- pesticide trade name, *Pest Control Products Act* registration number, container size and number of containers.

The records must be kept up to date, retained for at least three years, and available at the licensee's office location for examination by an inspector at any time.

An annual **summary of pesticide sales** must be submitted to the Administrator before April 1 of every year (for the previous calendar year's sales). The annual summary is to include information for all commercial, restricted and permit restricted class pesticides sold by the licensee, including: each product's trade name, *Pest Control Products Act* registration number and active ingredient; and the total litres or kilograms of each pesticide sold (by trade name).

B. Use Records[11]

Pesticide users are required to maintain records of pesticide use for each location and day of use that include:

- the client's name and address (when a pesticide is applied on a fee-for-service basis), or the name and address of the person who owns or manages the land where the pesticide is used (when a pesticide is applied on a non-service basis), or t
- the number of the permit, PUN confirmation or licence of the person for whom the service was performed, if applicable;
- the applicator's or supervising applicator's name and certificate number;
- the date and time of use;
- the name of the pest or purpose for using the pesticide;
- pesticide trade name and *Pest Control Products Act*; registration number;
- the method and rate of application and total quantity of each pesticide used;
- the temperature, precipitation and wind velocity and direction during outdoor applications;
- pest monitoring methods and treatment thresholds used to fulfill IPM requirements (unless recorded as part of a permit or PUN); and
- advice given to the owner, manager or occupant on the land or property where the pesticide was used, including the re-entry period, days-to-harvest information (where applicable), and any additional precautions taken to minimize exposure to the pesticide;
- a licensee who reduces the 30 m no-treatment zone around wells must record the information on which that decision was based;

[10] An indoor or outdoor area of a multi-residence property that is not being used for living accommodation and is not readily accessible to the general public or most building users. This would include a common area to which access can be restricted until after applicable post-treatment re-entry and ventilation periods have elapsed.

[11] Forms for recording and reporting pesticide use are available on the internet at: http://wlapwww.gov.bc.ca/epd/epdpa/ipmp/forms1.html

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information (where applicable), and any additional precautions taken to minimize exposure to the pesticide;
- a licensee who reduces the 30 m no-treatment zone around wells must record the information on which that decision was based;
- licensees who perform annual forestry pesticide applications on more than 20 ha of land managed by a single entity, and all PUN confirmation holders must also keep records of:
  - pest monitoring results including information on pest population levels and damage caused by pests;
  - the effectiveness and impacts of pesticide treatment;
  - how public notification was given and where notices were posted;
  - a summary of the public responses to the public consultation;
  - a summary of responses given by the licensee, PUN confirmation holder or permit holder;
  - equipment calibration records showing when the equipment was calibrated and the data upon which the calibration was based.

Records must be retained for three years from the date of pesticide use. The records must be made available upon request at the Licensee's or PUN Confirmation holder's office location for examination by an inspector at any time.

An **annual summary of pesticide use** must be submitted to the Administrator before January 31 of every year for the previous calendar year's use. The annual summary is to include information for all pesticides used including: each product's trade name, *Pest Control Products Act* registration number and active ingredient; and the total litres or kilograms of each pesticide used (by trade name).

The annual summary of a pesticide service licensee must provide separate records of the information required for those pesticides used for another licensee or permit or PUN confirmation holder and those pesticides used for a person who did not require a licence, permit or confirmation for the use.

Standards for the Protection of Human Health and the Environment When Using Pesticides

The IPM Act Regulations specify certain standards that apply to any person using pesticides. These include:

- pesticides must be used only in a manner that minimizes hazards to human health and the environment;
- no one may wash or submerge in a body of water, equipment or a container used to mix or apply a pesticide; and
- no one is to fill a container used for mixing or applying a pesticide directly from a body of water or irrigation system unless an air gap is maintained between the pesticide and the equipment used to draw the water.

All licensees and PUN Confirmation Holders will be expected to:

- apply pesticides only in accordance with integrated pest management principles;
- ensure that pesticide users working under supervision of a certified individual are informed of the treatment location, requirements for personal protection and the pesticide use procedures required to protect human health and the environment;
- ensure that all application equipment is in good working order and calibrated (if required) to ensure pesticides are used at pesticide label use rates;
- conduct an inspection of the treatment site to ensure that the applicable regulatory requirements and standards can be met;
- for aerial pesticide uses, the pilot will be expected to conduct a pre-treatment inspection of the proposed treatment area to ensure familiarity with the boundaries and other critical features of the target area);
- take precautions to prevent bystander exposure to pesticide spray;
- not apply a pesticide within 30 m of water wells and domestic water intake, unless it is determined with reasonable certainty by the licensee or PUN Confirmation holder, that water contamination will not occur;
- ensure that a minimum 10 m pesticide-free zone (measured horizontally) is maintained along all water bodies, classified wetlands[11] and wet or dry streams, unless otherwise prescribed;
- use the highwater mark of water bodies and watercourses as the starting point for measurement of pesticide-free zones;
- provide adequate no-treatment zones between the boundary of pesticide use and the pesticide free zone to ensure that the pesticide-free zones are maintained when pesticides are applied
- take appropriate precautions to ensure that pesticides are used in a manner that protects

[11] Classified wetlands are defined as a wetland in class W1, W2, W3, W4 or W5 prescribed under the *Forest and Range Practices Act*

- establish an appropriate distance between an outdoor pesticide treatment area and adjacent properties, to prevent release of pesticide spray or runoff into adjacent property;
- take appropriate precautions to avoid application of pesticides over vertebrate wildlife or domestic animals that are visible to the applicator;
- not apply outdoor pesticide sprays when wind speeds exceed 8 km/hr, based on wind speed measurements at the time and location of each use;
- conduct all outdoor pesticide spraying only during daylight hours between 30 minutes before sunrise and 30 minutes after sunset (with the exception of mosquito adulticiding);
- not use residual pesticides on any soils saturated with water, or when heavy rainfall is imminent or occurring;
- not spray pesticides on vegetation that has ice, frost or flowing water on target foliage (unless such use is specifically allowed for on the product label); and
- ensure that herbicide treatments are conducted in a manner sufficient to maintain vegetation needed to prevent stream bank erosion or debris transport that would result in significant downstream negative impacts to water bodies, and to prevent the loss of vegetation needed to maintain the stability of slide tracts.

In addition to the above standards for all licensees, **PUN confirmation holders** must ensure that, during pesticide use, all pesticide applicators have access to maps, diagrams or other appropriate visual indicators of the intended boundaries of pesticide use. These maps, diagrams, documents or visual indicators are to contain the location of any pesticide free zones, no-treatment zones and features that may require protection.

All **PUN confirmation holders** and **forest pest management** licensees must also conduct required monitoring activities on which treatment is based within 18 months prior to treatment.

A holder of a PUN confirmation for pest management on **railways and railway facilities** is specifically required to:

- apply pesticides using only ground operated application equipment;
- not apply pesticides to any *Rubus spp.* (raspberries and blackberries) that are greater than 3 m away from rails, signals and switch stands for the period from opening of flowers until the berries are predominantly dropped from the vines;
- when shrouded booms are used, not apply pesticides when wind speeds exceed 16 km per hour;
- not apply pesticides from a vehicle moving at a speed greater than 16 km per hour, except where shrouded booms are used (in which case the vehicle may move at a speed up to 30 km per hour);
- for the treatment of ballast and railway yards and individual tree treatments along the right-of-way, maintain a minimum 1 m no treatment zone along any temporary freestanding water body that:
  - is not fish bearing at any time of the year; and
  - does not drain into fish bearing waters[14]; and
- take sufficient measures to prevent pesticide deposition below the highwater mark of water bodies and streams when using wood preservatives on railways[15].

A licensee and holder of a PUN confirmation holder for control of **invasive plants** and **noxious weeds** must:

- not use herbicides intended for the control of invasive plants or noxious weeds beyond 1.5m of targeted plant species; and
- make efforts to identify and protect active release and collection sites of biological invasive plant control agents.

A licensee and holder of a PUN confirmation for use of pesticides for control of **mosquitoes** is required to:

- not use mosquito larvicides in permanent fish-bearing waters or in waters that have permanent direct surface water connections with fish-bearing waters;
- apply larvicides to water bodies only where water dip samples have confirmed the presence of larvae above established treatment thresholds;
- document the efficacy of larvicide use by pre-treatment and post-treatment larval samples;
- conduct spraying for adult mosquito control between sunset and sunrise;
- not use propoxur in wildlife management areas, wildlife or bird sanctuaries, ecological reserves, or other critical habitat; and
- advise residents within 200 m of ground based adulticiding operations, in writing at least 72 hours prior to the proposed treatment, of the proposed treatment and precautions to be taken to minimize exposure to the pesticide.

[14] This is an exception to the 10 m pesticide free zone required for pesticide uses in other situations.

[15] Use of wood preservatives on railways is exempted from other provisions pertaining to pesticide free zones, wind speed, signage requirements, application vehicle speeds and post-treatment inspection.

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Standards That Apply To The Use Of Particular Pesticides

Requirements for human health and environmental protection may be adjusted for individual pesticides if the product is proven to have such characteristics as low toxicity or low leachability, or if the product has characteristics that require specific directions for handling or application.

A. Glyphosate in situations other than forest vegetation management

A minimum 5 m pesticide free-zone must be maintained.along all water bodies that are fish bearing at any time of year, or drain directly to fish-bearing waters. This distance may be reduced to 2 m for:

- railway ballast, signal, switch and yard areas;
- other industrial areas to be maintained as vegetation-free; or
- when selective application methods are used.

The distance may also be reduced to 1 m for control of noxious weeds and invasive plants, provided that selective application methods are used between 1 m and 10 m from the highwater mark of applicable water bodies.

For non-fish bearing waters, glyphosate may be applied:

- up to 2 m from the highwater mark along all water bodies that are not fish bearing at any time of year and do not drain directly to fish-bearing waters;
- up to but not within the highwater mark of temporary free standing water bodies that are not fish bearing at any time of year and do not flow directly into fish bearing water bodies; or
- over dry streams that are not fish bearing at any time of year and do not drain directly into fish bearing water, at any time of year.

B. Glyphosate for forest vegetation management

A licensee or holder of a PUN confirmation for forest vegetation management is required to maintain a minimum 10 m pesticide free zone along all water bodies, streams and classified wetlands, except:

- for control of noxious weeds and invasive plants, in which case the minimum pesticide-free zones to be maintained can be reduced to 1 m, provided that selective application methods are used in areas between 1 m and 10 m from the highwater mark;
- along a water body or wetland that is non-fish bearing at any time, in which case the pesticide free-zone may be reduced to 2 m provided that selective application methods are used in areas between 2 m and 10 m from the highwater mark;
- along any temporary free-standing water body that is: not a wildlife habitat feature; is non-fish bearing; and does not drain into a fish bearing water body within 100 m, in which case glyphosate may be applied up to but not below the highwater mark;
- along any temporary free-standing water body that is: not a wildlife habitat feature; non-fish bearing; does not drain into a fish-bearing water body or stream within 100 m; and is either not a wetland or is less than 25 m^2, in which case glyphosate may be applied up to and within the highwater mark;
- along any dry stream that is not: a wildlife habitat feature; and not fish-bearing when wet, in which case glyphosate may be applied up to and within the highwater mark.

C. *Bacillus thuringiensis* var. *kurstaki (Btk)* and *Bacillus thuringiensis* var. *israeliensis* (*Bti*)

Specific provisions pertaining to protection of human health and the environment do not apply to the use of *Btk* and *Bti* by a licensee or holders of a PUN confirmation. These excluded provisions include those concerning: prevention of contamination of water; no treatment zones around wells; signage around vegetation; notification of graziers; and protection of vertebrate wildlife.

D. Use of fumigant gases

A licensee or holder of a PUN confirmation is required to:

- monitor every application of fumigant gases for leaks, treatment efficacy, safe re-entry conditions, and safe levels of human exposure (when fumigant is released into or immediately adjacent to buildings or spaces where people may be present);
- restrict entry to treated areas by unprotected persons until fumigant gas concentrations are determined by the certified applicator to be at safe levels; and
- ensure that any release of a fumigant gas into the atmosphere during aeration activities is done in a manner that prevents human exposure to hazardous concentrations of fumigant.

E. Rodenticide baits

A licensee or holder of a PUN confirmation will be required to apply rodenticide baits in a manner that ensures that unauthorized people and non-target animals cannot access them or that they are used in rigid-wall bait containers that are secured to prevent

unauthorized access, tipping or removal. When bait containers are used, the following information must be listed on the inside or outside of the container lid:
- the word "Poison";
- contact information for the applicator; and
- the pesticide active ingredient name and/or *Pest Control Product Act* registration number.

For applications in areas occupied as living accommodation, or in common areas that may be accessed by children, the applicator must ensure that the bait:
- contains a bittering agent, such as denatonium benzoate; and
- is removed from the treatment area after completion of a baiting program.

F. Use of slug bait in landscape pest management

A licensee or holder of a PUN confirmation will be required to deploy slug bait that may be hazardous to children, domestic animals or wildlife in bait stations that are resistant to tampering by children or animals, or to apply the bait in areas that are inaccessible to humans and bait-sensitive animals.

ENVIRONMENTAL MANAGEMENT ACT

The Environmental Management Act identifies powers of the Minister of Water Land and Air Protection This relates to pesticide use in an indirect way. Where the Minister considers that an environmental emergency exists (e.g. from a pesticide accident), the Minister may order that the hazard be reduced. The cost for this work will be charged to the person responsible for the environmental emergency.

The **Hazardous Waste Regulations** of the Environmental Management Act prohibits the introduction of wastes into the environment. Disposal of empty pesticide containers and pesticide contaminated rinse water is regulated under the Regulation. It requires that pesticide containers must:
- be emptied;
- rinsed out as specified (details are given in Chapter 5 under disposal of pesticide containers);
- recycled or disposed of in an approved landfill (details are given in Chapter 5).

Waste produced by cleaning pesticide application equipment or by rinsing product containers must be used in mixing a product solution for pest control use.

The Environmental Management Act also establishes that an Environmental Appeal Board will hear appeals to decisions under any provincial environmental regulations.

MUNICIPAL AND REGIONAL DISTRICT LEGISLATION

Within the province, a number of regional districts, municipalities and towns have bylaws regarding the use of pesticides and the control of weeds, insects, plant diseases and rodents. Applicators should inquire about local bylaws dealing with pests or pesticide use which might be important in their type of pest control.

TRANSPORTATION OF DANGEROUS GOODS ACT

The Transportation of Dangerous Goods Act and Regulations, administered In British Columbia by the Ministry of Public Safety and Solicitor General, are intended to protect people and the environment from the hazards of accidental spills of dangerous goods. Among other things, the regulations require that:
- people transporting dangerous goods be properly trained and certified;
- a shipping document (including the proper shipping name, UN number, class and packing group) describes the dangerous goods;
- safety marks such as labels and placards are used to provide visual clues about the hazards of the dangerous goods; and
- emergency actions protect people and the environment in case of a spill or leak.

Everybody who transports pesticides on public-access roads must familiarize themselves with the requirements applicable to the specific pesticides and quantities of pesticides they will be transporting. Some pesticides are not considered dangerous goods under the regulations but specific requirements do apply to the transportation of other pesticides. To determine if a pesticide is considered a dangerous good or not, consult your pesticide distributor and the Canadian MSDS.

The Transportation of Dangerous Goods regulations can be viewed on the web site: http://www.qp.gov.bc.ca/statreg/reg/T/203_85.htm

The BC regulations adopt most of the federal regulations which can be viewed at: http://www.tc.gc.ca/acts-regulations/GENERAL/T/tdg/regulations/tdg001/part_1.htm.

WEED CONTROL ACT

The Weed Control Act is the responsibility of the Ministry of Agriculture, Food & Fisheries. This act makes it a requirement to control and prevent spread of weeds designated as noxious in the province or in specific regional districts. Noxious weeds are generally those which pose a threat to farm crops. Inspectors may request that noxious weed control be performed on specific properties and, if no action is taken, can have the work done and the costs charged to the landowner.

WILDLIFE ACT

This Act is the responsibility of the Wildlife Program of the BC Ministry of Water Land and Air Protection. It states that is an offence to destroy or damage wildlife or wildlife habitat in a wildlife management area and that a poison may not be used to hunt or kill birds, threatened or endangered animals or fur bearing animals or game species. The only exception is when a pesticide is used for an approved predator control program conducted by staff of the Wildlife Program.

WORKERS' COMPENSATION ACT

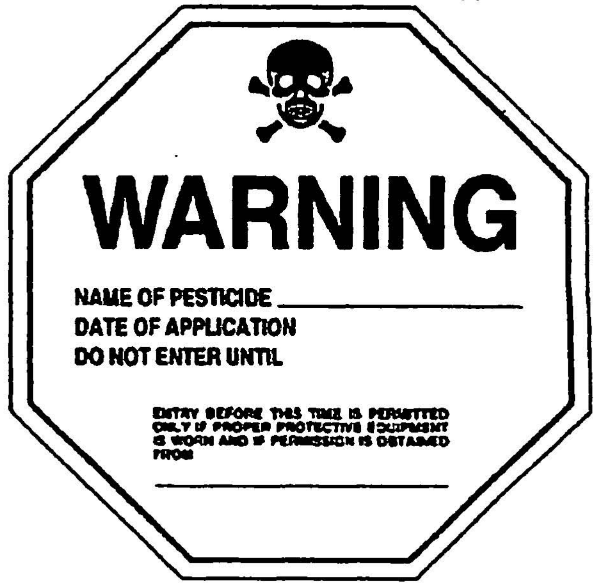
Under authority of the Workers' Compensation Act, the Workers' Compensation Board (WCB) enforces the Industrial Health and Safety Regulations. These Regulations apply to work places governed by the Workers' Compensation Act. Sections of these Regulations deal with pesticides.

The Regulations require, among other things, that:

- workers applying moderately toxic or very toxic pesticides hold a valid pesticide applicator certificate or be training to become certified;
- workers be equipped with and wear appropriate protective clothing;
- at least one change of outer clothing be available for each worker at the mixing and loading site;
- shower facilities be available for applicators;
- pesticide MSDS are readily available to all workers;
- written procedures are developed for handling and cleanup of pesticides;
- appropriate warning signs are posted[16];
- restricted entry intervals are enforced.

Industrial Health and Safety Regulations specific to pesticide use can be viewed on the web site http://regulation.healthandsafetycenter.com/s/Part6.asp#SectionNumber:6.70.

Figure 9. WCB acceptable entry warning sign for an area where pesticide has been applied



Note: Figures 4 – 8, inclusive, were removed during the 2004 editing of this chapter.

[16] Whenever a field or enclosed structure is sprayed with a moderately toxic or very toxic pesticide, the employer must post suitable warning signs at normal points of entry before spraying begins. The signs must have a danger (skull and crossbones) symbol and must indicate the pesticide used, the date sprayed, the re-entry date and emergency telephone numbers (see Figure 9)

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Questions

1. What federal Act requires registration of pesticides?
2. Does a pesticide manufacturer have to show efficacy as well as human safety when applying for product registration?
3. Is an applicator limited to uses listed on a pesticide label?
4. What precautions are required when applying pesticides to ensure compliance with the Fisheries Act?
5. Could a pesticide applicator be held responsible for harming birds which land in treated fields?
6. What are 'maximum residue limits', who sets them, and what happens if they are exceeded in food crops?
7. How do you determine what procedures are required for transport of a specific pesticide under the Transportation of Dangerous Goods Regulations?
8. What is the provincial Act that regulates pesticide use in B.C.?
9. In B.C., permit restricted class pesticides are the (most or least) hazardous? What is required to purchase these pesticides?
10. Can anyone sell domestic class pesticides in B.C.?
11. When must a pesticide use notice be confirmed?
12. Who needs a pesticide use licence to apply pesticides in B.C.?
13. Is it necessary for a pesticide use licence holder to keep a daily record of pesticide use?
14. Who requires certification to apply pesticides in B.C.?
15. When is a pesticide use permit required?

Answers

1. Pest Control Products Act
2. Yes. Registration of a new product requires data on safety to humans and the environment as well as data to show it will be effective for specified uses.
3. Yes. A pesticide may not be used for purposes not listed on the label.
4. An applicator must prevent contamination of a water system where there is any possibility of harming fish or fish habitat.
5. Yes. Under the Migratory Birds Regulations, it is an offence to harm migratory birds. Also, it is an offence under the Wildlife Act to kill any wildlife without authorization.
6. Maximum residue limits are set by Health Canada and are the maximum levels of pesticides in foods which are considered safe for human consumption. If these limits are exceeded, crops are subject to seizure by the federal Health Protection Branch.
7. All people transporting dangerous goods must be trained and certified. Training addresses required procedures for transportation of dangerous goods. To determine if a particular pesticide is considered a dangerous good or not, consult the MSDS and the pesticide distributor.
8. Integrated Pest Management Act.
9. Most Hazardous; a pesticide use permit and an applicator certificate are required to purchase permit-restricted pesticides.
10. No, Domestic Class pesticides must be sold by a certified pesticide dispenser.
11. A PUN plan must be confirmed before a pesticide is used: on more than 20 ha of public land per year; to manage vegetation along transportation or public utility rights-of-way on more than 20 ha per year; to control adult mosquitoes on public land or mosquito larvae in bodies of water larger than 1 ha that are not human made and self-contained; and to manage invasive weeds where the area of use is greater than 50 ha per year.
12. Any individual or company or agency that applies pesticides: to public land to manage pests of structures or landscapes, or vegetation on industrial sites where the treatment area is less than 20 ha per year; on private land in rooms occupied as living accommodation, or to the common area in a multi-resident building; or on a fee-for-service basis.
13. Yes.
14. An applicator certificate is required by any person using permit restricted or restricted pesticides; the pilot of an aircraft applying a pesticide; or performing duties under a licence, permit or PUN confirmation.
15. A pesticide use permit is required for: use of permit restricted pesticides; aerial application of a pesticide (other than to farm land); and any pesticide application on public land or body of water that is not human-made and self contained except those applications requiring a licence or PUN confirmation.

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SECTION II

HUMAN SAFETY CONSIDERATIONS

Chapter 4

PESTICIDE TOXICITY AND HAZARD TO HUMANS

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CONTENTS

INTRODUCTION

Toxicity is defined as the capacity of a substance to poison animals or plants. Poisons work by altering normal body functions. The biochemical changes caused by a particular substance may produce characteristic symptoms seen or felt in a certain part of the body.

It has been said that all substances can be poisonous; everything becomes a poison if absorbed in excessive quantities. Such common substances as coffee or salt become poisons if large amounts are consumed. Thus, toxicity is a function of both the severity of the ill-effects and the amount of substance which has to be consumed before any effects occur. A highly toxic substance causes severe symptoms of poisoning with small doses. A substance with a low toxicity generally requires large doses to produce mild symptoms.

The symptoms of pesticide poisoning in humans can be mild, e.g. headaches and nausea or they can be severe, e.g. convulsions, coma or death. Most toxic effects are reversible and do not cause permanent change, although complete recovery could take some time. Some toxic effects are irreversible and cause permanent damage.

Toxicity can be either acute or chronic. **Acute toxicity** is the capacity of a substance to cause ill-effects which develop rapidly following absorption, i.e. a few hours or a day. **Chronic toxicity** is the capacity of a substance to cause ill-effects which develop slowly and last a long time after exposure, i.e. months or years.

Pesticides are developed for their toxicity to certain undesirable forms of life. There is a great range in their toxicity to humans. Persons who handle pesticides should understand the nature and degree of their toxicity and how to prevent harm to themselves and the environment.

Pesticide applicators should know the hazards and risk associated with the pesticides they use. A **hazard** can be simply defined as a source of danger. The hazard in using a pesticide is partly determined by its toxicity; but is also determined by the likelihood that humans or the environment may be exposed to harmful concentrations of the pesticide. The likelihood of exposure depends on a number of factors such as the amount of pesticide used, concentration of the pesticide and how the pesticide and application equipment are handled to prevent exposure. A pesticide can be highly toxic as a concentrate, but pose little hazard to the user if (a) used in a very dilute formulation, (b) used in a formulation not readily absorbed through the skin or inhaled, (c) used only under conditions of no human exposure, or (d) used by experienced applicators who are equipped to handle the pesticide safely. By comparison, a pesticide may have a relatively low mammalian toxicity but present a hazard because it is used in the concentrated form which may be readily absorbed or inhaled.

Risk is defined as the likelihood that a worker or the environment may be harmed during a particular operation. There is little risk in handling a pesticide where the hazards have been minimized.

The hazards associated with pesticide exposure and toxicity are discussed below in this Chapter.

HUMAN PESTICIDE EXPOSURE

There are three ways in which pesticides can enter the human body: through the skin (dermal), through the mouth (oral) and through the lungs (respiratory or inhalation).

Dermal Exposure. In typical work situations, skin absorption is the most common route of poisoning from pesticides. This absorption may occur as a result of a splash, spill or drift when mixing, loading or applying a pesticide. It may also result from exposure to residue on

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application equipment, protective clothing or treated surfaces after pesticide application. The dermal toxicity of a pesticide depends on the pesticide formulation, the site of contamination and the duration of the exposure. In general, pesticides formulated as wettable powders, dusts or granules are not absorbed as readily through the skin as liquid formulations. The hazard from skin absorption increases when workers are mixing pesticides because they are handling concentrated pesticides that contain a high percentage of active ingredient.

Certain areas of the body such as the genital area and eyes absorb pesticides easily and rapidly. Absorption is a particular hazard through cut or abraded skin on the hands or face. A cut can greatly increase pesticide absorption.

The tissues of the eyes are particularly absorbent. Besides the potential for chemical injury to the eye itself, some pesticides may be absorbed in sufficient amounts through the eyes to result in serious or even fatal illness. Eye protection is needed when measuring or mixing concentrated or highly toxic pesticides. Protective face shields or goggles should be worn whenever there is a chance that pesticide sprays or dusts may come in contact with the eyes.

Oral Exposure. While skin absorption is the most common means of exposure, the most severe poisonings usually result when pesticides are taken in through the mouth. The most frequent cases of accidental oral exposure are those in which pesticides have been taken from their original labelled container and put into an unlabelled bottle or food container. There are many cases where people, especially children, have been poisoned by drinking pesticides from a soft drink bottle. Adults have mistakenly drunk from bottles containing pesticides or have been poisoned by drinking water stored in contaminated containers. Workers handling pesticides or application equipment can also consume excessive levels of pesticides if they do not wash their hands before eating or smoking. Applicators must never try to clear a spray line or nozzle by blowing on it while holding it to their mouth.

Respiratory Exposure. Certain pesticides may be inhaled in sufficient amounts to cause serious damage to nose, throat and lung tissues, or to be absorbed through the lungs into the bloodstream. The hazard of poisoning from respiratory exposure is great because of the rapid and complete absorption of pesticides through lung tissues.

Lungs may be exposed to pesticides by inhalation of powders, airborne droplets or vapours. Working with wettable powders can be hazardous because the powder may be inhaled during mixing operations and usually contains concentrated pesticide active ingredient. The hazard from inhalation of pesticide spray droplets is fairly low when dilute sprays are being applied with conventional low pressure application equipment. This is because most droplets are too large to remain airborne and be inhaled. However, when high pressures are used or ultra low volume (ULV) or fogging equipment are used, the potential for respiratory exposure is increased. The droplets produced during these operations are in the mist or fog size-range and can be carried on air currents for a considerable distance.

Many pesticides give off a vapour when exposed to air. Fumigants are used because their toxic vapours are desirable for pest control. They also have the highest hazard with respect to worker exposure to vapours. Some non-fumigant pesticides are toxic to pests as liquid or solid formulations, but also give off vapours which could be toxic to applicators or bystanders. The Workers' Compensation Board has established maximum permissible levels in the air for approximately 100 pesticides (W.C.B., 1985. *Standard Practices for Pesticide Applicators*). Some pesticides emit vapours that could exceed the maximum W.C.B. permissable levels under certain still air conditions (e.g. fumigants, fensulfothion, demeton, mevinphos, diazinon, disulfoton, carbaryl, parathion and chlorpyrifos). The hazard is greatest in enclosed spaces where there is little air movement. For example, high vapour levels could result from a spill in an unventilated storage area or application in a confined space such as a greenhouse. Air currents due to wind or ventilation can substantially reduce vapour levels.

Many pesticides that produce vapours provide a warning of their presence by their smell or by causing irritation of the eyes, nose and throat. However, some pesticide vapours have little smell and provide little warning of their presence.

As temperatures increase, vapour levels of many pesticides increase. This is why it is recommended that pesticides should not be applied when air temperatures are above 30°C.

Pesticides with high vapour hazards will have label directions to use respiratory protection equiment. It is important to use respirators if required on the label or if pesticides are used or mixed in poorly-ventilated areas or if there is a possibility of inhalation of pesticide mist or powder.

Toxicity of pesticides can vary depending on the type of exposure — dermal, oral or respiratory (inhalation), but it is important to remember that, in each case, the danger usually increases as concentration and duration of exposure increases. The longer a pesticide remains on the skin or in eyes, or the longer it is inhaled, the greater the damage that is likely to result.

In addition to route of entry into the body, there are two other ways that exposure is described: short-term (acute) or long-term (chronic) exposure.

Acute exposure refers to intake of a single dose or to a series of exposures within a short time period (e.g. one day). Acute exposures may be referred to as acute dermal, acute oral or acute inhalation poisoning. Usually the effects of acute exposure, if any, occur within 24 hours.

Chronic exposure is the exposure to pesticides over an extended period of time, such as where a pesticide applicator is frequently wetted with spray during unsafe spray practices. Pesticides which have a tendency to accumulate, or which break down slowly in body tissues, usually represent the greatest chronic exposure hazard. Someone who is frequently exposed to low doses of such pesticides may develop symptoms of poisoning long after the first exposure. Chronic exposure may be referred to as chronic oral, chronic dermal or chronic inhalation poisoning.

MEASURING ACUTE TOXICITY

In order to understand how toxic some pesticides are, it is important to know the way in which toxicity is measured and rated. One of the first questions scientists ask when developing a new pesticide is: how toxic is it to animals and humans following an acute exposure, i.e. a single dose? To answer this question, the pesticide is administered to test animals. Usually rats, guinea pigs, rabbits and dogs are used. The pesticide is applied to the skin (dermal exposure), fed by mouth (oral exposure) or inhaled (inhalation exposure) by the animal. In preliminary tests of a number of individual animals, scientists find a dosage or amount of the pesticide which will make some of the animals sick and cause a few to die. From such tests, scientists determine the **threshold of toxicity**, which is the lowest dose which will cause symptoms of poisoning in one or more test animals. Then other tests are performed to determine the amount of pesticide required to kill one half of the animals exposed to a specific dose. The amount of pesticide, administered in one dose, required to kill 50 percent of a test population is called the 'lethal dose to 50 percent' (LD_{50}), or 'lethal concentration to 50 percent' (LC_{50}). These values are statistically determined for test animal species under controlled laboratory conditions.

LD_{50}. The LD_{50} value is a measure of the toxicity of a pesticide applied to the skin or taken orally. The larger an animal, the greater the lethal dose required to kill it. Therefore, LD_{50} is expressed as milligrams of pesticide per kilogram of animal body weight. For example, assume the LD_{50} for a species of test animal is 10 mg/kg. If the test animals weigh 2 kg each, the lethal dose to kill 50% of these animals would be 10 mg/kg x 2 kg = 20 mg each. If the test animals weigh 25 kg each, the lethal dose to kill 50% of these animals would be 10 mg/kg x 25 kg = 250 mg each.

LC_{50}. The LC_{50} value for mammals is a measure of the toxicity of a pesticide when test animals breathe air mixed with pesticide dust, vapours or spray mist. The LC_{50} is the concentration of pesticide which is lethal to 50% of an animal population and is usually determined for a specific exposure period (e.g. inhalation for 4 hours). The duration of exposure is important because shorter exposure periods generally require higher pesticide concentrations to produce toxic effects. LC_{50} values for pesticides in air are expressed as the ratio of pesticide to air, in parts per million (ppm) or parts per billion (ppb). (LC_{50} values are also established for fish and aquatic organisms based on the concentration of pesticide in water for exposure periods of 24 to 96 hours, discussed in Chapter 22.)

There are several important characteristics to note about LD_{50} and LC_{50} values:

- they are based on a single dose (LD_{50}) or short exposure (LC_{50});
- they do not indicate cumulative effects of small doses;
- they are an indicator of the amount of chemical required to kill or severely injure animals, and do not indicate the amount of chemical causing less severe toxic effects; and
- the **smaller** the LD_{50} or LC_{50} value, the **greater** the toxicity (i.e. a pesticide with an LD_{50} of 5 mg/kg is 100 times **more** toxic than a pesticide with an LD_{50} of 500 mg/kg).

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LD_{50} and LC_{50} values are usually derived from tests using the active ingredient of a pesticide. The toxicity of a pesticide product which contains an active ingredient plus a carrier would generally be less than the toxicity of the active ingredient alone. A dilute spray would be even less toxic.

The acute oral LD_{50} value of a pesticide can be used to roughly estimate the amount of pesticide which might cause severe symptoms of poisoning to someone accidentally swallowing it, i.e. acute poisoning resulting from a single dose.

Example: The insecticide active ingredient, diazinon has an acute oral LD_{50} to rats of 300 mg per kilogram of body weight (mg/kg). A 70 kg person would be severely poisoned if he consumed 70 kg x 300 mg/kg = 21,000 mg = 21 g of active ingredient.

If a diazinon product contained 125 g/L active ingredient, a 70 kg person would be severely poisoned if he consumed

$$\frac{21\text{ g}}{125\text{ g/L}} = 0.168\text{ L} = 168\text{ mL of product.}$$

If the product was mixed in a spray solution of 100 mL/10 L of spray, then a person would be severely poisoned if he consumed

$$\frac{168\text{ mL}}{10\text{ mL/L}} = 16.8\text{ L of spray.}$$

Toxicological research has shown that the susceptibility of mammals to pesticides varies with the species, age, sex and nutritional state of the animals being tested. Therefore data on the toxicity of pesticides to test animals can only serve as a guide to the probable toxicity of a pesticide to an individual person. The LD_{50} values of some pesticides for rats and dogs could be quite inaccurate for predicting the lethal dose for birds or humans. However, LD_{50} values are very useful in classifying pesticides according to one measure of their toxicity. They also indicate how carefully some pesticides must be handled.

As a general guide, the approximate dose which would cause severe injury or death to an average human adult is illustrated in Table 4 for various LD_{50} ranges. On

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this basis, pesticides are classified into groups of low, moderate and high acute toxicity (Table 5).

Table 4. Relation of oral LD_{50} to approximate lethal dose in adult humans.

Oral LD_{50} of active ingredient	Approximate lethal dose to average size adult[1]
less than 5 mg/kg	less than 0.3 mL (one to two drops)
5 to 50 mg/kg	0.3 to 3 mL (a few drops to half a teaspoon)
50 to 500 mg/kg	3 mL to 30 mL (half a teaspoon to two tablespoons)
500 to 5,000 mg/kg	30 mL to 300 mL (1 to 10 fluid ounces)
5,000 to 15,000 mg/kg	300 mL to 900 mL (10 to 30 fluid ounces)

[1] Note that a larger amount of pesticide would have to be consumed to obtain a lethal dose if the active ingredient was diluted as in most formulated products and spray solutions.

Table 5. Relative toxicity of pesticides to humans based on acute oral and dermal LD_{50}'s.

Toxicity	Oral LD_{50}	Dermal LD_{50}
High	less than 50 mg/kg	less than 200 mg/kg
Moderate	50 to 500 mg/kg	200 to 1,000 mg/kg
Low	over 500 mg/kg	over 1,000 mg/kg

Acute toxicities for most pesticide active ingredients used in British Columbia are given in the reference list of pesticides at the end of Chapters 8 to 17 and in Appendix III of this Handbook.

It may be useful to compare the LD_{50} of certain pesticides with the LD_{50} of substances commonly used by people in their homes. The following three compounds have a low acute toxicity in terms of the rating for pesticides, but could cause toxic reactions if consumed in sufficient quantities.

Compound	Oral LD_{50} (mg/kg)
acetylsalicylic acid (Aspirin)	1,000
sodium chloride (table salt)	3,320
ethylene glycol (antifreeze)	3,460

MEASURING CHRONIC TOXICITY

The symptoms of chronic toxicity develop slowly and persist for a long time after exposure. Such symptoms may occur in three ways:

1. As a complication of acute poisoning. For example, a severe exposure to the herbicides paraquat or diquat causes acute effects such as nausea, chest pain and vomiting as well as chronic effects resulting from kidney, liver and lung damage.
2. As a slowly progressive condition, without any incident of acute poisoning. For example, increased breathing difficulty or skin sensitization (allergy) after repeated use of a pesticide.
3. As the occurrence of a disease or condition initiated by previous exposure. For example, the development of cancer years after a period of exposure.

Very few pesticides now in use are known to cause chronic effects, if used according to label directions. However, a few pesticides are suspected or known to cause chronic illness in test animals or humans, when exposure levels are high. The registration of some pesticides has been cancelled because the suspected or identified chronic effects represented a significant health hazard.

Some chronic toxicity effects have been detected in applicators, usually in relation to pesticide misuse. Symptoms have included loss of appetite, skin rash, weight loss, headaches and respiratory problems. Some pesticides such as organochlorines can accumulate in fatty tissues with repeated exposure to small doses. If released from storage as a result of fat depletion, these pesticides may produce symptoms similar to those following acute exposure (nausea, tremors, muscular weakness). The organophosphorous pesticides are not stored in body tissues but they interfere with the production of enzymes necessary for the function of the nervous system. One or two small exposures may produce no toxic symptoms, but repeated small exposures over a two to three week period may have a cumulative effect and may produce serious chronic effects.

It is not possible to assess chronic toxicity of a pesticide in the same way as an LD_{50} or LC_{50} is used to determine acute toxicity. Instead, a number of different tests are performed on animals which help to predict whether a pesticide will cause a number of possible long-term effects. Test animals are exposed to sublethal levels of pesticides for periods ranging from about 90 days to several years. They are examined for a wide variety of toxic effects from dermal, oral and respiratory exposure. Such effects include:

- carcinogenesis — the production of tumors (cancer),
- teratogenesis — the production of birth defects in developing fetuses,
- mutagenesis — changes in the reproductive cells which are passed on to future generations, and
- reproductive effects — changes in fertility.

Evidence of chronic effects is usually associated with long-term exposure of test animals to relatively high doses. Thus people who run the greatest risk of developing any chronic effects are workers involved in the manufacture of chemicals or applicators exposed to high levels of pesticides over many years.

If symptoms of chronic toxicity develop in humans, they may not be recognized as having been caused by exposure to a toxic chemical months or years in the past. The levels of exposure which might cause chronic effects in a human individual are very difficult to predict. Thus anyone handling pesticides should attempt to minimize their exposure and eliminate the possibility of chronic effects.

PESTICIDE LABEL HAZARD SYMBOLS

Precautionary symbols are required on many pesticide labels to identify the severity of the acute or chronic toxicity of the product. These are the danger, warning or caution — poison symbols. The type of symbol required is determined from six characteristics as shown in Table 6. Thus a 'danger poison' symbol is required if the pesticide has one or more of the following characteristics: an acute oral LD_{50} less than 500 mg/kg, an acute dermal LD_{50} less than 1,000 mg/kg, respirator is required, eye protection is required, chronic effects may be fatal or irreversible or it contains 10% or more petroleum distillates. No symbol is placed on a label if there is no significant toxicity to humans.

The LD_{50} values referred to in Table 6 are for the formulated product. When the precautionary symbol is being selected for a particular product, the product LD_{50} is estimated from the concentration of active ingredient in the product, or the product LD_{50} is obtained from laboratory testing of the product itself.

Table 6. Interpretation of precautionary poison symbol and shapes used on pesticide labels. The shape indicates a pesticide has one (or more) of the characteristics indicated below.

POISON HAZARD SYMBOL — the shape indicates one (or more) characteristics below	 DANGER POISON	 WARNING POISON	 CAUTION POISON
acute oral LD_{50}	less than 500 mg/kg	500—1,000 mg/kg	1,000—2,500 mg/kg
acute dermal LD_{50}	less than 1,000 mg/kg	1,000—2,000 mg/kg	2,000—5,000 mg/kg
respirator	required	advisable in confined spaces	advisable in confined spaces
eye effects	corrosive/irreversible	severe/reversible	irritant
chronic effects	fatal/irreversible	non-fatal/irreversible	non-fatal/reversible
petroleum distillates	10% or more (Domestic products)		

CHAPTER QUIZ

Questions

1. Explain the difference between acute and chronic toxicity.
2. Explain the difference between toxicity, hazard and risk.
3. Name the three ways pesticides can enter the body and which is the most common route of poisoning.
4. Which is the most frequent cause of oral poisoning?

Answers

1. Acute toxicity is the capacity of a substance to cause ill-effects which develop rapidly following exposure. Chronic toxicity is the capacity of a substance to cause ill-effects which develop slowly and last a long time after exposure.
2. Toxicity is the capacity of a substance to cause ill-effects; hazard is the danger in handling a substance, i.e. the possibility of being exposed to toxic amounts; risk is the likelihood a person will be harmed.
3. Dermal exposure is the most common route of poisoning; other ways of exposure are oral and respiratory.
4. The most frequent cause of oral poisoning is accidental drinking from unlabelled containers containing pesticides.

5. Why is respiratory exposure so dangerous?

5. Respiratory exposure is dangerous because nearly 100% of pesticide in contact with lung tissues is absorbed.

6. What is the source of (a) pesticide mist, (b) pesticide vapour?

6. Pesticide mist is produced when tiny droplets of pesticide are carried by air currents; vapours are produced when fumigants are applied or when some solid or liquid pesticides evaporate.

7. Explain the difference between acute exposure and chronic exposure.

7. Acute exposure is exposure to a single dose or series of doses over a short time, i.e. one day. Chronic exposure is exposure over an extended time period, i.e. months or years.

8. Why does the LD_{50} value of a pesticide for rats only roughly approximate the toxicity of a pesticide to other animals, including humans?

8. The susceptibility of animals to pesticides varies with the species, age, sex and condition of animals being tested and may not be accurate for humans.

9. Do LD_{50} values measure acute or chronic toxicity?

9. Acute toxicity.

10. If the LD_{50} value is small, is the toxicity high or low? Why?

10. If LD_{50} values are small, then toxicity is high. The LD_{50} measures the amount of pesticide required to kill an animal, i.e. if little is required, toxicity is high.

11. Is the toxicity of a product generally greater or less than the toxicity of the active ingredient?

11. The toxicity of a pesticide product is usually less than the toxicity of the active ingredient.

12. If the oral LD_{50} of a pesticide is 50 to 500 mg/kg, how much of this substance would cause severe injury or death if ingested by an adult human?

12. About 3 to 30 mL (half a teaspoon to 2 tablespoons) would be severely toxic.

13. Name a symptom (effect) resulting from chronic toxicity.

13. Severe chronic effects would include carcinogenic, teratogenic, mutagenic or reproductive effects, liver, kidney or lung damage; less severe chronic effects would include headaches, skin rash or weight loss.

Chapter 5

SAFE HANDLING OF PESTICIDES

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CONTENTS

INTRODUCTION

Pesticides can poison people, pets and livestock; they can harm beneficial insects, birds, fish and wildlife, and they can damage desirable plants. It is necessary to maintain careful and continuous control over the use and handling of these chemicals. Special precautions are necessary should pesticides be spilled or should storage facilities catch fire.

In this chapter, procedures are described for the transport, storage, mixing, application and disposal of pesticides and handling of pesticide spills and fires. Details about personal protective clothing and safety gear are described separately in Chapter 6 and first aid procedures are described in Chapter 7. More guidelines to protect the environment during specific types of pesticide application are listed in Chapter 23.

TRANSPORTING PESTICIDES

The transport of pesticides is regulated provincial legislation (see Chapter 3). The Transportation of Dangerous Goods Act may require shipping documents, safety marks, vehicle placards, emergency response plans and safety training. The provincial Integrated Pest Management Act also specifics certain transport procedures. This Act requires that pesticide containers be secured to prevent their accidental discharge or unauthorized removal. Pesticide containers must be separated from food or drink or other household materials in a manner that will ensure these goods are not contaminated during transport.

Some general precautions that will help prevent accidents when transporting pesticides include the following:

- Containers should be inspected for defects prior to transport. Do not accept materials in rusted, dented or otherwise damaged containers.
- Pesticides should not be transported in the passenger compartment of any vehicle. Do not allow anyone to ride in the back of a truck together with pesticides.
- Never transport pesticides along with food, feed or consumer goods.
- Avoid transporting pesticides on wooden truck beds. If your truck is provided with a wooden bed, use a storage box made of non-absorbent material or spread heavy plastic sheeting on the truck bed. Pesticides spilled on wooden truck beds are almost impossible to remove and may cause contamination of materials carried afterward in the truck.
- All pesticide containers must be secured to prevent accidental spillage. Be particularly careful with paper and glass containers. A safe practice is to transport glass containers in form-fitting, foam-lined shipping packages.
- Wettable powders and dusts in paper containers must be protected from rain and moisture.
- Commercial carriers and pesticide applicators should carry a spill clean-up kit that includes items such as a shovel and chemical neutralizer. Ensure that the driver is trained in emergency spill procedures.

When vehicles are used to hold pesticides on a fairly continuous basis, such as in pest control service vehicles, they are considered to be mobile storage facilities. They are discussed on the following pages under 'Storing Pesticides'.

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STORING PESTICIDES

A number of requirements for pesticide storage are specified in the Integrated Pest Management Act (Chapter 3). A now out-of-print publication of the Workers' Compensation Board (W.C.B.), *Standard Practices for Pesticide Applicators,* gave more detailed recommendations on storage facility design and safe storage practices. These practices are summarized below:

Storage Facility Location

- Pesticides should be stored in a facility separated from work and living areas. Depending on the quantity, the facility may be a cabinet, a room or a shed. For larger quantities of pesticides, a separate, detached building is preferred (Figure 10).
- Pesticides should not be stored in a basement. Toxic vapours are more difficult to ventilate from a basement than from a ground-level structure.
- Storage facilities should be located where spills, or run- off water used to fight a fire, will not contaminate surface waters or wells.

The local Fire Department must be informed about the location of storage facilities and the quantities of pesticides located there, as required by the Integrated Pest Management Act Regulation.

Building Materials

- Ideally, a storage shed should be made of fire-resistant materials. Drywall interiors are preferable to wood panelling.
- Paints or other sealants should be used to seal absorbent surfaces where pesticides could be spilled.
- Facilities should have a concrete floor with curbs to contain spills. Concrete is porous and should be painted with a sealing compound.

Entrances

- Entrances must be locked to prevent entry to unauthorized persons.
- Attach warning signs outside all entrances to warn people of chemical storage and indicate entry is to authorized personnel only.

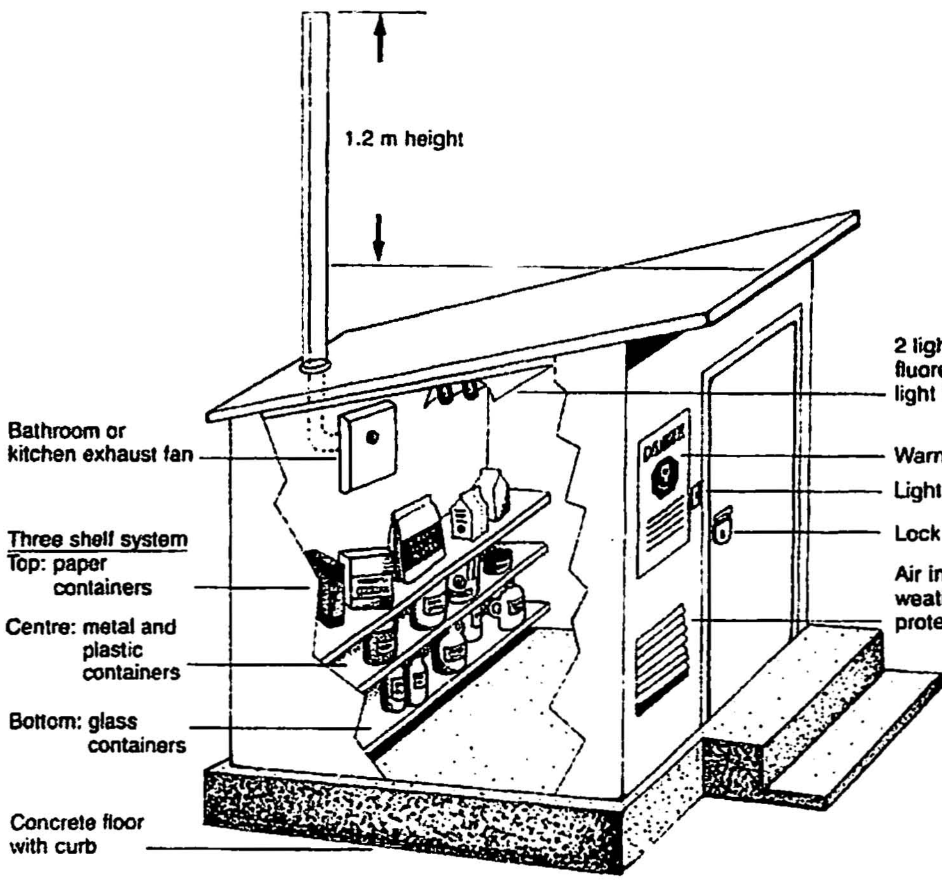

Figure 10. Layout of pesticide storage building suggested by W.C.B.

Ventilation

- If the storage facility is not used as a mixing area, W.C.B. indicates a reasonable ventilation rate is six air changes per hour. This would be about 300 L per minute of ventilation for every square metre of floor area in a 3 m high room. If mixing is done indoors, additional ventilation may be necessary.
- For storing small quantities of pesticides, an air vent without a fan may be sufficient. Structures with no vapour barriers or weather-stripping may have natural air leakage of one to three air changes per hour.
- It is a safe practice to locate the ventilation control switch outside the storage area. One technique is to interlock the ventilation switch with the light switch.
- For effective ventilation ensure that exhaust fans are located so as to pull pesticide vapours away from the work areas. Also provide an inlet air vent for make-up air. One technique is to mount exhaust fans near the pesticide shelving and mixing areas and to provide inlet grates in locations such as an opposite wall or in the door.

Plumbing

- There should be backflow prevention devices, if necessary, to prevent contamination of the water supply used for mixing pesticides (see discussion of cross-contamination below).
- Washing and shower facilities for routine clean-up and emergency situations should be located close to mixing areas.

Protection from Heat and Cold

- Store pesticides away from heat (e.g. windows facing south) and protect them from freezing. Degradation of pesticides is increased at high temperatures and some may explode. Bottles may break when exposure to heat or freezing causes excessive pressure.

Storage

- Observe any storage precautions listed on pesticide labels.
- Store the minimum quantities of pesticides possible.
- Store pesticides on shelves, if possible, and separate containers (Figure 10) as recommended by W.C.B.
- Separate incompatible pesticides and materials which could be hazardous on contact with each other. For example, some pesticides such as dazomet, maneb and mancozeb produce flammable vapours when wetted. Some pesticides such as difenzoquat, methyl bromide and paraquat produce flammable hydrogen gas on contact with aluminum. Glyphosate will produce hydrogen gas on contact with galvanized metal.
- Never store personal protective equipment, food, utensils, feed or seed with pesticides.
- The phenoxy herbicides (e.g. 2,4-D) should not be stored with insecticides or fungicides to avoid cross-contamination.

Containers

- Pesticide vendors must not sell a pesticide product unless the label is attached and is legible.
- Pesticides should be stored in their original container with a clearly legible label.
- Never store pesticides in old bottles or food containers, in which they might be mistaken for food or drink for animals or humans.
- Inspect containers regularly for leakage, corrosion, breaks, tears or other damage.
- Eliminate all defective containers. When paper containers are torn, transfer contents to an empty paper container of the same pesticide product or repair and enclose in a clear plastic bag. Do not cover up the label. Turn leaking metal or plastic containers leak-side up, where safe to do so, then clean-up spilled pesticide and transfer leaking container contents to a new container. Place a label on the new container. Contact your chemical supplier about replacement containers or labels. At the very least, a temporary label must include:
  1 — the pesticide common and trade name,
  2 — the concentration of pesticide active ingredient, and
  3 — the pesticide P.C.P. Act registration number.

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Emergencies

- It is recommended that a first aid kit (see Chapter 7) and spill clean-up equipment (see section on pesticide spills in this chapter) be provided outside or near the pesticide storage room. Emergency phone numbers should be posted.

Mobile Storage Facilities

Some pesticide users may store pesticides for extended periods in vehicles when performing a number of similar treatments. The vehicle is then considered a mobile storage unit and there are several potential hazards:

- the driver may inhale harmful levels of pesticide vapours,
- a vehicle accident may cause a pesticide spill,
- pesticides may contaminate personal protective clothing and respirators as well as driver or passenger areas of the vehicle,
- there may be inadequate quantities of wash water if the application site is far from a running water source.

Pickup trucks are most suitable for mobile storage. Pesticides can be placed in a locked canopy, separated from the driver. The W.C.B. recommends the use of a canopy divided into compartments (see Figure 11) to keep personal protective gear separated from pesticides and to provide easy access to pesticides and equipment stored forward of the tailgate area. This canopy has lockable compartments which open outward along each side of the canopy and an interior space accessible from the rear.

Cars or station wagons are not suitable for mobile storage.

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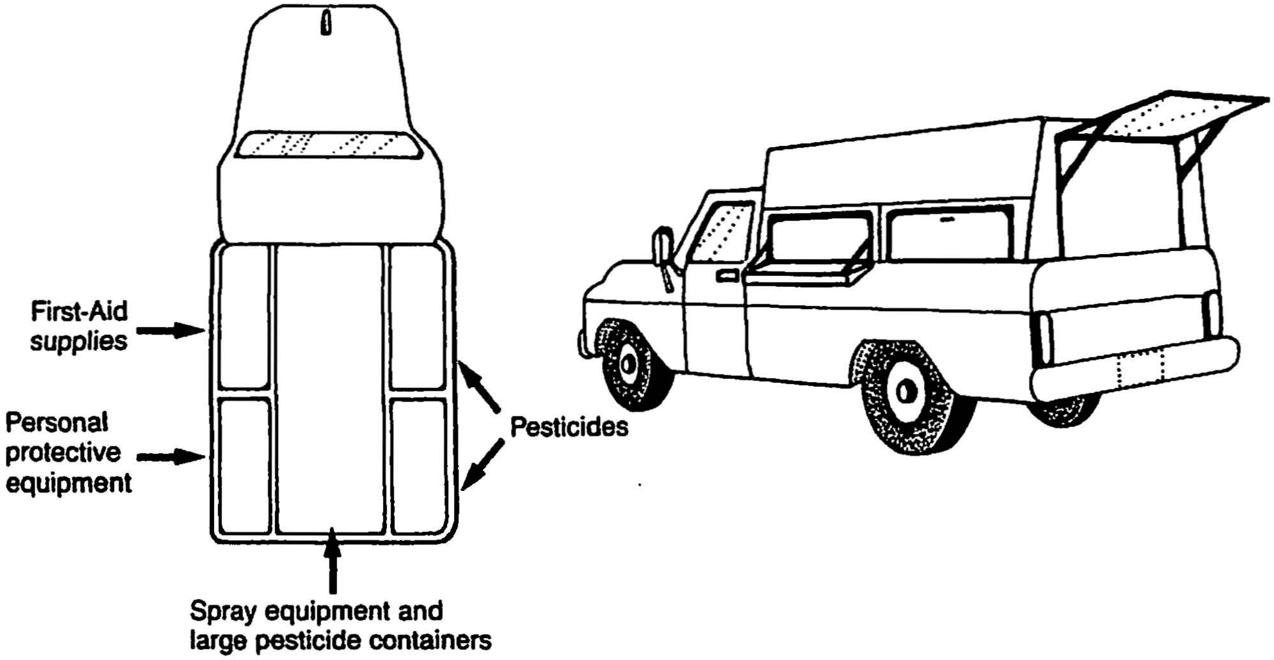


Figure 11. Plan for storage of pesticide application equipment in pickup truck (from W.C.B., 1985).

MIXING AND LOADING PESTICIDES

Many pesticide accidents occur when pesticides are being mixed for use. The most dangerous work with pesticides is pouring and mixing the concentrated products. Mixing and loading organophosphorous and carbamate insecticides can present a serious safety hazard, particularly when they are formulated with the solvent xylene which promotes their absorption through the skin.

A few common-sense rules can reduce the hazard involved in mixing and loading pesticides:

- Before mixing a pesticide, read the product label and double-check the safety precautions.
- Wear the correct protective clothing; this may include rubber boots, chemical-resistant aprons, coveralls and gloves, a face shield, a hat and possibly a respirator (see Chapter 6).
- Have emergency wash facilities, first aid equipment and emergency phone numbers close at hand.
- Mix pesticides only in good light and with adequate ventilation, preferably outdoors under low wind conditions. Stand upwind to minimize airborne exposure.
- When pouring a pesticide concentrate, keep the container well below eye-level to prevent splashing or spilling any pesticide in your face or eyes.
- Do not tear open paper bags as this may spill contents. Use a sharp knife to open bags and clean the knife after use.
- To reduce airborne dust and for better mixing, pre-mix wettable powders with a small amount of water before addition to the mixing tank. Make a slurry of wettable powder and water, then pour it into the spray tank.
- When transferring quantities of flammable materials (such as pesticides formulated with xylene or kerosene) from drums, it is essential to prevent sparking due to static build-up. Grounding procedures may be necessary.
- If you splash or spill a pesticide while mixing or loading, **stop immediately**. Remove contaminated clothing and wash thoroughly with detergent and water. Obtain medical assistance if exposure could result in more than a mild irritation. Speed is essential when you or your clothing are contaminated. Clean up any pesticides spilled.

Closed-Handling Systems

Closed-handling systems can reduce the applicator's exposure to concentrated pesticides. A closed-handling system is interconnected equipment which allows the applicator to remove a pesticide from its container, rinse the empty container, and transfer the pesticide and rinse solution to the spray tank without handling an open heavy container. Closed-handling systems have several advantages including increased applicator safety and a reduction in spills. There are two types of systems:

- **Gravity systems** are sometimes called "punch and drain" systems. The unopened pesticide container is inserted into a chamber, which is then sealed. A punch cuts a large opening in the container, allowing all of the material to drain into the mixing tank. A water nozzle attached to the punch sprays the inside of the container to rinse it thoroughly. The rinse water also drains into the mixing tank. The rinsed container is then removed for disposal. A limitation of this system is that only full container quantities can be used.
- **Suction systems** use a pump to remove the pesticide through a probe inserted into the container. Some containers are equipped with built-in probes. The pesticide is transferred to the mixing tank by hose and pipe. When the container is empty, it and the transfer sys-

tem are rinsed with water. The rinse water is added to the mixing tank. To allow the use of only part of the pesticide in the container, the system must measure the amount of pesticide transferred to the mixing tank and must allow the probe to remain in the container until all the pesticide is used and the container and probe are rinsed. Some probes have a breakaway head which allows the head to stay and the probe to be withdrawn and reused. In some systems, it is not possible to reseal partially-emptied containers.

Closed-handling systems are not yet widely available but should be used wherever possible.

Cross-Contamination

Cross-contamination is another hazard during the mixing of pesticides. It results when water is being added to a pesticide and the pesticide is drawn back into the pipe system supplying the water. Cross-contamination may occur in two ways:

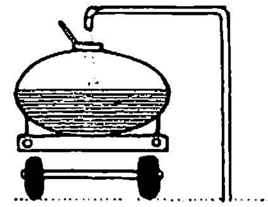
- **Back-siphonage.** This is a reverse flow of water caused by a reduction in water pressure. If a hose used for adding water is emersed in the pesticide spray tank, back-siphonage may draw the pesticide concentrate back into the main supply line. Water downstream of the main supply line will then be contaminated. Back-siphonage can occur when there is a large draw on the main supply line such as for fire-fighting or due to a break in the supply line.
- **Backpressure backflow.** This is a reverse flow which occurs when systems such as mixing tanks are above the height of the water supply source. For example, a pump may supply water from a pond to a mixing tank on a truck. If the pump fails, backpressure could cause the pesticide mixture to flow through the supply line into the pond.

Documented cases of illness and death have been attributed to cross-contamination. Those at risk may include co-workers, family members and the public. Two cases of mishaps demonstrate the hazard.

- A pesticide applicator used a sprayer attached to a garden hose to spray a weed killer. While at the job, there was a flow reversal in the water supply. The man disconnected the hose, and feeling thirsty, drank from the tap that had supplied the hose. Pesticide in the water killed him.
- A pesticide applicator was preparing to treat a building and left a garden hose submerged in a spray tank during mixing. The building was located on a hill and its water system experienced negative pressure during the mixing process. The pesticide that was sucked into the drinking water system resulted in 15 people becoming ill and required replacement of the plumbing in the building.

The most simple method of preventing backflow is to maintain an air gap between the discharge end of the supply line and the pesticide in the mixing tank. The air gap should be at least twice the diameter of the discharge pipe. At times, an air gap is not possible, such as when the pesticide is injected into an irrigation system. In such cases it is extremely important to use a device to prevent cross-contamination. These devices must be tested upon installation and on an annual basis. Examples of how backflow prevention methods are used in pesticide mixing and application are illustrated below.

1. **Air Gap:** without an air gap, spray tank contents can be drawn into the water supply line if pressure in this line drops (e.g. due to heavy water use elsewhere in the water supply system).



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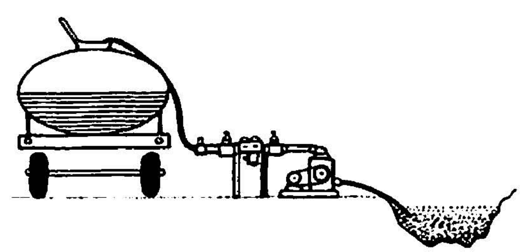
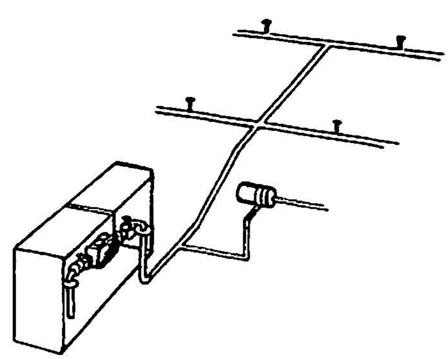
2. **Atmospheric Vacuum Breaker:** can prevent a reverse flow of concentrated pesticide into the hose and into the water supply system if pressure in the water system drops.

3. **Backflow Preventer (with a vehicle):** is required to prevent a reverse flow of pesticide into a water supply in the event a pump fails.



4. **Backflow Preventer (in an irrigation system):** is required to prevent pesticide injected into a system from flowing back into the supply line rather than out through the sprinkler heads.



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APPLYING PESTICIDES

Attention to a few simple guidelines during pesticide application will make the job much safer.

- Before starting to apply a pesticide, **read the label.** Do not trust your memory for details concerning the use of pesticides. The label of a Recently-purchased product may differ from the label of the same product purchased some time ago. Make certain you are aware of the current use directions and precautions.
- Check the application equipment. Look for leaking hoses or connections and plugged or worn nozzles. Examine the seals on the filter openings to make sure they will prevent pesticide spillage.
- Before you begin, make certain your protective equipment is appropriate for the hazard.
- Make sure that emergency facilities such as wash water are at hand in the event of an accident.
- Before applying pesticides ensure that appropriate warning signs are posted at normal points of entry to the treatment site so that unprotected workers or bystanders are not contaminated. It is also advisable to notify residents near treatment areas so they can keep children and pets away. Ensure safe re-entry periods are observed.
- When handling highly toxic pesticides, do not work alone.
- Mix and apply the pesticide at the rate recommended on the label.
- Ensure there is the required number of days between treatment and harvest of food crops or grazing.
- Minimize drift of pesticides away from the target area by the following precautions:
  - use the lowest possible application rate that will do the job
  - release spray as close to the ground as possible
  - use a slow speed for motorized application equipment
  - with sprays, use nozzles that eliminate, as much as possible, fine droplets (i.e. large nozzle orifice, low pressure)
  - do not apply pesticides when wind will cause substantial drift. Spraying should cease when wind speed increases above 8 km per hour unless sprayer shrouds are used. If winds come up during application, **stop immediately,** and do not resume the application until wind conditions improve
  - the release of vapours by many pesticides increase as temperatures increase. Be especially careful when temperatures exceed 30°C.

A well-managed pesticide program includes a record of applications. Proper records provide information on a treatment location, size of treatment, pest controlled, pesticide name, application rate, application equipment, total pesticide used, dates of application and weather conditions.

DISPOSING OF PESTICIDES AND CONTAINERS

Waste pesticides should be considered hazardous to the environment and to people handling them. These materials are also potential pollutants of water, air and land. Deciding how to dispose of pesticide wastes is an important part of safe pesticide use and should be considered with each pesticide application. Those who use pesticides are responsible for the safe disposal of all empty pesticide containers and surplus pesticide.

Disposal of Containers

Disposal of large numbers of empty pesticide containers can be a significant problem. Empty containers of non-pressurized commercial, restricted or permit restricted pesticides must be rinsed before disposal. Recommended rinsing practices for various types of containers are summarized in Table 7. Containers of liquid pesticide products should be emptied by draining for a minimum of 30 seconds into a spray or mixing tank. Then they should be either triple-rinsed or pressure-rinsed.

Table 7. Procedures for rinsing various pesticide containers.

Type of container	Rinsing Method
Rigid plastic or metal	Pressure-rinse or triple-rinse
Other metal (pressurized)	No rinsing required
Glass bottle	Triple-rinse
Paper bag	Single-rinse
Plastic bag	Single-rinse
Containers labelled "Domestic"	No rinsing required

Triple-rinsing means the container is filled at least one-fifth full with appropriate solvent (usually water) capable of removing the pesticide. The container is closed and shaken to rinse all inner surfaces, then opened and drained for at least 30 seconds. This is repeated two times.

Pressure-rinsing means rinsing for at least 30 seconds with an appropriate solvent under pressure. The high-pressure spray may be directed down into the container, or the empty container may be inverted over the spray nozzle so that all interior surfaces of the container are rinsed.

Where possible, return empty pesticide containers to the manufacturer for re-use. When re-use is not possible, crush, puncture or damage empty, rinsed containers so they cannot be reused and, if permitted by the pesticide label, recycle them. When neither re-use nor recycling is an option, emptied, rinsed and crushed containers should be disposed of in an approved sanitary landfill.

Rinse-water, produced by cleaning containers should be drained into spray tanks and applied to the treatment area. Waste water produced by washing equipment, or rinse water which cannot be applied to the treatment area, may, if necessary, be applied to the ground site of pesticide application under the following conditions:

- the site is flat;
- the site is not in a wet lowland (boggy area);
- the site does not consist of porous material such as gravel or sand; and
- the site is at least 200 m from surface water or any well.

Unused Pesticides

Disposal of unused pesticide concentrates and excess pesticide mixtures is a serious problem. There is no simple solution.

The best precaution against a pesticide disposal problem is good planning. Pesticide users should only buy sufficient pesticide for their immediate needs or at most, one year's supply. Sufficient spray should be mixed for just one treatment.

If you must dispose of unwanted pesticide, check with your pesticide distributor and see if they can find somebody who can use it. If no alternate users can be found, arrange with a hazardous waste disposal company to dispose of the pesticide for you.

PERSONAL CLEANLINESS

Do not eat, drink or smoke when working with pesticides. Studies have shown that workers with contaminated hands could swallow significant quantities of pesticide while eating lunch or smoking one cigarette. Wash hands and face before break periods or meals.

All protective equipment, such as respirators or goggles, should be thoroughly washed after completing the pesticide application, disposing of excess material and cleaning the application equipment. Then, work clothes should be removed and placed in an area separate from other laundry items. Shower and wash completely with soap and water, including hair and finger-nails. After showering, put on a complete change of underwear and clean outer clothing.

Do not allow children to play in or with contaminated clothing. Clothing washed immediately after use will be more easily decontaminated. Warn whoever will be washing clothes that they are contaminated and to follow these procedures:

- Wash separately from other laundry. Discard if completely saturated with pesticide.
- Pre-rinse clothing by presoaking in a suitable container, agitating in an automatic washing machine or hosing the garments outdoors.
- For washing machine settings, use **hot water** temperatures (140°F/60°C), **full** water level and **normal** (12 minutes) wash cycle.
- Re-wash the clothing two or three times if badly contaminated.
- Rinse machine thoroughly after laundering the contaminated clothing.
- Line dry to avoid contaminating the automatic dryer.
- Launder clothing daily when applying pesticides daily

Proper emergency wash facilities should be available where persons are exposed to pesticides harmful to the eyes or skin. For example, during agricultural spraying operations, a container of clean water on the tractor can provide an emergency wash for the operator. Minimum emergency facilities at the mixing and loading site include a portable container holding 45 L of clean water, and a portable eye wash facility capable of providing a continuous 15 minute supply of eye irrigation. Various plumbed-in systems for use at permanent work sites are available.

PESTICIDE SPILLS

The more you can prepare for accidents, the greater the chance you have to minimize health hazards and environmental contamination.

- Develop a spill contingency plan"
- Have spill treatment equipment ready at storage, mixing and loading sites including the following:
  - personal protective equipment (e.g., unlined gloves, boots and respirator),
  - absorbent material such as sawdust, sand, activated charcoal, vermiculite, dry coarse clay, kitty litter or commercial absorbent,
  - neutralizing material such as lime, chlorine bleach or washing soda,
  - long-handled broom, -shovel, and
  - waste-receiving container with lid.

Pesticide spills may happen around the home, on the farm or industrial sites, on public lands or highways. When a spill occurs, it should be cleaned up as quickly and safely as possible. The following general procedures apply to clean-up of most spills:

- Keep other people and animals away from the spill site. See that no one is exposed by walking or driving through a spill or by breathing fumes.
- Obtain as much information as possible on how to clean up the spill. Consult the product label or knowledgeable agencies (e.g. Ministry of Water, Land and Air Protection or CANUTEC operated by Transport Canada in Ottawa.)
- If the spill is sufficiently small to be handled without assistance, begin clean-up procedures immediately.
- Put on adequate personal protective gear. If the spill is inside a room or shed, ventilate the area; open doors and windows and use fans if necessary.

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- Do not try to wash away spilled material, this only spreads the pesticide. It takes a great deal of water to dilute the pesticide to non-hazardous concentrations.
- Provide a barrier to the spread of the pesticide. A barrier may consist of soil, sawdust, old newspaper or any- thing to soak up the pesticide.
- Absorb or soak up as much liquid pesticide as possible, using an absorbent material.
- With dusts, dampen with water using a fine mist before sweeping. Do not use a vacuum cleaner unless equipped with a filter bag capable of safe collection of fine dusts.
- Place waste material from spill clean-up into a water-proof container that can be removed from the site.
- Label with the name, P.C.P. number and quantity of the pesticide and treat as a hazardous waste. Contact the nearest office of the Ministry of Water, Land and Air Protection for advice' on disposal.
- Decontaminate the affected surface(s). Check if the label has specific instructions or contact the Ministry of Water, Land and Air Protection. Some general guidelines include:
  a) Organophosphates -many such as azinphos-methyl, chlorpyrifos, diazinon, dimethoate, malathion, parathion and temephos can be detoxified with a mixture of washing soda (sodium carbonate) and bleach (sodium hypochlorite).
  b) Carbamates -such as aldicarb and carbaryl - use caustic solutions such as washing soda (sodium carbonate), caustic soda (sodium hydroxide) or strong soap solution.
  c) Organochlorines - are difficult to detoxify. Chemicals frequently recommended are household ammonia, washing soda or activated charcoal.

The decontamination solution should be worked into a hard surface, such as pavement or cement, using a coarse broom or scrub brush. The solution should be picked up using fresh absorbent which is then removed for disposal.

Where there is a small spill of pesticide on soil, a recommended practice is to sprinkle a mixture of one gallon of water added to one gallon of bleach, then spread hydrated lime liberally over the area and let stand for at least one hour. Remove the top 2 to 5 cm of soil where the spill occurred.

Notify local police if the spill involves a public area such as a highway and there is a hazard to bystanders. Notify medical authorities if anyone is poisoned (see Chapter 7). The Ministry of Water, Land and Air Protection must be notified where a spill releases pesticide into the environment. Telephone the Provincial Emergency number at 1-800-663-3456 (24 hours). An operator will contact the appropriate Ministry of Water, Land and Air Protection staff to notify them of the spill or obtain assistance for you as may be required. While waiting for emergency personnel to arrive, do what you can to prevent others from being exposed to the pesticide. When emergency personnel arrive, tell them about the pesticide. Police or fire fighters may not know the degree of hazard until you tell them.

Assistance in obtaining technical information on pesticide clean-up and decontamination may be obtained from CANUTEC, a data bank in Ottawa operated by Transport Canada. You can call the emergency phone number (613 996-6666) collect, or cellular ·666, day or night, to obtain help in deciding on a spill clean-up action plan.

PESTICIDE FIRES

Whenever pesticides are involved in fires, there are potential hazards from toxic fumes, poisonous runoff and release of concentrated pesticides from leaking or exploding containers. Some general rules in dealing with such fires include:

- When first establishing a storage facility, notify the local fire department of the pesticides that will be stored and the exact location of the facility. This will allow the fire department to prepare for possible emergencies.
- If a fire occurs, first evacuate people and animals so they are upwind of the fire and keep bystanders away
- Call the fire department and make it clear that it is a fire involving pesticides. Provide any information you have about the pesticides that will aid them in fighting the fire and protecting themselves and others.
- With the fire fighting experts, weigh the hazards of fighting the fire and post-fire clean-up against the benefits of fighting the fire.
- Alert medical personnel about possible cases of poisoning in fire fighters or bystanders who may be exposed to pesticides from the fire.
- If contaminated water from fire fighting enters a drain-age system, inform authorities immediately.

Instructions to Fire Fighters

In general, fire fighting experts should always be called to fight uncontrolled fires. The following are some guidelines for fighting fires involving pesticides:

- Wear chemical-resistant gloves, boots and full-body protective clothing. A self-contained breathing apparatus is essential for those exposed to fumes and smoke.
- Wherever possible, fight fires from the upwind side.
- Wherever possible, use foam or carbon dioxide rather than water. Some pesticides can ignite or emit toxic gases on contact with water.
- If water is used, keep it to a minimum. Excess water will spread pesticide contamination. Dykes may have to be constructed to prevent the flow of water and pesticides into sewers, irrigation waters or streams.
- Apply water with a fog spray rather than a straight stream to avoid breaking bags and bottles. Dust from broken bags can be explosive.
- Avoid dragging hoses through pesticide-contaminated water.
- Wash before eating, drinking, smoking or using the toilet.
- If anyone is exposed to smoke and fumes, exposed body areas should be washed as soon as possible at the fire site. If anyone has symptoms of pesticide poisoning, consult medical authorities immediately.
- Once the fire is out, apply decontamination procedures to contaminated land, all fire fighting equipment and personal protective equipment and clothing.

CHAPTER QUIZ

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Questions

1. What are three major concerns about pesticide transport?
2. Name two desirable features of pesticide storage buildings involving (a) location, (b) building materials, (c) entrances, and (d) plumbing.
3. Name some pesticides that should not be stored together and why.
4. What is the least that should be included on a label on a replacement pesticide container?
5. What is the recommended way to keep pesticides separated from personal protective gear in a pickup truck?
6. What are closed handling systems for mixing pesticides
7. How can cross-contamination occur while mixing pesticides
8. What is the simplest way of preventing cross-contamination?
9. Name two approved methods of cleaning empty pesticide containers?
10. How often should you wash protective clothing used during pesticide applications? Should you use hot or cold water?
11. Name three steps in removing spilled pesticide on pavement.
12. Who would you notify in the event of a major spill?
13. What are three hazards from fires involving pesticides?

Answers

1. Contamination of people or goods in a vehicle, contamination of the vehicle and spills.
2. (a) separate shed, where spills will not contaminate surface water or wells, (b) fire resistant, concrete floor with curb, (c) locked, posted, (d) back flow prevention wash-up facilities.
3. Phenoxy-type herbicides should not be stored with insecticides or fungicides to avoid cross-contamination.
4. Pesticide common and trade names, concentration of active ingredient and the P.C.P. Act registration number
5. A canopy divided into compartments.
6. A system of transferring pesticides and rinse water form their container to a spray tank without the need for an operator to handle an open pesticide container.
7. A link through which a contaminant may enter a water supply as a result of backflow.
8. Maintain an air gap between the water supply line and a pesticide in a mixing tank.
9. Triple-rinsing, pressure-rinsing.
10. Every day after use. Hot.
11. Absorb or soak up, decontaminate, remove waste absorbent to a safe disposal site.
12. Local Police, medical authorities if necessary, Ministry of Water, Land and Air Protection, or if a spill represents an immediate danger to the environment, call the emergency 24 hour answering service. Call CANUTEC for technical information on spill cleanup.
13. Toxic fumes, poisonous runoff from water sprayed, release of concentrated pesticides from leaking or exploding containers.

Chapter 6

PROTECTIVE GEAR AND CLOTHING

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CONTENTS

INTRODUCTION

Various types of protective clothing and devices are available and may be specified on label directions, for reducing exposure to pesticides. Most frequently, pesticide-related illness occurs when insufficient protection is used to prevent skin, eye or lung contamination. Those who handle pesticides should have an understanding of the types of protective equipment available in order to select equipment appropriate for their situation.

The need for protective clothing to ensure an individual's safety varies with the toxicity of the pesticide and the possibility of exposure to the pesticide. Workers who handle pesticides during loading or mixing may be exposed to pesticide concentrates. They require protection from pesticide splashes or spills and possibly vapours. Workers involved in flagging for aerial applications may risk exposure to spray drift. They should have full protection for dermal exposure. Those workers who apply the diluted material during ground applications may not be exposed to significant levels of pesticide and minimum protective clothing may be appropriate. **No pesticides should be applied without at least a long-sleeved shirt, long-legged trousers and shoes and socks.**

Table 8 provides a general guide to protective clothing and equipment that should be worn for applications of granular and liquid pesticides. These recommendations may be modified to suit specific situations, based on an assessment of the hazard. Various items of protective clothing are illustrated in Figure 12.

PROTECTIVE CLOTHING

COVERALLS

Coveralls with long sleeves and full pant legs give protection for low to moderate hazard pesticides provided they will not become wet through from spray drift or spillage. They should be removed immediately after pesticide application is completed for the day. There are two types of coveralls: reusable and disposable. Reusable coveralls, commonly worn for construction work, are generally made of cotton or polyester. The material should be tightly woven. Polyester coveralls are more quickly penetrated by liquids than cotton and not as suitable for use with liquid pesticides. Coveralls should be washed separately from other laundry after each day's use, but should be discarded if badly contaminated (see section on personal cleanliness in Chapter 5).

The disposable coveralls are made of 'Tyvek' polyethylene fibres, and are initially more resistant to pesticide penetration than cotton coveralls. They should be washed after each day's use but can only withstand several washes. Effectiveness is reduced to that of cotton coveralls after the first or second wash. They should be discarded if damaged or badly contaminated. The disposable coveralls come with various accessories including attached hoods. They are light weight and reasonably comfortable in hot weather. They provide good skin protection for a single day's use in moderately hazardous situations, provided they do not become torn or frayed.

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BOOTS

Waterproof, unlined boots should be worn when loading, mixing or spraying pesticides, or walking on contaminated areas. Knee-length boots offer the best protection. Leather or fabric boots and shoes should not be worn because they will absorb pesticides and cannot be cleaned effectively.

Coverall pant legs should be worn outside the top of boots. This will prevent spills and splashes from running into the boot and soaking legs or feet. The outside of boots should be thoroughly washed after each use; the inside of boots should be washed if there is any likelihood of contamination.

GLOVES

As a rule, never handle pesticides without gloves. Most pesticides can be absorbed through hands, so hand protection is important. Do not use leather, cloth or canvas gloves or cloth-lined gloves with liquid formulations. If these materials become contaminated with pesticides they can increase the rate of absorption into the hand.

Protective gloves are made from various materials including natural rubber, neoprene, nitrile rubber, polyethylene, polyvinyl chloride and polyvinyl alcohol. Neoprene has been found to be superior to rubber in resisting the penetration of many pesticide carriers. However, no one material is likely to provide protection against all types of pesticides. Check with the supplier on the recommended use of a specific glove type. Some pesticide labels recommend specific gloves.

Wear coverall or spray suit sleeves outside gloves to prevent spray running down sleeves into gloves. If there is a chance that pesticide may drip from the glove onto the arm under the protective sleeve (e.g. if it is necessary to work with arms raised upward), tightly secure the garment sleeve to the glove (e.g. with elastic band).

Gloves that extend up the forearm (gauntlet type) are desirable for mixing pesticides.

It is important to minimize hand contamination when removing gloves. W.C.B. (1985), suggest three techniques as follows:

- wash gloves prior to removal, or
- wear a light pair of disposable plastic gloves inside the outer gloves. Remove both outer gloves before removing the disposable gloves. Discard the disposables after each use, or
- wear relatively loose-fitting gloves for easy removal.

Do not use gloves with excessive wear or punctures. Before use, check gloves for leaks. Roll the glove from the wrist to trap air in the fingers and immerse the glove in water. Under heavy use situations, gloves should be replaced after a few days use.

Table 8. Examples of protective clothing and equipment for application of granular or liquid pesticides.

	Precautionary Signal Words on Label		
FORMULATION	**CAUTION — POISON**	**WARNING — POISON**	**DANGER — POISON**
Granular	Long legged trousers and long-sleeved shirt, shoes and socks.	Coveralls, shoes and socks, hat, gloves.	Coveralls, boots, hat, gloves, cartridge or canister respirator if dusts in air or if label says to avoid breathing dust or vapours.
Spray (little exposure to spray)	Coveralls, boots, hat, gloves.	Coveralls, boots, hat, gloves. Goggles if advised by label. Cartridge or canister respirator if label says to avoid breathing vapours or spray mists.	Coveralls, boots, hat, gloves, goggles. Cartridge or canister respirator if label says to avoid breathing vapours or spray mists.
Spray (coveralls could be wet through or high exposure hazard)	Waterproof suit, boots gloves, hat, goggles.	Waterproof suit, boots, gloves, hat, goggles, cartridge or canister respirator.	Waterproof suit, boots, gloves, waterproof hood, full-face cartridge or canister respirator.

HATS

Waterproof headgear must be worn where pesticides might splash or spray drift might occur at head level. Felt, straw or leather hats or hats with cloth sweatbands should not be worn by applicators. These materials will absorb pesticides. Preferable hat designs include a rubber or plastic rain hat or wide brim safety helmet without cloth liner. Neck capes that attach to the back of a helmet are available to reduce spray drift contacting the neck. Where there is potential for splashing of pesticides or severe spray drift, a helmet that covers the head, attached to a hood that covers the neck and upper shoulders is particularly effective in preventing pesticide contact in the upper body areas.

Wash and dry headgear after each use, before storing.

APRONS

When pouring or handling concentrated pesticides, it is a good practice to wear an apron. The label on some pesticides indicates an apron must be worn. The apron protects the front of a worker's body from spills or splashes. The apron should be made of rubber or a synthetic liquid-proof material and should resist the solvents used in formulating the pesticide. It should cover the front of the body from chest to boots.

SPRAY SUITS

The labels of some toxic pesticides require that applicators wear a waterproof spray suit during spray operations. Waterproof suits should also be worn by applicators or observers who could have their coveralls wetted through by working near sprayed objects, or by accidental spray drift. Such a suit should cover work clothes and should be tear-resistant. The suit should be made of fabric that will resist penetration of the solvents used to formulate the pesticides. Neoprene and polyvinyl chloride both provide substantial protection against most pesticides, but are less resistant to penetration from emulsifiable concentrate solvents such as xylene and some of the organochlorines. The resistance of a fabric to penetration also depends on the thickness of the coating. Check the equipment suppliers for recommendations on fabric for the specific pesticide used. Follow manufacturers' recommendations in cleaning, decontamination and care of your spray suit. Full body spray suits tend to become hot in warm weather. Ideally, pesticide treatments should be made when temperatures are low enough for applicators to work under conditions that are both safe and comfortable.

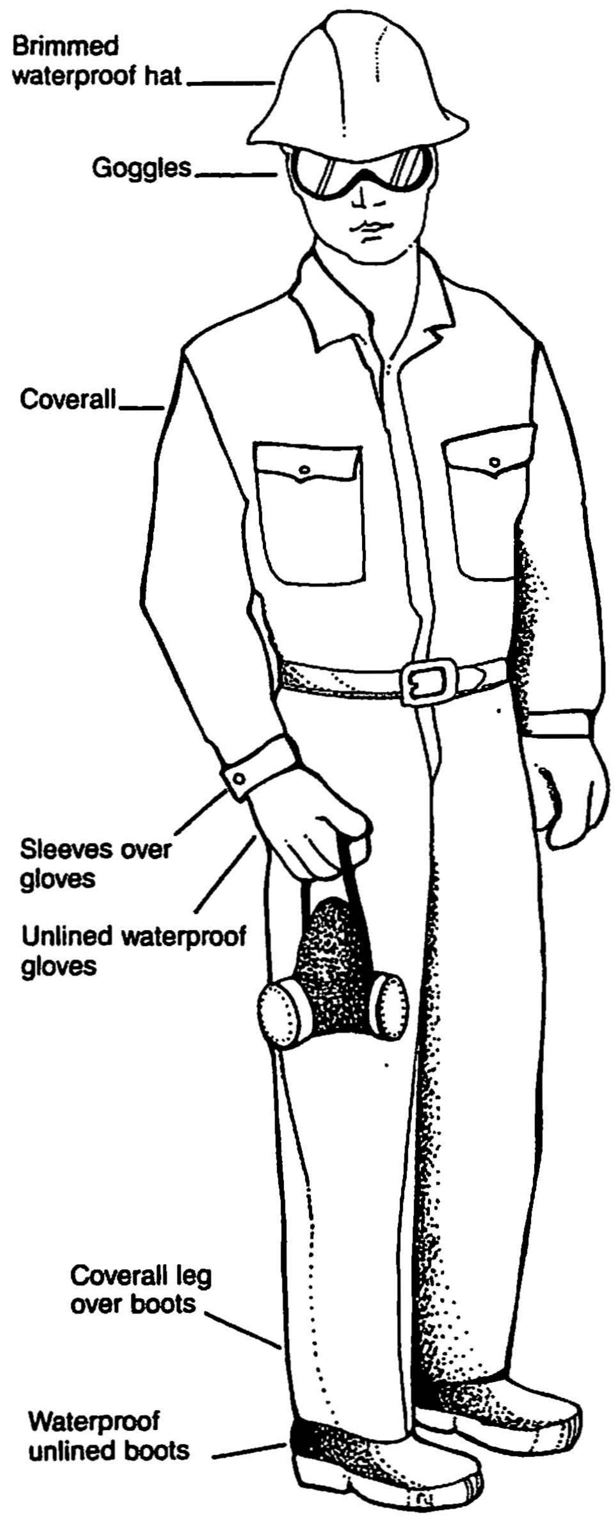

Figure 12. Example of minimal protective clothing to be used when applying pesticide sprays.

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EYE AND FACE PROTECTION

GOGGLES

Eyes must be protected where there is a possibility of their exposure to powder or liquid pesticides which might drift or splash from various directions (e.g. during spray application). They are particularly important to protect the eyes where pesticide spray mists are present. Several types of non-fogging goggles are available. Some fit over eyeglasses. Do not use designs made only to protect against projectiles from grinding or cutting. These may have ventilation holes which allow pesticides to leak inside. Avoid goggles with a headband made of foam or other material which readily absorbs pesticides. Wash goggles with soap and warm water after each use.

FACE SHIELDS

Face shields are required to protect the eyes and face when there is a possibility of a splash of relatively toxic pesticide from one direction. It is especially important to protect the eyes and face when pouring or mixing liquid concentrates. Clear plastic visors which provide the maximum coverage of the face and neck should be selected. Some visors attach to a hard hat and can be raised or lowered as needed. Note that face shields will not protect the eyes in spray mist situations. Face shields should be washed with soap and warm water after each use.

RESPIRATORY PROTECTION EQUIPMENT

Appropriate respirators must be worn by workers who may be exposed to harmful levels of pesticides in the air. Specific types of respirators protect against specific chemical gases and vapours. Be sure you choose one made and approved for the pesticides you will use. There are five general types of respirators for use with pesticides.

DUST, FUME AND MIST RESPIRATORS

Dust, fume and mist respirators are physical filters (Figure 13) which only protect against pesticide dusts. They are not effective against spray mists and the many pesticides which emit vapours. This type of respirator should only be used for dusts which give off virtually no vapours. Although the name of these respirators includes the term 'fume', it refers to particles formed during welding operations, not pesticide fumes or vapours.

Figure 13. Dust, fume and mist respirator.

CHEMICAL CARTRIDGE RESPIRATORS

Chemical cartridge respirators are usually designed as half-face masks that cover the nose and mouth but do not protect the eyes (Figure 14). Full-face cartridge respirators are available, however, which provide more protection to the face and eyes. They have one or two cartridges containing absorbants, such as activated charcoal, attached to the face plate. There is usually a one-way valve which allows the inhaled air to pass through the cartridge and the exhaled air flows out through a separate exhaust valve. The chemical filters must be provided with a dust/mist prefilter to be effective.

Figure 14. Chemical cartridge respirator.

Chemical cartridge respirators are recommended for short-term outdoor use for protection against low concentrations of pesticides. They can be used, for example, when mixing pesticides outdoors. W.C.B. approves this use where pesticides in air are at concentrations around or just above the maximum permissible levels for no protection in the workplace. They should not be used for work with fumigant gases such as methyl bromide, aluminum phosphide and hydrogen cyanide.

Guidelines on the operational life and performance of filters and cartridges generally accompany the products. See the section below on the use and cleaning of respirators.

POWERED AIR-PURIFYING RESPIRATORS

Powered air-purifying respirators use an electric pump to draw air through a filter at a specific rate. The air is delivered to a tight-fitting face plate or a loose-fitting helmet. These respirators must be approved for chemical filtration and sufficient air must flow through them. Air replacement must be at least 113 L/min (4 ft^3/min) with a face plate and 170 L/min (6 ft^3/min) with the hood and helmet. With these air replacement rates, powered air-purifying respirators offer somewhat better protection than cartridge respirators.

CANISTER RESPIRATORS (GAS MASKS)

These devices work on the same principle as chemical cartridge respirators but usually have a full face-piece that covers eyes, nose and mouth (Figure 15). They also have a larger container of absorbant material. Canisters specify the maximum concentration of contaminant against which the respirator is considered effective. They also warn that the unit is **not** to be used in situations **immediately** dangerous to life or health. Canister gas masks are generally suitable for continuous use in ventilated areas not subject to rapid change. They should not be used in confined spaces where oxygen deficiency or high gas concentrations may occur, such as in fumigated structures.

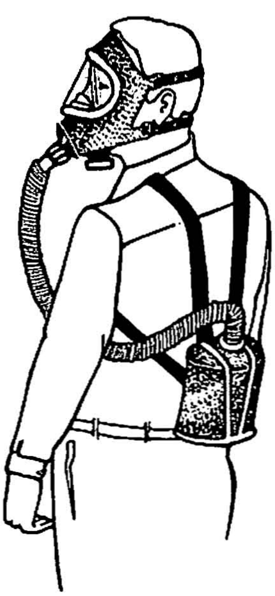

Figure 15. Cannister respirator (gas mask)

SELF-CONTAINED BREATHING APPARATUS

A self-contained breathing apparatus is equipped with a cylinder of compressed air which is usually carried on the back. These respirators may be used for short duration work in areas with a high concentration of toxic gases, such as a fumigated greenhouse. They are also used for emergency situations, such as fire-fighting, where toxic fumes might be present.

SUPPLIED-AIR RESPIRATORS

Supplied-air respirators are provided with an air supply through a hose from a safe, distant supply. They are suited for work in contaminated atmospheres where a long-term air supply is needed. In such situations where the absence of respiratory protection would be immediately hazardous to life or health, supplied-air respirators must be equipped with a reserve air bottle (e.g. sufficient for five minutes) carried by the user for emergency escape purposes.

USE AND CLEANING OF RESPIRATORY DEVICES

Before use, ensure the respirator is clean and in good working order. The half-face cartridge respirator can be checked to ensure the chemical cartridge is properly connected to the respirator and the prefilter is in front of the cartridge with the correct side facing out. Ensure the valves are clean and function correctly and the face-piece is not warped or cracked.

A respirator or mask should be fitted properly to the face. Adjust headbands tightly enough to obtain a good seal. Manufacturers can usually supply special face-pieces if the standard one does not fit. If you have long sideburns, moustache or a beard, you may find it impossible to seal the respirator or gas mask to your face. **Shave; do not risk your life for a few hairs.**

Prior to entering the use area, the face seal of respirators should be checked in accordance with the manufacturer's instructions. You should use the inhalation and exhalation test with the face mask (W.C.B., 1985).

Inhalation Test: Place the palm of the hands over the cartridge assemblies or inhalation points and inhale. If no air enters and the face-piece collapses slightly, the respirator is properly fitted and the exhalation valve is closing correctly.

Exhalation Test: Place the palm of the hand or thumb over the exhalation valve guard and press lightly. Exhale to cause a slight pressure inside the face-piece. If no air escapes, the face-piece is properly fitted and the inhalation valves are closing correctly. If air escapes, readjust the respirator and test again, or check the condition of the exhalation valve.

Respirators with specific cartridges or canisters are required for use with certain types of pesticides. Be sure to wear the correct respirator approved for the pesticide you are handling. It is recommended that only respirators with the NIOSH (National Institute for Occupational Safety and Health) seal of approval be used. Use of non-approved respirators may provide no protection.

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The life of chemical absorbing cartridges or canisters varies according to the concentrations of pesticides encountered. Change the prefilters on cartridges if breathing through the respirator becomes difficult. Change chemical cartridges if any pesticide odour is noticed when breathing through the respirator. As a rough guide, one should change prefilters after every **four hours** of use in moderately dusty or misty conditions. Chemical cartridges should usually be changed after **eight hours** of use with moderate exposure to vapours. These times will vary depending on the pesticide, its hazards and the application method.

Replace canisters when they have exceeded their expiry date or when the colour in those equipped with a view window indicates the end of service life. While an unopened canister may have a shelf life of three years, it will not last as long when the seal is broken. Do not use a canister with a broken seal if it is not known when and where it was last used.

Respirators should be cleaned after each use. Remove filters, cartridges or canisters. Disassemble further as indicated by the manufacturer's instructions. Wash the face-piece with soap and warm water. Rinse thoroughly in clean water to remove all traces of soap. Dry the face-piece with a clean cloth, that is not contaminated with pesticide, and reassemble. Check the hose clamps and lens clamps surrounding the visor of canister respirators. Store in a clean dry location, preferably in a tightly-closed paper or plastic bag.

Much of the information on respirators in this chapter was summarized from the following publication:

W.C.B. 1985. *Standard Practices for Pesticide Applicators. A manual of health information and safe practices for workers who apply pesticides.* First Edition. Workers' Compensation Board of British Columbia. 216 pp.

CHAPTER QUIZ

Questions

1. What protective clothing and equipment should you wear for applying a pesticide with the label signal word "Warning" where you may be exposed to little spray drift?
2. Why should you wear unlined boots and gloves when working with pesticides?
3. When would you use an apron for protection from pesticides?
4. When would you use a waterproof spray suit?
5. Match the following respirators with their recommended uses: cartridge, cannister, supplied air —

   a) continuous use in ventilated areas where pesticide concentrations are below levels immediately dangerous to health.

   b) long-term work in contaminated or oxygen-deficient atmospheres.

   c) short-term, outdoor use, low pesticide concentrations.
6. How often should you change the prefilters and cartridges in a respirator?

Answers

1. Coveralls, boots, hat, gloves, goggles if advised by label; respirator if label says to avoid breathing dusts, vapours or spray mists.
2. A contaminated lining can increase the rate of absorption of pesticides.
3. When mixing most pesticides.
4. When required by the label or when coveralls could be wetted through by spray.
5. cartridge — (c); canister — (a); supplied-air — (b).
6. Change prefilters when breathing becomes difficult or after four hours use; change cartridges when any pesticide odour breakthrough is noticed, or after eight hours of use.

Chapter 7

PESTICIDE POISONING AND FIRST AID

CONTENTS

EARLY RECOGNITION OF PESTICIDE POISONING

It is essential that a pesticide poisoning be recognized quickly and treated promptly. Immediate treatment may mean the difference between mild or serious effects from over-exposure to a pesticide. An incident of pesticide poisoning may be obvious, such as when a person is exposed to excessively high levels during an accidental spill or splash. Sometimes, however, poisoning may only be identified from the symptoms seen or felt by the poisoned person or noted by co-workers, without the knowledge that excessive exposure has occurred. Everyone working with pesticides should be familiar with typical symptoms of pesticide poisoning (Table 9).

In particular, workers should be alert to symptoms of the early stages of poisoning; if any symptom of poisoning develops, the source of exposure must be removed immediately and completely. Additional exposure must be prevented in order to minimize injury. **Immediate and complete removal of the source of exposure may save a person's life.** Then, first aid treatment should be provided and medical attention should be obtained.

Table 9. Some general symptoms which might indicate pesticide poisoning has occurred.

mild poisoning	moderate poisoning	severe poisoning
headache dizziness	any mild symptoms plus any of the following:	any mild or moderate symptoms plus any of the following:
loss of appetite thirst nausea irritation of throat and nose diarrhea	vomiting excessive salivation coughing feeling of constriction in throat and chest abdominal cramps	inability to breathe severe secretion from respiratory tract
eye irritation constriction of pupils	blurring of vision	chemical burns on skin
skin irritation	rapid pulse	respiratory distress
perspiration	excessive perspiration	
weakness fatigue	profound weakness trembling muscular incoordination	loss of reflexes uncontrollable muscular twitching
restlessness nervousness changes in mood insomnia	mental confusion	unconsciousness

In some situations it may not be easy to decide whether an individual's symptoms are caused by pesticide poisoning, even if the person was using pesticides. Many sicknesses and diseases also produce similar symptoms. If in doubt, obtain advice from a physician or the nearest Poison Control Centre.

Advice on the management of poisonings can be obtained by telephoning local **Poison Control Centres**, listed on the inside of the front cover of telephone directories, or the **B.C. Drug and Poison Information Centre in Vancouver** at 682-5050. When calling these agencies, it is helpful to tell them the name and concentration of the active ingredient and registration number on the product label, if possible. Notify the Workers' Compensation Board as soon as possible if an accident results in the death or serious illness of a worker. Telephone the nearest W.C.B. office during working hours, or their Vancouver office at 273-7711 at all other times.

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At the work site, post the name, address and current telephone number of the physician, clinic or Poison Control Centre that will provide care in the event a person is poisoned.

TYPICAL HEALTH EFFECTS OF MAJOR PESTICIDE GROUPS

Generally, pesticides with similar chemical structure cause similar symptoms of poisoning. Those people working with pesticides should be familiar with symptoms of poisoning caused by the major groups of pesticides.

Organochlorine Pesticides (chlorinated hydrocarbons). This group includes such insecticides as endosulfan, lindane and methoxychlor. Pesticides in this group generally have moderate to low toxicity to humans. They are absorbed effectively from the gut and through the skin. In sufficiently large doses, they interfere with nerve impulses, resulting in behavioral changes. Symptoms of poisoning may include **headache, dizziness, fatigue, nausea, apprehension, excitability, vomiting, trembling** or **convulsions.**

Some of these pesticides can accumulate in the fatty tissues of humans as a result of a few large doses or repeated small doses. However, such pesticides stored in fatty tissues appear inactive and have not been demonstrated to cause chronic (long-term) toxicity problems.

Organophosphorous Pesticides. This group includes such insecticides as dimethoate, diazinon, dichlorvos, malathion and parathion. Many pesticides in this group are highly toxic and are readily absorbed through the skin, lungs or digestive tract. Even the least toxic of this group is easily capable of poisoning humans when used improperly. Repeated exposure to small doses is also dangerous. Symptoms of acute poisoning occur during exposure or usually within 12 hours of contact and include **headache, dizziness, weakness, excessive perspiration, nausea, diarrhea, blurred vision, excessive salivation, feeling of constriction in the throat and chest, muscle twitching, constriction of pupils** and **convulsions.**

Organophosphorous pesticides affect humans and animals by interfering with an enzyme called cholinesterase, necessary for proper nerve functioning. When cholinesterase is unable to perform its normal function, the nerves in the body continue to send messages to the muscles. These continuous messages cause the muscles to twitch constantly and 'tremors' or 'fibrillations' occur. If the muscle action becomes intense, the victim may have fits or convulsions. In cases of severe poisoning, quick and proper medical treatment can still save persons in the advanced stages of organophosphorous poisoning, even though they may be near death.

In general, mild exposure to these pesticides at infrequent intervals is unlikely to produce toxic effects. However, there is a danger from repeated small exposures, as symptoms of poisoning may occur suddenly without warning. There are usually no serious long-term effects from small exposures, so long as renewed exposure is avoided until such time as cholinesterase levels return to normal. However, if exposure continues, there may be an irreversible inhibition of cholinesterase, resulting in long-term health effects.

Carbamate Pesticides. This group includes such insecticides as aldicarb, carbofuran, carbaryl and propoxur. Some are highly toxic, others moderately toxic.

The mode of action of these compounds is very similar to that of the organophosphorous compounds in that they inhibit the enzyme cholinesterase. However, the carbamates are broken down in the body rather rapidly and their effect on cholinesterase is quite brief. Carbamates are therefore referred to as rapidly reversing inhibitors of cholinesterase. The reversal is so rapid that, unless special precautions are taken, measurements of blood cholinesterase of humans exposed to carbamates are likely to be inaccurate and always in the direction of appearing to be normal. The symptoms of carbamate poisoning are similar to those caused by the organophosphorous pesticides, but of shorter duration.

Dithiocarbamate and Thiocarbamate Pesticides. This group includes many fungicides and herbicides such as thiram, ziram, maneb, butylate and vernolate. They are generally not very toxic. They do not inhibit cholinesterase. Some may be **irritating to the skin, eyes, nose, throat or lungs.** Very large doses may cause **nausea, vomiting or muscle weakness.**

Phenoxy Herbicides. These are herbicides of moderate to low toxicity to mammals and include 2,4-D and MCPA. Exposure by breathing and absorption of the formulated products can produce ill effects particularly with some solvents used. Some are moderately irritating to skin, eyes, respiratory tract and gut lining. Symptoms of poisoning include **burning in chest from inhalation, chest and abdominal pain, diarrhea, muscle twitching,**

muscle tenderness or stiffness in extremities, fever, **hyper-ventilation, coma** and **convulsions** in cases of severe exposure.

Dinitrophenols. Compounds in this group are used as fungicides, insecticides and herbicides (DNOC, dinocap, dinoseb). Dinitrophenol poisoning stimulates certain body processes and may cause **fever, sweating, thirst,** rapid breathing, **rapid heartbeat,** or **convulsions**. In cases of a single, large exposure to dinitrophenols, the signs and symptoms of poisoning may occur rapidly. If death occurs, it probably will be within 24 to 48 hours. However, if the patient receives adequate medical attention and the exposure to the chemical has not been severe, the patient will probably recover completely.

Botanical Pesticides. These pesticides vary greatly in their chemical structure and also in their toxicity to humans.

Pyrethrins are insecticides derived from certain chrysanthemum flowers. They have a moderate acute toxicity to mammals, but can produce allergic-type reactions from dermal exposure or **irritate the throat and lungs** (producing wheezing or coughing in some individuals) from inhalation. The pyrethroids (synthetic analogues of pyrethrins) have a low to moderate acute toxicity to mammals and may be irritating to the skin.

Strychnine is a highly toxic botanical rodenticide which acts on the nervous system. Doses as small as 16 mg have been known to be lethal to an adult. Within 10 to 30 minutes after swallowing strychnine the victim exhibits symptoms. There may be a series of **violent convulsions** or fits at intervals of 10 to 15 minutes. Between convulsions, the victim usually relaxes and may fall asleep. Any stimulus, such as noise, may trigger another convulsion. If the victim survives the first 5 to 6 hours, there is a good chance of recovery.

Petroleum Products. Petroleum products are used as solvents and carriers, or for their pesticidal properties (e.g. dormant oils). Two types should be considered:

(a) petroleum distillates (e.g. kerosene, solvent distillate, diesel oil) have a wide range of toxicities. Symptoms of acute poisoning may include **nausea, vomiting, cough and irritation to the lungs** which may progress to **bronchial pneumonia** with fever and cough. If more than 1 mg/kg has been ingested, symptoms of central nervous system depression and irritation may occur, including **weakness, dizziness, slow and shallow respiration, unconsciousness and convulsions.** Chronic poisoning may cause **weakness, weight loss, anemia, nervousness, pains in the limbs or peripheral numbness.**

(b) aromatic hydrocarbons (e.g. xylene) — lethal doses range from 200 to 1,000 mg/kg. Symptoms of acute poisoning may include **dizziness, euphoria, headache, nausea, vomiting, tightness in chest and staggering.** More severe symptoms are **blurred vision, rapid respiration, paralysis, unconsciousness and convulsions.**

FIRST AID TREATMENT FOR PESTICIDE POISONING

It is essential that victims showing effects (intoxication) from contact with pesticides be attended to immediately. **Prompt treatment may mean the difference between life and death.** Remember that first aid treatment is not a substitute for medical treatment, but it can sustain a patient or prevent further complications until medical help is available. Know what first aid to follow in poisoning emergencies.

The procedures listed below should be followed when pesticide exposure results in, or is expected to result in, more than a mild irritation. For minor exposures resulting in no poisoning symptoms, take steps to stop further exposure to the pesticide.

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GENERAL INSTRUCTIONS

STEP 1. PREVENT ADDITIONAL PESTICIDE EXPOSURE

Move the patient away from the pesticide-contaminated area and remove any contaminated clothing. Avoid contaminating yourself.

STEP 2. CHECK IF VICTIM IS BREATHING

If breathing is very weak or has ceased, clear airway of obstructions and administer artificial respiration. **Artificial respiration takes precedence over all other first aid procedures. Continue until victim is breathing normally without assistance or until medical help is obtained.**

When performing mouth-to-mouth resuscitation, it may be necessary to use a plastic face-mask (available from St. John Ambulance) to avoid direct contact with a patient's mouth, if contaminated with a toxic pesticide. A shaped plastic airway is useful to maintain a clear air passage to the lungs.

During mouth-to-mouth resuscitation, remove objects from the patient's mouth, hold the chin up, tilt the head back as far as possible, pinch the nostrils and blow into the mouth until the chest rises. Repeat 10 times per minute.

STEP 3. OBTAIN MEDICAL ATTENTION AS FAST AS POSSIBLE

Call a physician or Poison Control Centre. Provide as much information as possible about the pesticide, history of exposure and poisoning symptoms. Save the pesticide container and material in it (if any remains), and get a readable label or the name of the pesticide product, active ingredient and product registration number to give the attending physician or Poison Control Centre. If the poison is not known, save a sample of vomitus for analysis. **If medical help cannot be obtained or is delayed, transport the victim to the nearest hospital or physician's office.**

STEP 4. KEEP VICTIM AT REST, WARM AND COMFORTABLE. CONTINUE FIRST AID TREATMENT

Do not leave a critically ill patient alone. Get someone else to arrange transportation to the Emergency Department of the nearest hospital.

INSTRUCTIONS FOR SPECIFIC TYPES OF POISONING INCIDENTS

Poison on Skin

- Remove clothing and place contaminated clothing in a marked plastic bag.
- Drench skin with water (shower, hose, faucet).
- Wash contaminated skin and/or hair thoroughly with soap and water (remember to clean under fingernails and toenails); follow with a rubbing alcohol wash, then repeat procedure. Speed in washing is most important in reducing the extent of injury.
- Dry the victim and wrap in a blanket.

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Poison in Eyes

- Hold eyelids open, wash eyes immediately with gentle stream of clean warm water. Use large amounts of water. Delay of a few seconds greatly increases the extent of an eye injury.
- Continue washing for 15 minutes or more.
- Do not use chemicals or drugs in wash water; they may increase the extent of injury.

Inhaled Poisons (dust, vapours, gases)

- If victim is in an enclosed space, do not attempt to rescue without proper respiratory equipment.
- Carry patient (do not allow walking) to fresh air immediately.
- Loosen all tight clothing.
- Apply artificial respiration if breathing has stopped or is irregular.
- Prevent chilling (wrap patient in blankets but do not overheat).
- Keep patient as quiet as possible.
- If patient is convulsing, watch breathing and protect from falling and striking head on the floor or wall. Keep patient's chin up so the air passage will remain free for breathing.

Swallowed Poisons

- Try to contact a medical authority (e.g. at a Poison Control Centre listed inside the front cover of telephone directories). Ask if vomiting should be induced.
- Where medical advice cannot be obtained, quickly induce vomiting if:
  - (a) the pesticide label recommends to induce vomiting,
  - (b) patient is conscious and not too drowsy to sit up or has not lost the gag reflex,
  - (c) patient is not having convulsions, and
  - (d) patient has not swallowed a corrosive poison; symptoms include severe pain and burning sensation in mouth and throat.

Induce vomiting by giving the patient water and gently tickling the back of the throat and tongue with a finger to make the person gag.

- Where a medical authority can be contacted, ask directions before inducing vomiting. The medical authority will likely recommend that vomiting be induced by giving the individual 2 tablespoons (30 mL) of Ipecac syrup, followed by 2 cups of water.

  The medical authority may recommend to induce vomiting, even if not indicated on the pesticide label. Sometimes pesticide labels recommend against vomiting because the pesticide contains a petroleum product as a carrier or solvent. This is because there is a risk that the petroleum product may be inhaled, leading to chemical pneumonitis. However, a medical authority may recommend vomiting where the risk of injury from the pesticide active ingredient is greater than the risk of injury from inhaling the petroleum product.
- When retching and vomiting begin, place patient face down with head lowered, thus preventing vomitus from entering the lungs and causing further damage. Do not let patient lie on back. Clean vomitus from patient and collect some in case the doctor needs it for chemical tests.
- If there is some difficulty in getting the patient to vomit, it is better to start moving toward the hospital; vomiting may be induced enroute to the hospital. Head for the hospital because drugs can be administered there to induce vomiting and stomach pumps are available.
- Activated charcoal may be used to absorb any remaining pesticide in the stomach. It may be given after vomiting is complete or if vomiting is not appropriate. Activated charcoal should be administered only with the advice of a medical attendant or doctor.
- If a person has swallowed a corrosive poison, immediately give them 1/2 to 1 glass of milk or water. Larger quantities may cause vomiting. Do not give substances to neutralize acid or alkali. Do not induce vomiting.

Chemical Burns on Skin

- Remove contaminated clothing.
- Wash with large quantities of running water.
- Immediately cover with loosely-applied clean cloth (any kind will do).
- Avoid use of ointments, greases, powders or other drugs. Do not try to neutralize corrosive poisons.
- Treat shock by keeping patient lying down, warm, and reassured until the arrival of a doctor.

If Pesticide is Known to be an Organophosphorous or Carbamate Product and Symptoms are Severe

If so instructed by a Poison Control Centre or a physician, administer 2 atropine tablets of 0.6 mg each. Place tablets either under the tongue or between the gum and upper lip, so that they can dissolve. If medical attention has not been reached at the end of one hour and the victim still shows an organophosphorous reaction, give two more atropine tablets. Inform attending physician if atropine has been administered.

Ensure victim is conscious and breathing before administering atropine. Do not give atropine if victim is already turning blue from lack of oxygen or is unconscious.

If Pesticide is Known to be a Dinitrophenol Compound

Keep victim cool. Give cool liquids by mouth. **Never administer atropine.** If a dinitrophenol compound has been swallowed, induce vomiting.

Where you are the Victim and Alone

- If you have been exposed to a toxic pesticide and are beginning to feel any illness, have someone take you to a doctor without delay. Take along information about the pesticide, preferably a label or name of the product and registration number.
- If you have been exposed to a pesticide and are alone, remain calm. The serious effects are generally not instantaneous so you will have time to protect yourself.
- Prevent additional exposure: on clothing — remove clothing and wash; in eyes — wash for 15 minutes; if swallowed — read label and **if vomiting is recommended, induce it with Ipecac syrup. This may save your life.**

FIRST AID KIT AND EMERGENCY SUPPLIES

If you plan to work with any pesticide and especially if you intend to use any of the highly toxic chemicals, you should have a specially designed first aid kit available. Supplies such as bandages and tape for other emergencies may also be included. This first aid kit may save your life, keep it handy! Your first aid kit should include the following for pesticide emergencies:

- Soap — plastic bottle of detergent to wash pesticide off skin.
- Rubbing alcohol — for cleaning skin (e.g. 70% isopropyl alcohol).
- Gloves — pair of clean, waterproof gloves to prevent skin contamination of person who administers first-aid.
- Clean drinking cup.
- Eye wash bottle — for washing eyes.
- Plastic face-mask — for use during mouth-to-mouth resuscitation to avoid direct contact with patient's mouth if contaminated with pesticide.
- Paper towels to wipe up splashes or small spills.
- Telephone information — numbers of Poison Control Centres and several quarters for emergency phone calls.

THE FOLLOWING CONTENTS ARE TO BE ADMINISTERED UPON INSTRUCTION OF A PHYSICIAN ONLY

- Ipecac syrup — to induce vomiting.
- Activated charcoal — to adsorb pesticide in stomach.

In addition to the first aid kit materials there should be a supply of fresh water for drinking if a pesticide is swallowed, for washing if skin is contaminated or for a continuous eye wash, if a pesticide is splashed in the eyes. Running water or a portable container with at least 45 litres of water must be present at all mixing, loading and application sites.

CHOLINESTERASE TESTS

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Persons who handle or apply organophosphorous or carbamate pesticides on a regular basis should consult their physician or the Workers' Compensation Board regarding the necessity of periodic cholinesterase tests. Cholinesterase enzyme levels in the body are depressed by both organophosphorous and carbamate pesticides. It is possible to measure cholinesterase levels in the blood in order to help determine whether a person is suffering from exposure to these pesticides. This can help diagnose the cause of a poisoning or warn that someone is being exposed to these pesticides before he suffers serious symptoms of poisoning.

In order to use the blood cholinesterase test, either in an emergency or on a routine check, it is important to determine an individual's normal (pre-spray season) level of cholinesterase. There are wide differences in cholinesterase levels among individuals and the normal level for each person must be known before they are exposed to pesticides.

A low cholinesterase reading may not necessarily be caused by exposure to an organophosphorous or carbamate pesticide, but severe exposure will always be accompanied by depressed cholinesterase.

In the absence of additional exposure, blood cholinesterase enzymes will regenerate in about 120 days from very low to normal values in the case of organophosphorous poisoning and more rapidly for carbamate poisoning. For carbamate insecticides, cholinesterase testing must be done immediately following exposure to be of much value. The test is ineffective for the carbamate fungicides.

It is highly recommended that applicators working frequently with organophosphorous pesticides or carbamate insecticides monitor the severity of their exposure to these compounds through a cholinesterase test program. Contact the nearest Workers' Compensation Board office directly or through your family physician and plan the time of your preseason baseline test and one or more tests during the spray season. This program is established primarily for workers under W.C.B. coverage, but other workers can apply.

CHAPTER QUIZ

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Questions

1. What degree of poisoning (mild, moderate, severe) would the following symptoms suggest: (a) vomiting, (b) irritation of throat and nose, (c) uncontrollable muscle twitching?

2. Who would you call to obtain advice about pesticide poisoning?

3. Who would you call to report a serious injury caused by a pesticide accident, after the victim has received medical help?

4. Match the following pesticides with their general toxic properties: organochlorine, organophosphorous, carbamate, phenoxy, nitrophenol, botanical —

   a) can be very toxic, danger from repeated small doses, inactivate cholinesterase, affect nerve impulses to muscles.

   b) can be very toxic, speed up body processes, cause fever, rapid breathing.

   c) moderate to low toxicity, moderately irritating to skin, eyes, respiratory tract and gut lining.

   d) some are highly toxic, others moderately toxic, inactivate cholinesterase, broken down quickly, affect nerve impulses.

   e) wide range of toxicity, some produce allergic reactions or are irritating to throat and lungs.

   f) moderately low toxicity, accumulate in fatty tissues, interfere with nerve impulses resulting in behavioral changes (e.g. apprehension, disorientation).

5. When working with what groups of pesticides should you consider having a cholinesterase test? Why?

6. What would you do to stop pesticide exposure in the following cases (a) pesticide spilled on pant leg, (b) pesticide in eyes, (c) pesticide swallowed?

7. When would you not induce vomiting?

8. What information should you have available when you obtain medical help to attend a pesticide poisoning?

   Why should you carry a bottle of Ipecac syrup and gloves in your first aid kit?

Answers

1. (a) moderate, (b) mild, (c) severe

2. Local Poison Control Centres or the B.C. Drug and Poison Information Centre

3. Workers' Compensation Board, and Pesticide Control Branch if there has been a spill.

4. organochlorine — (f), organophosphorous — (a), carbamate — (d), phenoxy — (c), nitrophenol — (b), botanical — (e).

5. organophosphorous, carbamates (cholinesterase-inhibiting). Test is taken to determine exposure to these pesticides.

6. (a) remove clothing, drench skin with water, wash with soap and water — additional first aid as required.
   (b) hold eyelids open, wash eyes immediately for 15 minutes or more — additional first aid as required.
   — additional first aid as required.
   (c) if a corrosive poison swallowed, give 1/2 to 1 glass of milk or water; if noncorrosive, induce vomiting if advised by doctor — also administer activated charcoal to absorb pesticide in stomach if advised by doctor.

7. Patient is unconscious, having convulsions or has swallowed a corrosive pesticide, or if there is concern about the petroleum product content of the pesticide.

8. Pesticide label or name of pesticide product, active ingredient and product registration number, plus a history of exposure and poisoning symptoms.

   Ipecac syrup to induce vomiting, gloves to prevent exposure to pesticide while handling/washing patient.

SECTION III

PESTS, PESTICIDE USE AND PROPERTIES

Chapter 8

INSECTS AND INSECTICIDES

Chapt. 8

CONTENTS

INSECT BIOLOGY

INTRODUCTION

Insects, and their close relatives, spiders, ticks, mites and scorpions, are **arthropods** or "jointed-legged" animals.

There are about 850,000 named species of insects. They range in size from less than 1 mm to over 15 cm long. The large number of insects can be divided into three categories according to their importance to man:

- **Species of minor economic importance.** About 99 percent of all species are of minor economic importance. They are food for birds, fish, mammals, reptiles, amphibians and other insects. Some have aesthetic value.
- **Beneficial insects.** In this small but important group are the predators and parasites that feed on destructive insects, mites and weeds. Also in this category are the pollinating insects, the honey-producing bees and other insects producing products used by man.
- **Destructive insects.** This category is probably the most well known but it includes the fewest number of species. These are the insects that feed on or cause injury to humans, animals, and plants, or damage food, fiber and structures.

Since not all insects are pests, they do not all need to be controlled. It is necessary to identify which insects need to be controlled and to select the most effective control methods. These decisions require information about insect structure, how they reproduce and develop, their habits, and how they are identified.

INSECT STRUCTURE

All insects in the adult stage have two physical characteristics in common. They have three pairs of jointed legs and they have three body regions — the head, thorax and abdomen. Figure 16 illustrates the main characteristics of a typical adult insect.

The **head** of an insect contains antennae, eyes and mouthparts. The antennae and eyes vary in size and shape and are used to help identify some insects. There are four general types of mouthparts:

- **Chewing mouthparts** are used to bite and tear food. Silverfish, springtails, grasshoppers, cockroaches, earwigs, termites, beetles, ants, wasps, bees and the caterpillar stage of many butterflies and moths have these mouthparts.
- **Piercing and sucking mouthparts** consist of a long slender tube which is forced into plant or animal tissue to suck out fluids or blood. Insects with these mouthparts include stable flies, sucking lice, bed bugs, mosquitoes, true bugs and aphids.

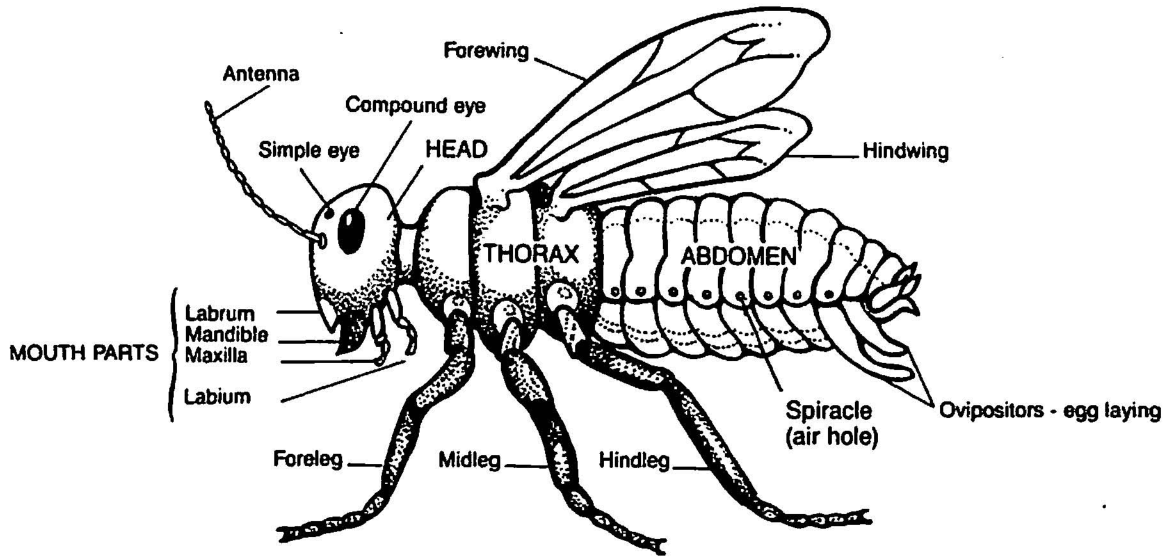


Figure 16. The general characteristics of a nonspecialized adult insect.

- **Sponging mouthparts** have a tubular tongue-like structure with a spongy tip to suck up liquids or soluble food. This type of mouthpart is found in the flesh flies, blow flies and house flies.
- **Syphoning mouthparts** are formed into a long tube for sucking nectar. Adult butterflies and moths have these mouthparts.

The insect thorax contains the legs and the wings (if present). The legs may be highly modified for such activities as running, jumping, digging or swimming. The thorax of adult insects may have two pairs of wings (e.g. bees), one pair of wings (e.g. flies), or no wings (e.g. silverfish and fleas). The wings may be simple and transparent (e.g. flies) or covered with brightly covered scales (e.g. butterflies), or hardened to provide a tough body covering (e.g. beetles).

The insect abdomen may have various forms, but in the adult it lacks true legs or wings. Feeler-like appendages may be present on the hind end. The abdomen bears the reproductive organs in both the male and female insects. Along each side of the abdomen are openings (spiracles) through which the insect breathes.

INSECT REPRODUCTION AND DEVELOPMENT

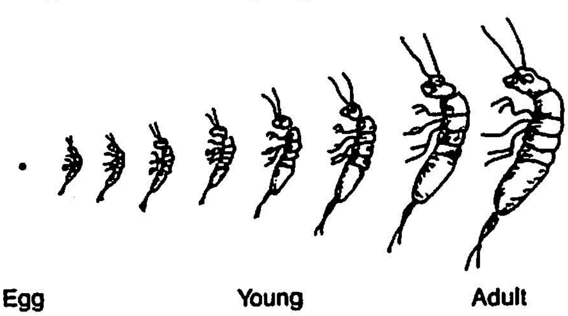
Knowledge about insect reproduction and development can be used to apply control measures at times when pest species are most susceptible.

Most insect reproduction results from males fertilizing females. The exceptions include some aphids and parasitic wasps which reproduce without mating. A few insects give birth to live young; however, life for most insects begins as an egg. Eggs may be deposited as a single egg or in masses in soil or on plants, animals, or structures. Temperature, humidity and light are major factors influencing the time of hatching.

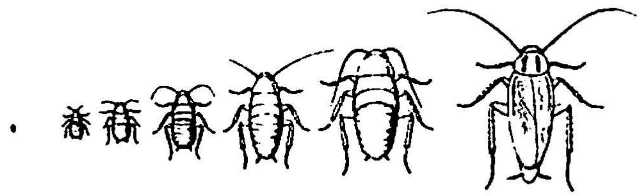
When an insect first hatches from an egg, it begins to feed and grows until its skin cannot stretch further. The insect then sheds its skin (molts) and a new skin is formed. The growth stages between molts are called **instars** — the last growth stage is the adult. The number of instars varies with different insect species and, in some cases, may vary with the temperature, humidity and availability and kinds of food. The heaviest feeding generally occurs during the final two instars.

Some insects change their shape or acquire new characteristics as they develop into adults. This change is called **metamorphosis**. There are three main types of insect development:

Without Metamorphosis. There are three development stages: egg, young, and adult. The young (juvenile stages) visually resemble the adult stage, except they are smaller. A few insects have this type of development, e.g. silverfish and springtails.



Gradual Metamorphosis. There are three development stages: egg, nymph and adult. **Nymphs** are missing certain adult features (e.g. wings or reproductive organs) when they hatch, but gradually develop these features as they mature. Wings become fully developed only in the adult stage. Many insects have this type of development, e.g. cockroaches, grasshoppers, termites, earwigs, lice, thrips, plant bugs, aphids, scales and leafhoppers.

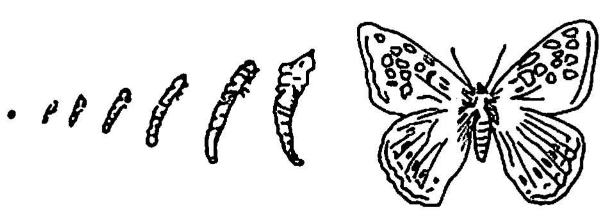


Egg Nymphs Adult

Complete Metamorphosis. Four development stages are recognized: egg, larva, pupa and adult. **Larvae** hatch from the egg and grow larger by molting and passing through one to several instar stages. The larvae do not resemble the adult stage. The true or thoracic legs of larvae may be underdeveloped, some have false legs (prolegs) in the abdominal region and others have no legs at all. Other names for the larval stage of certain insects are:

- **Caterpillars**, the larvae of many moths, butterflies and sawflies.
- **Loopers**, some larvae of moths and butterflies in which some of the middle abdominal legs are missing.
- **Grubs**, some larvae of beetles and weevils.
- **Maggots**, the legless larvae of many flies and midges.

The **pupa** is a resting stage during which the larva radically changes shape to become an adult with legs, wings, antennae and functional reproductive organs. The adults usually live in different habitats and consume different foods than the larvae. Many insects have this type of development, e.g. beetles, weevils, butterflies, moths, flies, mosquitoes, fleas, bees, wasps and ants.



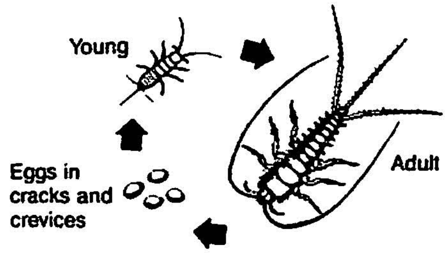
Egg Larvae Pupa Adult

INSECT CLASSIFICATION

An important requirement of any pest control program is accurate identification of the pest species. Scientists have divided all insects into groups called **orders**. Insects are placed in an order according to common characteristics such as the presence or absence of wings, wing texture, type of mouthparts and type of metamorphosis.

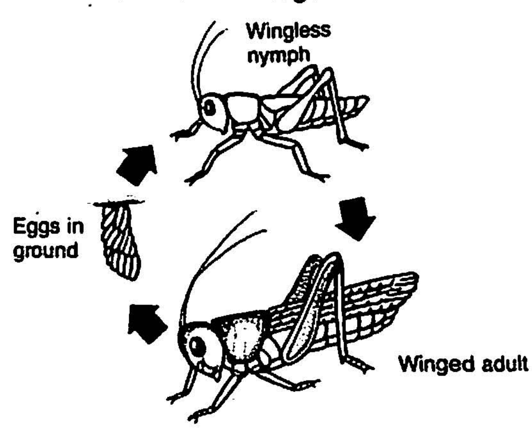
The following is a brief description of the 14 orders which contain most insect pests (scientific names of orders are in brackets).

Silverfish and firebrats (Thysanura) are wingless insects with chewing mouthparts. They can feed on and damage fabrics, paper products, paste and books.



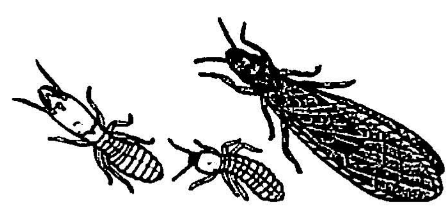
Silverfish Lifecycle

Grasshoppers, crickets, cockroaches (Orthoptera) have two pairs of wings and chewing mouthparts. Both nymphs and adults cause damage.



Grasshopper Lifecycle

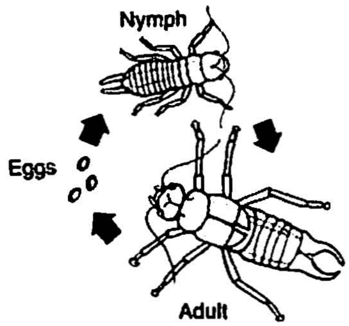
Termites (Isoptera) colonies contain three different classes of individuals: workers, soldiers and swarmers. The injurious termites are generally placed in two groups: the dampwood and subterranean types. The dampwood termite does not usually feed on sound wood, whereas the subterranean termite can be found in sound wood buildings and cause considerable damage if not controlled.



Soldier Worker Winged reproductive

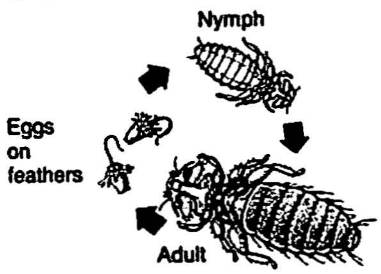
Adult Termites

Earwigs (Dermaptera) are medium-sized insects, distinguished by the non-poisonous pinchers on their abdomens. They have chewing mouthparts. The European earwig is occasionally a pest of gardens, ornamentals, small trees and homes.



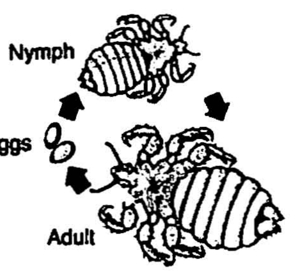
Earwig Lifecycle

Biting lice or bird lice (Mallophaga) are small flat, wingless parasitic insects with chewing mouthparts. They feed on feathers, hair, wool and skin scales. Examples of injurious lice are the chicken body louse and cattle biting louse.



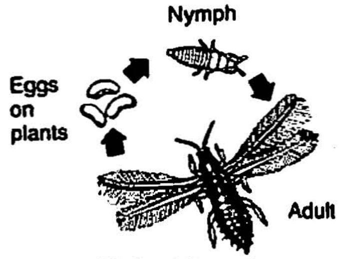
Chicken Body Louse Lifecycle

True lice or sucking lice (Anoplura) are small flat, wingless parasitic insects with mouthparts formed for piercing skin and sucking blood. The body louse can be a vector of disease in humans. Short- and long-nosed cattle lice can be pests of beef and dairy cattle.



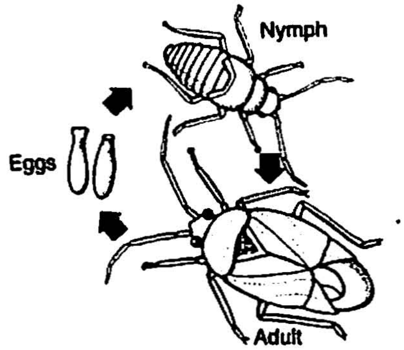
Human Body Louse Lifecycle

Thrips (Thysanoptera) are mostly very small insects about 3 mm long with piercing and sucking mouthparts. Some feed on plants and are very injurious in greenhouses or on vegetable crops. Onion thrips nymphs and adults cause severe damage to onion crops. Western flower thrips cause malformed and spotted flowers. Some species of thrips can also transmit plant virus diseases.



Thrips Lifecycle

True bugs (Hemiptera) usually have four wings folded flat over the body. The mouthparts are prolonged into a beak for sucking. Examples include stink bugs which feed on many fruits and vegetables and lygus bugs which are serious pests of seed crops, especially of alfalfa.



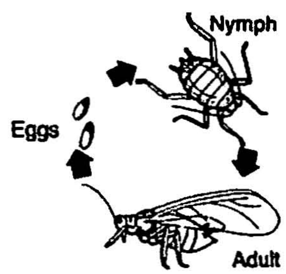
Bug Lifecycle

Aphids, leafhoppers, cicadas, whiteflies, mealybugs and scale insects (Homoptera) all have sucking mouthparts and feed on plants. There are winged and wingless species and many sizes and shapes of insects in this order. They cause damage to many crops and ornamental plants.

Aphids have a complex method of reproduction which involves the production of a series of generations without fertilization; some of the broods may be wingless, others winged.

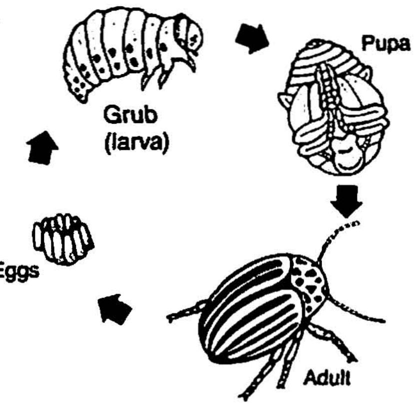
Scale insects are usually small and are protected during most of their life cycle by a hardened covering or scale. San Jose scale is a pest of many fruit trees and ornamentals.

The secretion of honey-dew by aphids and scale insects may result in the growth of a black unsightly mold on the surface of leaves and stems. Many of these insects can also transmit viruses which cause very destructive plant diseases.



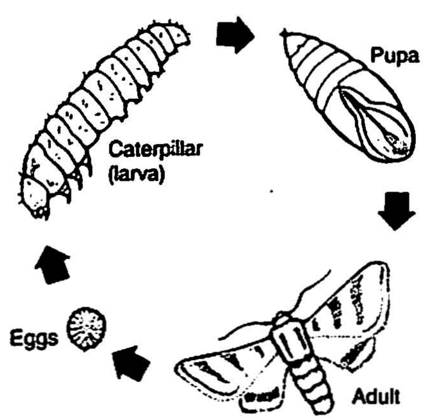
Aphid Lifecycle

Beetles and weevils (Coleoptera) usually have two pairs of wings and have chewing mouthparts. Many of their larvae are commonly called **grubs**. Some grubs live in the soil and feed on plant roots. Others bore into plant stems. The larvae of click beetles are called wireworms which feed on the roots, bulbs and crowns of plants and are especially destructive to germinating seeds. Bark beetles, which bore through the bark of trees, are considered the most destructive insect pests of forests.



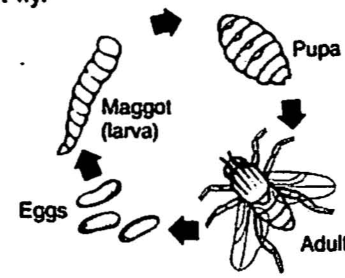
Beetle Lifecycle

Butterflies and moths (Lepidoptera) have adults which feed by means of sucking mouthparts, largely on nectar of flowers, and are not particularly injurious. The larvae have chewing mouthparts and are often destructive. Some larvae are known as caterpillars, cutworms or hornworms. This group includes some of the most severe insect pests such as the codling moth, army worm, cabbage worm, tent caterpillars, the alfalfa, celery and cabbage loopers, and the peach twig borer.



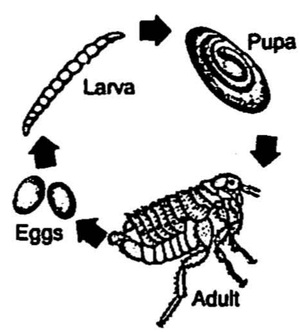
Moth Lifecycle

Flies, mosquitoes and gnats (Diptera) are winged and have sponging or piercing and sucking mouthparts. The immature stages are usually known as maggots. The adults of this group include many well known insects such as house flies, mosquitoes, gnats, horse flies and deer flies. Some can be a danger to human health because they transmit diseases. The larvae of some are leaf-miners. Agricultural insect pests in this order include the cherry fruit fly, the onion and cabbage maggot and the carrot rust fly.



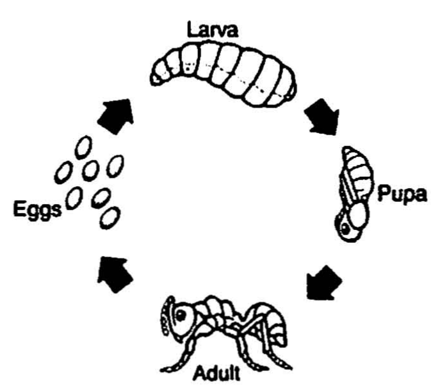
Fly Lifecycle

Fleas (Siphonaptera) are small wingless insects with piercing and sucking mouthparts. The immature stages are wormlike and quite different from the adults. The adults of dog and cat fleas are well-known pests of domestic animals and man. Some species of fleas can transmit human diseases.



Flea Lifecycle

Bees, wasps, ants (Hymenoptera) are winged or wingless insects with chewing and sucking mouthparts. The immature stages are maggot-like. This group includes many beneficial species as well as some pest species.



Ant Lifecycle

INSECT-LIKE ARTHROPODS

Spiders and mites are related to the insects. Most spiders are beneficial predators. They feed almost entirely on insects. Mites are discussed in the following chapter.

Millipedes are elongate with two visible body regions: a head and a body. They are rounded in cross section and, with the exception of the first four or five segments, all of the body segments possess two pairs of legs. They are relatively slow-moving. Millipedes are generally inoffensive creatures that feed on fungus and decaying plant material. However, they can be destructive to vegetables.

Centipedes resemble millipedes. They are different in that they have longer antennae, are flattened in cross section, have one pair of legs on each body segment, and move rapidly. They are beneficial in that they are predators on other small arthropods.

Sowbugs or pillbugs are oval with a hard outer shell made up of a number of plates. They require moisture and live in damp habitats. Generally, they feed on decaying plant materials, but will injure young plants in greenhouses and gardens.

Garden centipede or symphylans are 3 to 6 mm long and resemble tiny centipedes. They can be distinguished from centipedes by their rapid movements and vibrating antennae. They sometimes injure the roots of vegetable and berry plants in damp soils, rich in organic matter.

BENEFICIAL INSECTS

A few examples of insects which are beneficial to man are illustrated in Figure 17. These insects should be protected wherever possible.

Beneficial insects are divided into three categories: predators, parasites and pollinators.

Predators prey on and eat other insects, or mites. For example, adult **lady beetles** and their larvae consume many kinds of soft- bodied insect pests. They are voracious feeders on aphids. **Lacewing** larvae are predaceous on a number of insects including aphids, scales, mites, and mealybugs. The **minute pirate bug** feeds by sucking body fluids from aphids, thrips, mites and young scales. Adult **syrphid flies**, which resemble bees, are important in regulating aphid populations in many field and vegetable crops. **Big-eyed bugs** are one of the

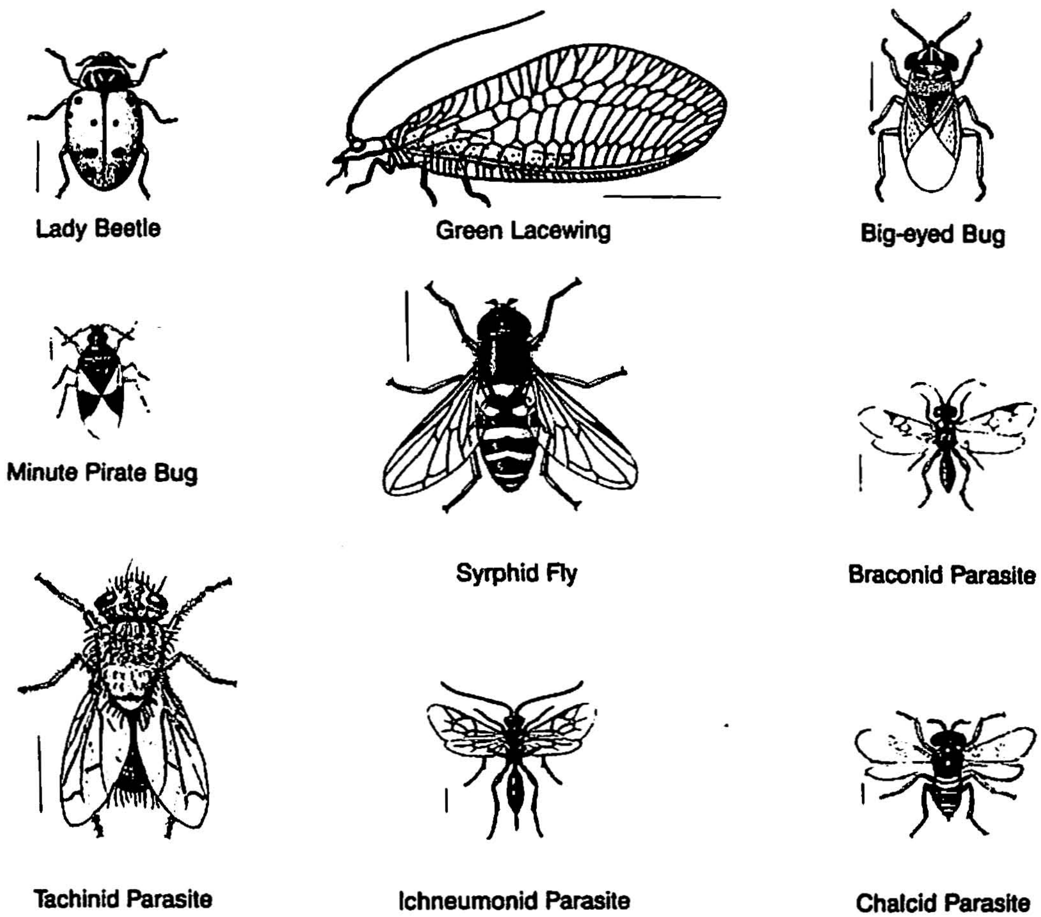


Figure 17. Some predaceous and parasitic insects (line beside each represents actual size of adult).

primary enemies of lygus bug pests and also prey on leafhoppers and aphids.

Parasites live on or in other insects or weeds (hosts), causing some harm and usually death of the host[1]. Parasites are usually small. There are parasites of insect egg, larva, pupa and adult stages. Some well known ones are the **tachinid flies.** Their larvae develop and feed on the caterpillar stage of many destructive pests such as cutworms, army worms, codling moth, horn worms, cabbage worms and grasshoppers. There are a number of parasites belonging to the bee and wasp group **(ichneumonids, brachonids and chalcids)**. Their life cycles are often closely synchronized with their prey. The adult females lay eggs in or on the prey and the parasite larva consumes the internal organs of the prey, eventually killing it. Some native and introduced species help regulate populations of aphids, weevils and cutworms.

Pollinating insects are important in the pollination of many berry, fruit and seed crops. Examples are honey bees and leafcutter bees as well as some flies, butterflies and moths that feed on nectar and pollen of flowers.

INSECT CONTROL AND INSECTICIDES

APPROACHES TO CONTROL

Insects are considered pests when they transmit disease, damage crops, destroy products or annoy man. The mere presence of an insect pest is not usually an indication of a threat of economic damage. In fact, low numbers of a pest species on agricultural crops or forest lands may be necessary to maintain the continuity of predators, parasites and pathogens of the pest. In most situations, the goal should be to manage pest populations so as to eliminate them as pests but not to eradicate them or their predators and parasites. Indoor pests may be an exception where the goal is usually to prevent entry or to eradicate pests from a specific building or structure.

Usually a variety of options should be considered for control of a specific pest. Information about the insect pest life cycle and its predators are desirable in order to select the best control methods for a specific situation. Ideally, the process of gathering this information should include the following steps:

- identify the pest and determine the extent of the damage,
- assess the size of the pest population,
- assess populations of the pest's natural enemies and other beneficial insects,
- obtain information on their life cycles, and
- consult the most recent control publications.

One of the most important considerations is the relation between visible damage and insects present during an investigation. In some cases, the damage may be old and insects now present may not have caused the damage. The pest species may have completed its development and pupated or left the area. It may be best to wait until new generations of the pest are detected before control is attempted.

Insect numbers can be estimated using a variety of sampling devices. In some agricultural situations, an insect sweep net is useful. Traps are often used to detect insects. Sticky boards, bait, light or pheromone traps may help to determine emergence of some insects so that control measures may be accurately timed. Soil insect numbers can be estimated by taking standard volumes of soil and sifting it through screens to detect such pests as wireworms, white grubs, subterranean cutworms or root weevils.

Sometimes it is necessary to estimate insect numbers by checking for signs of their activity. This may include the degree of tree defoliation, the number of dropped fruits in an orchard, or the number of damaged plants in a field crop. Other signs of activity may include cast skins, fecal pellets or empty cocoons.

Assessment of beneficial insects can be made while sampling for insect pests. Samples may expose adult fly or wasp parasites or predators or carcasses of pests killed by their enemies.

Information on insect identification, life cycles and control measures can often be obtained from specialists working with specific insect pest groups. Agencies such as Agriculture Canada, the B.C. Ministry of Agriculture and Fisheries, B.C. Ministry of Forests and Lands and the Pacific Forestry Centre produce many publications dealing with specific pests. Some reference publications are listed toward the end of this chapter.

If control measures are implemented, it is important that good records are made of treatment rates, locations, times and conditions. Follow-up observations should be made to determine the effectiveness of control measures, to look for undesirable effects and to determine whether re-treatment is required.

METHODS OF INSECT CONTROL

There are several categories of insect control methods:

Mechanical and physical methods may be suitable under special circumstances. Examples include handpicking, the use of screens and traps, and the use of electricity, light or heat and cold treatments. The use of screens in greenhouse openings and introduction of relatively pest-free plant material will reduce or delay infestations of aphids, caterpillars or cutworms in greenhouses. Traps, consisting of yellow surfaces covered with sticky material, have been used to control

[1] Those insects which kill the insect host they live on are more correctly called parasitoids.

whiteflies in greenhouses. Lights are sometimes used to attract insects to killing mechanisms. Fabrics and furs can be protected from insect attack by storage at low temperatures. Cold storage of farm produce will usually eliminate further insect damage during the storage period.

Cultural control depends on manipulation of the environment to make conditions less favourable for pests. Sanitation can be a highly effective cultural control technique. A good example is cleaning orchards of dying wood which may be a breeding ground for wood-infesting beetles. Fly control in and around barns and livestock pens is greatly aided by proper manure management. Tillage can be a cultural control method where it interferes with pest insect life cycles or destroys their habitat. Rotation of crops may be used to eliminate pest species surviving year after year on the same crop. Other approaches such as the removal of attractive alternate hosts, a change in planting distances and changes in planting and harvest times are often used to control or reduce outbreaks of destructive insects. Indoors, sanitation is a major method of preventing insect pest problems.

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Biological control is the release or enhancement of predators, parasites or diseases to control or manage a population of pest species. It has been particularly successful against some introduced insect pests. For example, the European earwig, when first introduced to British Columbia, multiplied to epidemic proportions. A parasitic fly was subsequently imported and has been partially effective in controlling populations in the south coastal region. Another example is the introduction in 1979 to 1982 of a parasitic fly and a parasitic wasp to southern Vancouver Island for control of the winter moth. By 1985, about 45 percent of the winter moth larvae were parasitized.

Chemical control of insects has become a necessary practice in agriculture, forestry, public health and structural pest control. Such control includes not only direct poisons but also repellents, hormones (growth regulators) and pheromones.

Regulatory control is the attempt to regulate commerce, farming and other human activities that affect the distribution and prevalence of destructive insect pests. Such control includes plant quarantine and restrictions on the movement of some soils and plant material. Probably the greatest value of a well-planned regulatory program is the ability to slow down the movement of insect pests until research can develop adequate control measures.

Integrated pest management (IPM) is the use of pest control methods which minimize harm to beneficial insects and the environment. A knowledge of the pest's environment and life-cycle is used to develop a management program which may combine cultural, mechanical, biological or selective chemical controls to keep the pest species at tolerable levels.

IPM is presently used on greenhouse cucumbers and tomatoes in British Columbia. The two main pests of those crops are whiteflies and two-spotted spider mites. A tiny parasitic wasp is introduced to control the whiteflies, and a predaceous mite is introduced to control the spider mites. Selective sprays are used only when the biological agents cannot keep the pests under control.

IPM is also used on carrot and onion fields in the Lower Mainland and on southern Vancouver Island. Fields are monitored for carrot rust flies and onion maggots. When they occur in high enough numbers to be a threat to the crop, a spray is applied. This procedure has greatly reduced the number of sprays that have to be applied per season, and those sprays that are applied are more effective.

IPM is recommended for control of apple aphids on mature apple trees. Parasites and predators normally hold this pest in check. Sprays are usually not required on mature trees unless the top 7 to 10 leaves of terminal growth are infested. Controls applied before this level of infestation will destroy the beneficial insects and may result in the need for additional sprays.

INSECTICIDE MODES OF ACTION

Insecticides can be divided into several types according to the way in which they affect insects.

Contact insecticides are capable of killing insects when absorbed through their body wall or intestinal tract. In the past, insecticides were classed as either stomach poisons which had to be eaten by the insect or contact poisons which would be effective if an insect walked over a treated surface. Now, most insecticides are effective both ways and are referred to simply as contact insecticides.

In the structural pest control industry, the term 'contact insecticide' is used more specifically to refer to pesticides which should contact the insect directly while being applied. Some of these have a good **'knockdown effect'** — that is, insects are paralyzed almost immediately after contact. **'Residual'** insecticides, on the other hand, remain on surfaces where they can kill insects for some period of time after application.

Systemic insecticides spread internally through the plant or animal to which they are applied. Thus a systemic insecticide applied to a plant's leaves, stems or roots is absorbed by the plant and is transported around the plant within its sap. Here the systemic is effective only for killing sucking insects. For example, the systemic insecticide, dimethoate, can be painted on a tree trunk, and will kill aphids and other sucking insects on its leaves. It will not kill caterpillars that chew on the leaves. Some systemics also have contact activity. For example, dimethoate will act as a contact insecticide if sprayed on tree foliage.

Systemic insecticides are also used to control some pests of livestock. When the systemic is applied to an animal it is carried via the blood to different parts of the animal's body where it will kill sucking insects such as lice.

Fumigant insecticides generally enter an insect body through its respiratory system or body wall as a gas. They are useful in enclosed spaces or for the treatment of soil, structures or various products.

Suffocating insecticides are materials (usually oils) which clog the breathing mechanism of insects and interfere with oxygen uptake.

Desiccant insecticides kill by removing or absorbing the protective, waxy outer coating on the insect body. This causes the loss of body fluids, so that the insect dies of dehydration.

Growth regulators are designed to mimic the action of certain insect hormones. When applied at a critical life cycle stage, they interfere with insect development.

Pheromones are chemicals emitted by insects to affect the behavior of other insects, such as attracting males to females of the same species. In some control programs, synthetic pheromones are used to attract insects to traps or to disrupt reproductive behavior.

Repellents are used to make an insect pest avoid or leave a treated surface.

Microbial insecticides are insecticides which contain microorganisms. Most must be eaten by the insect pest to cause injury. Several insecticides are now marketed which contain a bacterium *(Bacillus thuringiensis* or 'B.t.') which produce toxins that injure the gut of certain larvae that ingest it. An insecticide containing a nuclear polyhedrosis virus has been used to control Douglas-fir tussock moth larvae.

INSECTICIDE CHEMICAL GROUPS

One method of classifying insecticides is by their chemical structure. The following is a description of the more commonly encountered chemical groups of insecticides.

Botanical compounds are insecticides that have been derived from plant material. These insecticides tend to be unstable and short-lived. They have good knockdown qualities. Examples are:

nicotine
pyrethrins
rotenone

Inorganic compounds are derived from naturally-occurring minerals. Many of them are persistent, and several, including arsenic, mercury, and thallium, are cumulative poisons. Most of the inorganic materials have been replaced by the synthetic organics. A number of the following examples are no longer registered (NR) for use in British Columbia:

borax	silicon dioxide
calcium arsenate (NR)	sodium arsenite (NR)
lead arsenate (NR)	sodium fluoride
lime sulphur	sodium fluorosilicate
mercurous chloride (NR)	thallium sulphate (NR)

Petroleum and mineral oils have been used for insect and mite control on fruit trees for many years. The use of these oils as dormant or delayed dormant foliar sprays began in the last decade with the introduction of highly refined oils which are less injurious to plant tissue. Their mode of action is not well understood although they are known to block oxygen uptake by insect eggs. Examples include:

superior oil (Volck oil)
supreme oil

Organochlorine compounds act mainly as contact poisons. The tendency of many of them to build up in natural food chains creates a hazard to fish and wildlife populations and has brought about a large reduction in their use in North America. In British Columbia, many of these materials may only be sold and used under permit. Examples below include some which are no longer registered for use (NR) and some which have had all sales discontinued (D) and can not be used in B.C.:

aldrin (D)	endrin (D)
benzene hexachloride (NR)	heptachlor (NR)
chlordane (D)	lindane
chlordecone	methoxychlor
DDT (NR)	paradichlorobenzene
dieldrin (D)	terpene polychlorinates (NR)
endosulfan	

Organophosphorous compounds include both contact and systemic poisons. Most of them have a moderate residual activity, which is desirable for reducing residues on food crops, but is often a problem where longer protection is desired. Repeated applications may be necessary. Examples include the following insecticides with and without systemic activity:

Systemics	Non-Systemics
acephate	azinphos-methyl
coumaphos	chlorpyrifos
demeton	crotoxyphos
dimethoate	diazinon
disulfoton	dichlorvos
famphur	ethion
methamidophos	fensulfothion
mevinphos	fenthion
oxydemeton-methyl	fonofos
phorate	malathion
	naled
	parathion
	phosalone
	phosmet
	sulfotep
	temephos
	tetrachlorvinphos
	trichlorfon

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Carbamate compounds include both contact and systemic poisons and usually have a short residual activity. Examples include the following systemics and non-systemics:

Systemics	Non-Systemics
aldicarb	aminocarb
carbofuran	bendiocarb
methomyl	carbaryl
	dimetilan
	propoxur

Pyrethroids are synthetic analogues of the botanical insecticide pyrethrins. They possess a wide range of both knockdown and killing power. They are used mainly for fly control. They are generally very toxic to fish and other aquatic organisms. Examples include:

allethrin	fenvalerate
cypermethrin	permethrin
deltamethrin	resmethrin
	tetramethrin

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FACTORS AFFECTING INSECTICIDE EFFICACY

Insect Life Cycle

Successful control of insects requires knowledge of the stage(s) of their life cycle in which they are most susceptible. The best control is usually achieved during the early larval or nymphal stages when the insects are small and vulnerable. Control during these stages requires careful monitoring of pest populations. Control of late instars or adults is often attempted because they are most visible. However, the larger insects are often more resistant to pesticides, and adults already may have laid eggs for another generation. It is also difficult to control insects in either the egg or pupal stage, because these stages are often inactive, not feeding, or in inaccessible areas such as underground, or in cracks and crevices. Some pupae may be enclosed in protective cocoons or cases.

Environmental conditions, such as humidity, temperature and availability of food, can alter the rate of growth of insects and thus affect the length of the life cycle. Optimum environments (usually warm and humid) can decrease the time of development from egg to adult.

Susceptible insect life stages may be present for only a short time period. This time can vary from year to year, often depending on weather conditions. For example, wireworms are larvae which damage the roots of germinating grasses, cereal grains or other plants. The larvae move up through the soil to feed in spring, when soil temperatures rise, and later burrow down and become inactive when the soil is too hot and dry. Chemical controls applied too late or early could miss the period of wireworm activity.

There is also a short time period for effective treatment of the codling moth which damages tree fruits. The first spray should be made after they emerge in May or June as days grow warm, but before the insects mate and lay their eggs when night time temperatures are warm. The use of codling moth pheromone traps in apple and pear orchards help to determine the need for sprays and timing of applications.

Weather

Most insecticides can be used in a wide range of temperatures, but the efficacy of some varies with temperature. Cool temperatures slow the degradation of most insecticides and can increase the duration of their effectiveness. Deltamethrin is most effective at cool temperatures (around 5°C) and is not very useful around 25 to 30°C. Endosulfan's efficacy increases as temperature increases. Malathion works best at about 21°C.

A heavy rain shortly after an insecticide application will usually reduce its effectiveness and re-treatment may be required earlier than during dry conditions.

Insect Resistance

Several cases have been noted in British Columbia where insects appear to have developed a resistance to traditional insecticides. When applications have to be made more frequently to obtain the desired control, a different insecticide should be used, provided that one is registered for that use. For example, the green peach aphid has developed resistance to diazinon or endosulfan in some areas. Where these insecticides are ineffective, it is recommended that oil or lime sulphur be applied at the dormant stage. There has been a suspected resistance of the strawberry aphid to endosulfan, malathion and diazinon in some Lower Mainland fields. If poor control has been obtained with one of these, another should be used. The pear psylla has well-known ability to develop resistance to insecticides. Growers should limit spray applications by using cultural controls and well timed treatments. When chemical control is required, growers should alternate among insecticides from different chemical groups, e.g. carbamates or pyrethroids.

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Berries

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Field Crops

BCMAF. Field Crop Guide to Weed, Disease, Bird and Rodent Control. Updated yearly.

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See also reports and publications of the Canadian Forestry Service on such insects as the Douglas-Fir tussock moth, European pine shoot moth and spruce budworm.

Structural

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Anon. 1985. *Insect Control in the Home.* Communications Branch, Agriculture Canada, Ottawa. 18 pp.

Ebeling, W. 1975. *Urban Entomology.* University of California, Division of Agricultural Sciences. 695 pp.

[1] B.C. Ministry of Agriculture and Fisheries.

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Mosquitoes

British Columbia Mosquito Advisory Committee. 1984. *British Columbia Mosquito Control Guide.* B.C. Ministry of Agriculture and Food. 12 pp.

Miscellaneous

See the publications list of the BCMAF for Fact Sheets on specific pest insects. Also see the technical publication list of Agriculture Canada for their publications on control of many specific pests.

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REFERENCE LIST OF INSECTICIDES AND THEIR PROPERTIES

The following reference list includes a description of most insecticides used in British Columbia and some of historic interest when this text was published. Insecticides are listed alphabetically by active ingredient with some examples of trade names. No endorsement of products is implied. Information contained in this list could become out-of-date and not represent current use recommendations. **The current registered label is the authority on a pesticide's registered uses, application methods and safety precautions.**

The relative acute mammalian toxicity is given for each active ingredient listed. LD_{50} values (mg/kg body weight) are listed where available and are derived from tests with rats unless indicated otherwise (Rb = rabbit). The lowest LD_{50} is listed for each insecticide where several values are given in the literature reviewed.

acephate *(Orthene)* — an organophosphorous compound with contact and systemic activity, formulated as an emulsifiable concentrate and soluble powder. It is registered for control of a wide variety of agricultural insect pests and for several forest insect pests. It has a moderate persistence with residual activity of 6 to 9 days. Its acute toxicity to mammals is low (LD_{50}: oral = 866; dermal = 2,000). It is moderately toxic to birds, slightly toxic to fish and highly toxic to bees.

aldicarb *(Temik)* — an extremely toxic carbamate pesticide with considerable systemic action and persistence against mites and sucking insects. Aldicarb is so toxic that it is very hazardous if misused. It is no longer sold for use on ornamentals or potatoes and there is now no permissible use in B.C. It has a high mammalian acute toxicity (LD_{50}: oral = 0.8; dermal = 3) but is not very toxic to fish.

aldrin — an organochlorine material that was extensively used for soil preplanting treatments to control cutworms, wireworms, white grubs, tuber flea beetle and root weevils. It was also used as a foliar treatment against root weevil adults on berry crops and ornamentals. Aldrin is highly persistent. In the soil it is oxidized to dieldrin, an even more persistent material. It is insoluble in water but soluble in most organic solvents. It is highly toxic to mammals (LD_{50}: oral = 39; dermal = 98). A permit is required for its purchase and use in British Columbia. There has been no authorized use in this province for several years.

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allethrin — a non-chlorinated pyrethroid compound which has good insect knockdown qualities. It is usually formulated with synergists for use in household aerosols, livestock sprays and mosquito coils. It has a low mammalian acute toxicity (LD_{50}: oral = 680), although exposure can produce allergic reactions.

aminocarb *(Matacil)* — a broad spectrum, non-systemic carbamate compound registered for spruce budworm control. It has a high mammalian acute toxicity (LD_{50}: oral = 21; dermal = 275) and is hazardous to bees.

azinphos-methyl *(APM, Guthion)* — an organophosphorous material formulated as a dust, emulsifiable concentrate and wettable powder. Azinphos-methyl is widely used in agriculture against a broad range of insects, including leafrollers, codling moth and crown borers. It is also registered for use on a number of forest and shade tree insects, including pine shoot moth, aphids, and seed and cone insects. It is not registered for domestic use because of its relatively high mammalian acute toxicity (LD_{50}: oral = 7; dermal = 220). It is highly toxic to bees, fish and wildlife, and has a long residual action.

Bacillus thuringiensis *(Dipel, Envirobac, Novabac, Thuricide, Vectobac)* — a microbial insecticide based on toxins produced by a bacterium species. There are a number of varieties of this bacterium which are toxic to specific groups of insects. The main varieties now used in commercial products are *Bacillus thuringiensis* var. *Kurstani* (B.t.) used primarily to kill leaf-eating caterpillars, and *Bacillus thuringiensis* serotype H-14, also known as var. *israeliensis*, used to kill aquatic larvae of mosquitoes and blackflies. Products are formulated as a wettable powder, dust or stabilized slurry of spores and crystals produced by the bacteria. The spores and crystals must be eaten by the target insects to cause toxic effects; there is no contact activity. It has a short residual effect. It appears to have no hazard to humans, animals, birds, bees, fish, or to predatory or parasitic insects.

bendiocarb *(Ficam)* — a broad spectrum carbamate material registered for control of household insect pests including cockroaches, carpenter ants, fleas, silverfish, ticks and wasps, and for wall sprays on outdoor buildings. It is formulated for commercial use as a wettable powder and as a dust. It has a rapid knockdown effect as well as good residual activity. Bendiocarb has a high mammalian acute toxicity (LD_{50}: oral = 40. For *Ficam* 80W oral = 179; dermal = 1,000). It must not contaminate food or animal feed. It is highly toxic to bees and fish.

borax — an inorganic material formulated as a bait for use against ants and as a dust against cockroaches. It is slow-acting and not useful in damp situations. It has a low acute toxicity to mammals (oral LD_{50} = 2,660).

boric acid *(boracic acid)* — an inorganic compound formulated as a dust for use against cockroaches. It is slow-acting. It has a low acute toxicity to mammals (oral LD_{50} = 3,000).

carbaryl *(Sevin)* — a carbamate which is effective against many insects, including ants, leafrollers, cutworms, and flea beetles. It is formulated as a bait, dust, granule, suspension, wettable powder and pressurized spray. Under dry conditions it has long residual action, but effectiveness decreases markedly following rain or overhead sprinkler irrigation. It has a moderate mammalian acute toxicity (LD_{50}: oral = 400; dermal > 2,000), but is extremely toxic to honey bees. Foraging bees may be killed up to two weeks after treatment.

carbofuran *(Furadan)* — a systemic carbamate available in granular and flowable formulations. It is applied as a foliar spray or soil application at planting time to control such insects as weevils, carrot rust fly, aphids, flea beetles, leafhoppers and root maggots. Carbofuran is highly toxic to mammals (LD_{50}: oral = 5; dermal = 1,000). It is highly toxic to bees as well as fish, birds and other wildlife. Granular formulations should not be applied to fields that are subject to winter flooding and used by waterfowl.

carbophenothion *(Trithion)* — an organophosphorous insecticide and miticide formulated as granules and a wettable powder. It has residual activity and was registered for use against many fruit tree and vegetable crop insects. Carbophenothion is highly toxic to mammals (LD_{50}: oral = 7; dermal = 27). It is no longer registered for use in Canada.

chinomethionat *(Morestan)* — registered for use against pear psylla and mites. See reference list of miticides.

chlordane — a persistent organochlorine compound that was used for control of a wide variety of agricultural and structural insect pests. The technical material consists of several isomers and heptachlor. It is insoluble in water but soluble in most organic solvents. It has a moderate mammalian acute toxicity (LD_{50}: oral = 283; dermal = 530). It is toxic to fish and birds. Because of its long persistence and chronic toxicity effects in test animals, its use has been restricted to liquid formulations and only for control of subterranean termites. In British Columbia a permit is required for its purchase and use.

chlordecone *(Kepone)* — an organochlorine compound used with bait in ant traps. It has a moderate acute toxicity to mammals (LD_{50}: oral = 95; dermal = 345 Rb), but chronic exposure produced severe illness in plant production workers. It is very persistent in the environment.

chlorfenvinphos *(Birlane)* — an organophosphorous material available in granular, wettable powder, and emulsifiable concentrate formulations. It has long residual action and is effective against a number of soil insect pests including root maggots on cole crops and onions. Chlorfenvinphos has a high mammalian acute toxicity (LD_{50}: oral = 10; dermal = 30). It is corrosive to metals and decomposes slowly in the presence of moisture.

chlorpyrifos *(Banisect, Dursban, Lorsban)* — an organophosphorous compound which is formulated as an emulsifiable concentrate, pressurized spray, dust, granules, wettable powder, or as a slow-release pellet for use as a mosquito larvicide or adulticide. It can be used in nonfood areas of buildings (recently registered for subterranean termites) and for the control of some insect pests of vegetable crops and ornamentals. Chlorpyrifos has a moderate mammalian acute toxicity (LD_{50}: oral = 82; dermal = 202). It has a residual effect and is toxic to shrimp, crab and fish.

coumaphos *(Co-Ral)* — an organophosphorous material formulated as a dust, emulsifiable concentrate and wettable powder for control of insects, mites, and ticks on cattle, goats, sheep, swine, poultry, dogs and horses. It is an animal systemic of relatively high mammalian toxicity (LD_{50}: oral = 13; dermal = 860).

crotoxyphos *(Ciodrin)* — an organophosphorous material available in dust, emulsifiable concentrate, or solution formulations for control of livestock pests, including stable flies, hornflies, ticks, lice and certain mites. There are liquid formulations for use in backrubbers. It is nonflammable, slightly corrosive to mild steel, and noncorrosive to stainless steel and most organic linings. Crotoxyphos has a short residual action. It has a moderate acute toxicity to mammals (LD_{50}: oral = 74; dermal = 202) and a high toxicity to fish.

cypermethrin *(Ripcord)* — a chlorinated pyrethroid compound available as an emulsifiable concentrate. It acts as a contact and stomach poison. Cypermethrin has a moderate mammalian toxicity (LD_{50}: oral = 251; dermal = 1,600). It is highly toxic to fish.

DDT — a persistent organochlorine material which was widely used for mosquito control and for the control of agricultural, home garden and forest insect pests. DDT has been found to persist for many years in soils and to build up in biological food chains where it is passed from prey to predator in body fat. DDT is moderately toxic to mammals (LD_{50}: oral = 113; dermal = 2,150). It is highly toxic to birds and cold-blooded animals such as fish. It is insoluble in water. DDT is no longer registered for use in Canada.

deet (Off) — an organic hydrocarbon material available in a variety of formulations including aerosols, spray and creams for application to human skin to repel insects. Products are formulated with concentrations of deet ranging from about 10 to 100%. Deet is absorbed through the skin into the circulatory system. The mammalian oral acute toxicity is considered low (LD_{50} = 1,950), but some toxic and allergic reactions have been reported. Toxicity has been associated with excessive or prolonged use of low concentrations (particularly in infants or children) or with brief exposure to high concentrations in some children and adults.

deltamethrin *(Decis)* — a brominated pyrethroid compound available as an emulsifiable concentrate. It is effective against some agricultural pests at very low application rates. Deltamethrin is temperature-sensitive in its effect against insects, being most toxic at cool temperatures and becoming less effective as temperatures rise. It has a moderate to low mammalian acute toxicity (Decis LD_{50}: oral, oily solvent = 128; aqueous suspension > 5,000; dermal > 2,000 Rb).

demeton *(Systox)* — a mixture of two closely-related organophosphorous materials formulated as an emulsifiable concentrate. Demeton is a systemic with some fumigant action. It is effective against a number of mites and insects such as aphids, leafhoppers and leafminers. Demeton is phytotoxic to some fruit trees and ornamentals. It is registered for use on a wide range of fruits, vegetables and ornamentals. It is highly toxic to mammals (LD_{50}: oral = 1.7; dermal = 8.2). *Protective clothing* and a respirator must be worn by applicators.

diazinon *(Basudin)* — an organophosphorous material available in a wide range of formulations. It is a contact poison and has a moderate residual activity. Registered uses include fruit and vegetable sprays, seed treatments, control of flies, home and garden pests, and turf insects. Diazinon is a broad-spectrum insecticide of moderate mammalian toxicity (LD_{50}: oral = 300; dermal = 2,150).

dichlorvos *(Vapona, DDVP)* — an organophosphorous material of high volatility with a rapid knockdown effect. It is used as a spray, fog, bait, or resin strip, for mosquito and fly control, and as a fog against greenhouse crop insect pests. It has been found to be phytotoxic to a number of chrysanthemum varieties. Dichlorvos is also used for treatment of stored product pests and in food processing plants. It has a high toxicity to mammals (LD_{50}: oral = 25; dermal = 75). It is also highly toxic to bees and fish.

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dieldrin — an organochlorine insecticide with a long soil persistence. It has a high acute toxicity to mammals (LD_{50}: oral = 40; dermal = 60) and to bees and fish. In British Columbia a permit is required for its purchase and use and there has been no authorized use in this province for several years.

diflubenzuron *(Dimilin)* — a chlorinated diphenyl compound used as an insect growth regulator. It is registered in Canada as a mosquito larvicide (1st to 3rd instar) in temporary pools on noncrop land. It has a low acute toxicity to mammals (LD_{50}: oral = 4,640). It has a low toxicity to most fish and wildlife, but a high toxicity to shrimp and crabs.

dimethoate *(Cygon, Hopper Spray, Lagon, Sys-Tem)* — a systemic organophosphorous compound available in emulsifiable concentrate formulations. As a systemic, it is effective against mites and sucking insects such as aphids, leafminers, leafhoppers and thrips. It is effective as a foliar contact spray against grasshoppers, spruce budworm, pine shoot moth, seed and cone insects. Dimethoate is also effective as a residual spray on walls of farm buildings for fly control. It can be phytotoxic to a large number of plant species, including chrysanthemums, hops, plums, peaches, tomatoes and beans. It is highly toxic to mammals (LD_{50}: oral, rat = 215, human = 30; dermal, rat = 400) and is also toxic to bees.

dimetilan *(Snip)* — a carbamate compound formulated into fabric bands/strips for control of house flies in farm buildings and poultry houses. It has a high acute mammalian toxicity (LD_{50}: oral = 25; dermal = 4,000).

disulfoton *(Di-Syston)* — a systemic organophosphorous material chemically related to demeton. It is available in granular or liquid concentrate formulations. Granules applied to the soil give up to seven weeks of control against many foliar feeding insects, including aphids, leafhoppers, flea beetles, thrips, whiteflies and leafminers. Disulfoton is registered for use on ornamentals, forest trees, and on a wide range of vegetable crops. It is highly toxic to mammals (LD_{50}: oral = 2.3; dermal = 6) and is only available for commercial use.

DNOC (dinitrocresol, *Sodinoc, Elgetol*) — a dinitrophenol compound used as a herbicide, fungicide and insecticide. It is formulated as an emulsifiable concentrate and a soluble powder. DNOC is effective against aphid eggs, rust mites, and scale insects on fruit trees. It is phytotoxic to foliage and recommended only as a dormant spray and, at reduced rates, for blossom thinning. It is not compatible with lime sulphur but is sometimes applied with dormant oil. DNOC has a high acute toxicity to mammals (LD_{50}: oral = 24; dermal = 200).

dormant oil — see mineral oils

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endosulfan (*Thiodan*) — an organochlorine compound used commercially on vegetables, fruit trees, and on various plants in greenhouses. It is particularly effective against aphids, rust mites, whiteflies, and cyclamen mites. Endosulfan contains two isomers, one of which has high volatility and fumigant action. Endosulfan is fairly persistent, undergoes slow hydrolysis, and is stable in sunlight. It is formulated as a dust, emulsifiable concentrate, and wettable powder. Endosulfan has a high acute toxicity to mammals (LD_{50}: oral = 18; dermal = 74). It also has a high toxicity to fish but low toxicity to bees.

endrin — an organochlorine which is chemically related to dieldrin. Like dieldrin it is extremely persistent in soils. Endrin is the most toxic of the organochlorine insecticides (LD_{50}: oral = 3; dermal = 12). A permit is required for its purchase and use in British Columbia. There has been no authorized use in this province for several years.

ethion — an organophosphorous material available in emulsifiable concentrate, granular and wettable powder formulations. It is a contact material with an extended residual action. Ethion is effective against a number of mite species, aphids, scales and leafhoppers on grapes. It can be applied with oil as a commercial dormant spray for aphid and rust mite control. Ethion is only moderately toxic to predaceous mites and is used as a summer spray in integrated mite control programs. A granular formulation is available for onion maggot control. It is highly toxic to mammals (LD_{50}: oral = 13; dermal = 62) and is toxic to fish, bees and wildlife.

famphur (*Warbex*) — a systemic organophosphorous compound registered as a pour-on treatment for cattle to control warbles, and to reduce cattle lice infestations. It has a high mammalian acute toxicity (LD_{50}: oral = 36; dermal = 2,730 Rb).

fenitrothion (*Sumithion, Folithion, Novathion*) — an organophosphorous material formulated as an emulsifiable concentrate and wettable powder. Fenitrothion is registered for use on forest trees for the control of a number of forest insect pests. It has some residual activity. Fenitrothion has a moderate mammalian acute toxicity (LD_{50}: oral = 130; dermal = 300). It is moderately toxic to fish.

fensulfothion (*Dasanit*) — an organophosphorous insecticide formulated as an emulsifiable concentrate or as granules. It has long residual action and has proved effective on a wide range of soil insects, particularly root maggots on rutabaga and other cole crops. It has a high acute toxicity to mammals (LD_{50}: oral = 2; dermal = 4). It is toxic to bees and fish. Its rate of application must be exact because it is phytotoxic at slightly above the effective recommended rates.

fenthion (*Baytex, Entex, Tiguvon*) — an organophosphorous material available in an oil formulation. It has a residual action of up to two or three weeks. Fenthion is registered for control of aphids, leafminers and scale insects on ornamentals, as a mosquito larvicide and adulticide, and as a pour-on systemic insecticide for use on cattle. It can be used in nonfood areas of buildings, processing plants, and warehouses. It is moderately toxic to mammals (LD_{50}: oral = 190; dermal = 320). Because of its extreme toxicity to birds, the distribution of most fenthion formulations is restricted by the manufacturer to qualified individuals. It is toxic to aquatic life and bees.

fenvalerate (*Belmark*) — a chlorinated pyrethroid material registered for use on agricultural and ornamental crops. It is also available as ear tags for cattle to control face flies. It has a good knockdown effect as well as some residual activity. It has a moderate acute toxicity to mammals (LD_{50}: oral = 451; dermal = 2,500 Rb) and a high toxicity to fish.

fonofos (*Dyfonate*) — an organophosphorous material which is available in a granular formulation and used as a soil treatment for wireworm control. It is persistent in soils for up to three months. It has a high mammalian acute toxicity (LD_{50}: oral = 3.4; dermal = 134) and is for use only by commercial growers. Fonofos is toxic to fish, birds and other wildlife.

heptachlor — a nonsystemic, organochlorine material. It is persistent in soils, stable in light, air, moisture and moderate heat. It has a high acute toxicity to mammals (LD_{50}: oral = 40; dermal = 195). It is no longer registered for use in Canada

isofenphos (*Amaze*) — an organophosphorous insecticide formulated as an emulsifiable concentrate and as granules and temporarily registered for control of northern and western corn rootworms. It has a high acute toxicity to mammals (LD_{50}: oral = 28, dermal = 162 Rb). It is moderately toxic to fish.

kinoprene (*Enstar*) — a commercial insect growth regulator for use against aphids and greenhouse whitefly on greenhouse ornamentals. It generally results in a gradual reduction of the pest insects unless high rates are used. Very low mammalian acute toxicity (LD_{50}: oral = 5,000; dermal = 9,000 Rb).

lime sulphur — a fungicide that is also effective against blister and rust mites and scale insects. It is used on fruit trees mainly during the dormant and prebloom period. Lime sulphur may cause leaf yellowing, browning, and defoliation, particularly if applied in the calyx stage or early summer, without previous application in the pink stage. Some fruit tree varieties are particularly sensitive to lime sulphur. It should not be applied to wet foliage or at temperatures above 29°C. It is caustic to the skin and irritating to the eyes.

lindane (*gamma-BHC*) — an organochlorine material effective against a number of insect pests. Lindane is available in a wide variety of formulations. Its use is limited to a wireworm seed treatment on cereal crops and to treatment of several insect pests on beef cattle, sheep, goats and horses. It has fumigant, contact and stomach activity. It is moderately toxic to mammals (LD_{50}: oral = 88; dermal = 900). It is toxic to fish, bees and wildlife.

malathion *(Cythion)* — a broad spectrum organophosphorous contact insecticide, formulated as baits, dusts, emulsifiable concentrates, solutions and wettable powders. There are over 140 different products containing malathion, many of them for home garden use. Malathion is registered for flea powders, home and garden sprays, mosquito sprays, cattle backrubbers, seed treatments and agricultural crop protection sprays. Malathion is somewhat phytotoxic to a number of plants, including ferns, petunias, orchids, and some apple varieties. There have also been reports of injury to beans and cucurbits under greenhouse conditions, and of damage to the paint finish of cars. It is nonpersistent and has a low mammalian acute toxicity (LD_{50}: oral = 1,000; dermal = 4,100 Rb). It is toxic to fish and bees.

methamidophos *(Monitor)* — a systemic organophosphorous compound available as an emulsifiable concentrate formulation. Registered for use by commercial growers for control of insect pests of a number of vegetable crops. Highly toxic to mammals (LD_{50}: oral = 19; dermal = 118 Rb). Toxic to fish, bees, and wildlife.

methidathion *(Supracide)* — an organophosphorous material available as an emulsifiable concentrate. It has broad spectrum activity and is registered for use on a number of vegetable and forage crops. It may be applied by aircraft or by ground rigs. Residual effectiveness for three to five weeks has been noted. It has a high toxicity to mammals (LD_{50}: oral = 25; dermal = 150). It is highly toxic to bees, fish and wildlife.

methomyl *(Lannate)* — a carbamate systemic insecticide formulated as a water-soluble powder and solution. It is registered for use against cabbage worm and diamondback moth on cabbage, cauliflower, broccoli, and Brussels sprouts; corn earworm in sweet corn; fruitworm and aphids on tomato; leafhopper, flea beetle, and aphids on potatoes. Lannate has a high oral mammalian toxicity (LD_{50}: oral = 17; dermal > 1,500 Rb). It has a high initial toxicity to honeybees. It has a short residual effect and therefore is favoured over carbaryl for earworm control on corn.

methoprene *(Altosid, Apex)* — an organic compound used as an insect growth regulator for mosquito, mushroom fly, whitefly, and mealybug control. Formulations include an emulsifiable concentrate and slow-release briquets. It must be applied to the larval stage of these insects. Treated larvae continue to grow but die before reaching the adult reproductive stage. Methoprene shows little effect on adult insects or pupae. It has a very low mammalian toxicity (LD_{50}: oral > 34,600; dermal > 3,000 Rb). It is moderately toxic to fish.

methoxychlor *(Marlate)* — an organochlorine insecticide effective against a large number of insects. Although closely related to DDT, methoxychlor is not stored in body or milk fats. It is recommended for a wide range of garden and crop insect pests and for fly control in livestock barns, but is not as effective against aphids or mites and is phytotoxic to some cucurbits. Unlike other organochlorines, methoxychlor has a relatively short persistence. It has a low mammalian acute toxicity (LD_{50}: oral = 5,000; dermal = 6,000), but is toxic to fish and bees.

methyl bromide — see fumigants chapter.

mevinphos *(Phosdrin)* — an extremely toxic organophosphorous insecticide. Mevinphos is a short-lived contact and systemic insecticide used as a 'clean up' material on vegetable crops shortly before harvest for control of a wide range of foliar feeding insects, including aphids, leafhoppers, thrips, and loopers. It is nonphytotoxic and compatible with most other pesticides. Mevinphos should be used only by competent individuals; protective clothing and respirators must be worn. It has a high mammalian acute toxicity (LD_{50}: oral = 3; dermal = 4.2) and is toxic to bees, birds and fish.

mineral oils *(Dormant oil, Summer oil, Superior oil, Supreme oil, Petroleum oil, Volck oil)* — are complex hydrocarbon distillation products of petroleum and coal tar used as contact insecticides. Oils kill by suffocation and may be used on the egg, larvae, and sometimes adult stage of specific insect and mite pests (e.g. mites, scales, pear psylla, leafrollers). Some highly refined oils are available for use as mosquito larvicides. Oils can be phytotoxic to plant foliage. Dormant oils are most phytotoxic and cannot be used after buds have opened in spring. Summer oils are safer on foliage but some plant species are more sensitive than others. Generally, the lower the viscosity and higher the unsulfonable residues, the less phytotoxic the oil product. Applications of other pesticides (e.g. sulphur sprays, captan, carbaryl, folpet) soon before or after oil sprays may also cause some phytotoxicity. Unlike diesel oil, these oils are of low hazard to fish and wildlife, and have a very low mammalian toxicity.

naled *(Dibrom, Bromex)* — an organophosphorous material formed by the action of bromine on dichlorvos. It is a non-systemic, contact and stomach insecticide and miticide with some fumigant action. Naled has a short residual effect and is recommended for use close to harvest time on several vegetable crops. It is also recommended as a spray or as a vapour for control of aphids, thrips and mites in greenhouses. Naled may injure flowers of cucumbers and tomatoes. It is effective for fly control. It is the active ingredient in some pet flea collars. It has a moderate mammalian acute toxicity (LD_{50}: oral = 250; dermal = 800).

naphthalene — a synthetic organic material formulated as blocks, flakes, or balls and used as a fumigant for control of clothes moths. It has a low mammalian acute toxicity (LD_{50}: oral = 2,200; dermal > 2,500).

nicotine *(Nicotine Sulfate)* — a by-product of waste tobacco, this contact and fumigant insecticide is used as a spray and as a smoke bomb. The mammalian acute toxicity at the time of application is dangerously high, especially from breathing vapours or smoke, but the residual effect is low (LD_{50}: oral = 50; dermal = 50 Rb).

nuclear polyhedrosis virus *(NPV, Virtuss, Lecontvirus)* — a microbial insecticide containing virus particles which will infect specific insect larvae. Virtuss is for control of Douglas-fir tussock moth, Lecontvirus is for control of red-headed pine sawfly. These are Restricted-Use products for use only under direct supervision of Federal or Provincial Forestry Service personnel. They are formulated as wettable powders or emulsifiable concentrates to be mixed with water or oil. Applicator exposure to these products may result in skin or eye irritation.

oil — see mineral oils

oxydemeton-methyl *(Metasystox R)* — a systemic and contact organophosphorous material of short persistence, available in an emulsifiable concentrate formulation. It is effective against a number of mites, leafhoppers, thrips, leafminers and aphids and is registered for use on a wide range of crops. Oxydemeton-methyl is phytotoxic to some ornamentals, especially in combination with other pesticides. It has a high mammalian acute toxicity (LD_{50}: oral = 47; dermal = 158) and is toxic to bees and to fish and wildlife.

paradichlorobenzene — an organochlorine material formulated as crystals or blocks. It is used for control of clothes moths and carpet beetles and also as a repellent against a wide range of birds and pest animals, including rats, cats, *dogs, skunks*, and bats. Paradichlorobenzene has fumigant action, is noncorrosive and nontainting. It has a moderate mammalian acute toxicity (oral LD_{50} = 500).

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parathion *(Aqua)* — one of the first organophosphorous materials to be developed and available in several formulations. It has stomach, contact, and some fumigant action, but is not systemic and has a short residual effect. Parathion is effective against a wide variety of insects, but some mites have developed resistance to it. In British Columbia it is used on certain vegetable and fruit tree insect pests. It is phytotoxic to some ornamentals and apple and pear varieties. Parathion has an extremely high oral and dermal mammalian acute toxicity (LD_{50}: oral = 3; dermal = 7). It is for commercial use only. Protective clothing and a respirator are essential.

pentachlorophenol *(Penta)* — a phenolic material with fungicidal, herbicidal, and insecticidal properties. It is used as a wood preservative against wood-destroying insects such as termites. Pentachlorophenol is moderately toxic to mammals (LD_{50}: oral = 125; dermal = 320). Illness may be produced by the cumulative action of several doses and the onset of critical illness can be sudden. Atropine should not be used as an antidote for poisoning. Protective clothing must be worn when handling this pesticide. It must not be used in home interiors or outside near or in contact with humans, animals or their food. It is highly toxic to fish and wildlife.

permethrin *(Ambush, Ectiban)* — a broad spectrum pyrethroid insecticide, registered for white fly control in greenhouses and a wide range of insects on food crops, ornamentals and fly control on buildings. It is not effective against aphids. Permethrin has a low mammalian acute toxicity (LD_{50}: oral > 4,000; dermal > 2,000 Rb), but is very toxic to fish and bees.

phorate *(Thimet)* — a systemic and contact organophosphorous insecticide miticide available in a granular formulation. It is registered for use on a limited number of agricultural crops for control of several sap-sucking and soil insects. Phorate has good residual action but has a very high mammalian acute toxicity (LD_{50}: oral = 1.1; dermal = 2.5). There have been a number of reports of phytotoxicity to seedlings. It is toxic to bees.

phosalone *(Zolone)* — an organophosphorous contact and stomach poison. It is registered for use on grapes and fruit trees for control of a number of insect pests, including codling moth, aphids, pear psylla, European red mite and leafhopper. Toxicity to mammals is moderately high (LD_{50}: oral = 82; dermal > 2,000). Toxicity to fish and bees is also moderately high.

phosmet *(Imidan, Prolate)* — an organophosphorous material with a long residual effect which is recommended in British Columbia for summer pear psylla control and as an alternative to azinphos-methyl against codling moth. Phosmet has a low toxicity to predaceous mites, so it can be used in an integrated mite control program. Phosmet has a moderate acute toxicity to mammals (LD_{50}: oral = 113; dermal = 1,550).

piperonyl butoxide — a synthetic organic material with low insecticidal properties. Piperonyl butoxide is used primarily as a synergist to increase the toxicity of pyrethrins and related compounds. It is incorporated into aerosols, solutions, emulsions, and dust formulations. Toxicity to mammals is very low (LD_{50}: oral = 6,150; dermal > 7,950).

pirimicarb *(Pirimor)* — a carbamate compound used as a selective contact insecticide. It is formulated as a wettable powder. It is specific for control of aphids. Pirimicarb has a quick knockdown effect and is fast-acting. Nonphytotoxic at recommended rates. Toxicity to bees is low. It does not kill ladybugs and lacewings at recommended rates. Pirimicarb is useful in greenhouses. It has a moderate acute toxicity to mammals (LD_{50}: oral = 147; dermal > 500).

propoxur *(Baygon)* — a carbamate formulated as an emulsifiable concentrate, wettable powder, dust, granule, bait, pressurized spray, and in pet flea collars. It is nonphytotoxic and nonsystemic and has a rapid knockdown effect. Propoxur kills plant bugs and aphids, but is used mainly to control household pests and for mosquito abatement. It has a moderate mammalian acute toxicity (LD_{50}: oral = 80; dermal > 2,400). It is highly toxic to honeybees. Its residual effect can last up to 3 months.

pyrethrins — these are botanical materials extracted from dried flowers of the chrysanthemum family. Pyrethrins have excellent knockdown properties and leave no dangerous residues. They are unstable when exposed to light, moisture, or air. There are over 400 formulated products containing pyrethrins in Canada with a wide range of uses as home and garden aerosols, pet shampoos, and livestock sprays. The majority of the pyrethrin products are formulated with synergists such as piperonyl butoxide, n-octyl bicycloheptene, dicarboximide and sulfoxide. Pyrethrins are moderately toxic to mammals (LD_{50}: oral = 200; dermal > 1,800). They are highly toxic to fish.

resmethrin — a non-chlorinated pyrethroid for commercial and domestic use, chemically related to pyrethrins. Many household and garden pesticides contain resmethrin, and are available under a host of trade names. The concentration needed to be effective is very low. Resmethrin has rapid knockdown properties. It is non-irritating to the skin, eyes or throat and has a low mammalian acute toxicity (LD_{50}: oral = 1,100; dermal = 2,400 Rb). It is highly toxic to fish.

rotenone *(Deritox, Rotenone)* — a botanical material derived from roots of *Derris* spp., *Lonchocarpus* spp. and several other members of the pea family. It is formulated as a dust and wettable powder. Rotenone is a contact insecticide of short persistence. It is broken down in the presence of light and alkaline waters. Rotenone is nonphytotoxic. The technical material (i.e. active ingredient) has a moderate mammalian acute toxicity (LD_{50}: oral = 132), however, it is usually formulated as a one or five percent dust. Rotenone is highly toxic to pigs and to fish.

silica aerogel *(Drione)* — an inorganic insecticide which acts on insects by removing their oily protective coating, resulting in dehydration. It is combined with small amounts of pyrethrins for control of structural insects such as roaches, ants, silverfish, spiders, lice and fleas. It has a very low mammalian acute toxicity (LD_{50}: oral = 3,160).

soap *(Safer's Insecticidal Soap)* — an organic substance consisting of the salts of oleic acid — a natural constituent of oils and fats. It is available as a concentrate or dilute solution and is registered for use on house plants, vegetables, fruit trees and ornamental plants for the control of many insects such as aphids, mealy bugs, whitefly, scales, earwigs and mites. Thorough coverage of all surfaces of the sprayed plants is essential as it kills only on contact at the time of application and has no residual effect. It can be used up to the day of harvesting fruits and vegetables. Its mammalian toxicity is very low. Eye exposure to concentrated soap may cause irritation.

sodium fluoride — an inorganic stomach insecticide with some contact activity. It is formulated as a bait for control of cockroaches, silverfish, and some other structural pests. In combination with other materials it is formulated as a paste or solution for use as a wood preservative. Sodium fluoride is highly phytotoxic and highly toxic to mammals (lethal dose to man = 75 to 100 mg/kg).

sodium fluorosilicate *(Weevil Bait, Earwig Bait)* — an inorganic, odourless, and nonvolatile material formulated as a bait for control of weevils and earwigs. Due to the high water-solubility of sodium fluorosilicate the effectiveness of baits is much reduced by rainfall and irrigation. Sodium fluorosilicate has a moderately high mammalian acute toxicity (LD_{50}: oral = 125).

sulfotep *(Plantfume 103)* — an organophosphorous sulphur-containing compound used in smoke or thermal fog generation for insect control in commercial greenhouses. It is nonpersistent on foliage and effective against a broad spectrum of insects. Oral and dermal toxicity to mammals is extremely high (LD_{50}: oral = 5; dermal = 20 Rb). A respirator and protective clothing are essential during application. Its use is restricted to certified applicators.

temephos *(Abate)* — an organophosphorous material formulated as emulsifiable concentrates and granules for use as a mosquito and black fly larvicide. Abate is soluble in most organic solvents but not in water. When applied to water, it forms a thin film over the surface which blocks the oxygen supply to mosquito larvae. Because it has a short persistence, repeated treatments and exact timing are necessary. It is not registered for use on crops or pastures. It has a low mammalian toxicity (LD_{50}: oral = 1,000; dermal > 4,000 Rb). It has a low toxicity to bees, birds, and fish.

terbufos *(Counter)* — an organophosphorous compound available in granular formulations. It is registered for use on corn to control soil pests such as corn rootworm, wireworms, and seed corn maggots. It has a very high mammalian acute toxicity (LD_{50}: oral = 1.6; dermal = 1.1 Rb). It is toxic to fish and wildlife.

tetrachlorvinphos *(Gardona, Rabon)* — an organophosphorous insecticide formulated as an emulsifiable concentrate and a wettable powder. It is registered for control of the house fly and chicken lice and mites on farm premises and in other outdoor areas. It has a low mammalian acute toxicity (LD_{50}: oral = 1,100; dermal > 4,000).

tetramethrin — a non-chlorinated pyrethroid used for control of fleas, wasps, mosquitos and garden pests. It has a fast knockdown activity. It has a low acute toxicity to mammals (LD_{50}: oral = 1,010 mouse), but is highly toxic to fish.

trichlorfon *(Dylox, Neguvon, Dipterex)* — an organophosphorous material which is formulated in a number of ways. It has a wide range of registered uses, including a pour-on cattle systemic for warble control (Neguvon); a fly bait; a foliar spray against such insects as stink bugs, cutworms, and armyworms on ornamental, cereal, and vegetable crops; and a spray for fly control around farm buildings. It has a moderate mammalian acute toxicity (LD_{50}: oral = 450; dermal = 2,000).

CHAPTER QUIZ

Chapt. 8

Questions	Answers
1. Are most insects pests?	1. No, most insects are of little economic importance or are beneficial; few are pests.
2. What are the two characteristics of an adult insect body which distinguish it from other animals?	2. Insect adults have three pairs of jointed legs, and have three body regions — a head, thorax and abdomen.
3. What are four types of insects based on mouthparts?	3. chewing, piercing and sucking, sponging, syphoning.
4. What happens to an insect skin to allow the insect to grow bigger?	4. The insect molts and a new skin is formed.
5. Match the following: without metamorphosis, gradual metamorphosis, complete metamorphosis — a) egg, nymph, adult b) egg, larva, pupa, adult c) egg, young, adult	5. without metamorphosis — (c); gradual metamorphosis — (a); complete metamorphosis — (b).
6. What life stage of insects are all of the following — caterpillars, loopers, grubs, and maggots? What is the main feature of their development into adults?	6. Larvae — all show a dramatic change from larval to adult stage.
7. What are the three main types of beneficial insects?	7. predators, parasites, pollinating insects.
8. Why is it often important to maintain low numbers of pest species?	8. Low numbers of an insect pest help to maintain the pest's predators and parasites.
9. What information should be obtained, if possible, before control of insects pests?	9. 1) identity of the pest and extent of damage, 2) size of the pest population, 3) presence of the pest's natural enemies and other beneficial insects, 4) life cycles of pests and beneficials, 5) pest control recommendations.
10. What are three types of cultural control methods?	10. sanitation, tillage, crop rotation, change in planting distances.
11. What is integrated pest management?	11. IPM is the use of various control methods which keep pest species at tolerable population levels with minimal damage to non-pest species.
12. What is the difference between a systemic and a contact insecticide?	12. Systemic insecticides spread internally through the plant or animal to which they are applied and are effective against sucking insects. Contact insecticides do not spread internally and will kill when an insect crawls over a treated surface.
13. What is the difference between growth regulator and pheromone type insecticides in the way they control insects?	13. Growth regulators affect insect development; pheromones usually act as attractants or disrupt reproductive behavior.
14. At what growth stage are many insects most vulnerable to insecticides?	14. early larval or nymphal stages.
15. How does temperature generally affect insecticide persistence?	15. cool temperatures slow degradation.
16. Should you consider increasing application rates or switching to other insecticides if insects build up resistance to treatments?	16. switch to other insecticides.

Chapter 9

MITES AND MITICIDES

CONTENTS

MITE CHARACTERISTICS

Mites are very small arthropods which are more closely related to spiders and ticks than to true insects. Adult mites range in size from about 0.1 mm to 1 mm in length. They have no wings or antennae. Most adult mites have four pairs of legs, although a few species (including the rust and blister mites) have only two pairs of legs. Figure 18 illustrates a typical mite.

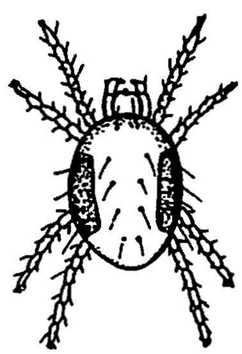

Figure 18. Spider mite enlarged nearly 100 times actual size.

Mites can multiply very rapidly and complete their life cycle in one to three weeks under favourable conditions. In a typical life cycle, females deposit eggs which hatch into six-legged larvae. The larvae feed and molt to form eight-legged nymphs. There are generally several nymphal stages before the adult stage is reached. The adult mites and their eggs are sometimes covered by a delicate web which provides some protection from contact sprays. Some species give birth to live young.

There are many species of mites, but only a few species are a nuisance or cause damage to crops, livestock, food or fibre. Some mite pests cause damage when large numbers feed by sucking on crop or ornamental plants. Leaves may become mottled and turn brown, buds may be stunted or deformed or fruit may be blistered or not fully developed. Some mites are parasites on domestic animals, livestock or fowl.

There are a number of beneficial mites which are predaceous on certain pest mites and insects. It is important to avoid reducing predaceous mite numbers too severely where they control pest species.

MITE CONTROL AND MITICIDES

COMMON MITE PESTS AND THEIR CONTROL

Mites affecting fruit trees. The most troublesome mite pests on fruit trees in British Columbia include the following:

- European red mite on apples, pears, cherries and prunes. It overwinters in the egg stage and can become a problem early in the season.
- McDaniel spider mite, mainly a pest on apples. It overwinters in the adult female stage and generally becomes a problem during periods of hot weather in July and August.
- Apple rust mite, mainly a pest on apples. It is a minute, elongated species which overwinters in the adult female stage and may be present in enormous numbers on foliage in early summer.
- Pear rust mite, mainly a pest on pears. It is similar in appearance to the apple rust mite. It overwinters in the adult female stage and various stages feed on buds, flowers, leaves and fruit during spring and summer.

There are several species of beneficial mites (e.g. phytoseiids) which feed on the pest mites of fruit trees. When selecting miticides, it is important to consider the need to avoid injury to the predaceous mites. As well, the pest species should not be eliminated entirely because the predator cannot survive without its prey. Use of miticides which eliminate the beneficial predator populations can result in a rapid build-up of injurious mites.

The use of carefully timed sprays with selective miticides, to minimize injury to beneficial mites, is a form of integrated pest management (IPM). IPM requires monitoring the abundance of pest mites at various fruit tree growth stages. Spraying should not take place unless the number of pest mites has exceeded the recommended threshold level. The number of mites must be determined either with hand magnifying lens examination or through one of the commercial mite counting services. Addresses of these services are available at district offices of the B.C. Ministry of Agriculture and Fisheries.

IPM for mites is used mainly on apple trees, but can be applied to other fruit trees such as apricot, cherry, peach and plum. It has not been used on pear trees as they cannot tolerate high enough numbers of injurious mites to support the predaceous mites.

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Mites affecting vegetables. The two-spotted spider mite, which can increase rapidly under hot, dry conditions, is the main pest species on vegetables. Beans, cucumber, eggplant, marrow, melon, pepper, pumpkin and squash may be damaged. For the past several years, a predaceous mite species has been used to control two-spotted mites on greenhouse-grown cucumbers.

Mites affecting berry crops. Two species of mites are important pests of berries in British Columbia. The two-spotted spider mite often causes severe browning and drying of the foliage of raspberries and strawberries in hot weather. The strawberry mite is light coloured and barely visible without a magnifying lens. It attacks strawberry plants and feeds mainly on new growth at the crown, causing stunting, yellowing and distortion of the leaves.

Surveys during the 1970's have shown that there are naturally-occurring predaceous mites in some strawberry fields. Where there is a ratio of one predaceous mite to 30 or fewer two-spotted mites, the two-spotted mite is kept under control and no miticide sprays are needed. When chemical control is required, there are several selective miticides (e.g. cyhexatin or fenbutatin oxide) which will reduce two-spotted mites without eliminating the predaceous mites.

Mites affecting ornamentals and house plants. Mites can be pests on various ornamental plants, shrubs and trees. If these are grown in the garden or in a nursery, there are several effective miticides. When mites infest house plants, control may be difficult because most miticides can damage the tender foliage. If such plants must be treated, miticides should be tried on a few leaves first. If no damage is seen from the spray in a few days, the whole plant can be treated.

Mites in stored food. There are a number of species of mites that feed on flour, grain, cereal products, fruit, cheese and other stored food. The most important are the grain mite and the long-haired mite. Both species are slightly less than 1 mm long and greyish-white.

Most miticides cannot be used on infested foods. If the food item is not severely infested, mites can be killed by heating the item in the oven at 60° to 70°C for 20 to 30 minutes, or by placing the item in a deep freeze for about 2 weeks. Storing foods that are susceptible to mite infestation in a refrigerator will prevent the mites from reproducing.

Mites that invade structures. The clover mite, which feeds on grasses, clovers and lawn weeds, can invade houses in large numbers during the spring or fall. It swarms over the outer walls, particularly those with a sunny exposure, and enters the house through cracks and crevices around windows and doors. They are brownish or reddish in colour.

The eggs are laid during the late fall at the base of trees or near walls. The eggs hatch in the early spring and the young mites begin feeding on the foliage of plants. There are several generations each year.

Bird and poultry mites. The most common species of mites on chickens are the chicken mite and the northern fowl mite. The chicken mite is approximately 1 mm long. It is grey before feeding and dark red or black after feeding. During the day it lives in joints and cracks of roosts, nesting boxes and walls of chicken houses. At night it crawls on birds and sucks blood.

The northern fowl mite is about the same size and appearance as the chicken mite, but it lives continuously on the birds and often congregates near the vent, tail and neck.

Poultry mites from nearby poultry houses, or other species of mites from bird nests on the outside of buildings, may sometimes invade buildings occupied by people. A skin rash may develop if they bite humans.

Sanitation will usually help prevent populations of chicken and fowl mites from developing. Miticides are generally needed to control infestations of these mites.

MITICIDE PROPERTIES

There are about 20 miticide active ingredients used in British Columbia. These active ingredients belong to various chemical groups and include inorganic, organochlorine, organophosphorous, carbamate and dinitrophenol compounds. Miticides are registered for use on many agricultural crops, ornamentals, animals, stored products or building surfaces.

A few miticides are used to control mites only and usually have little effect on insects. Some of these are wide-spectrum miticides (e.g. dicofol) while others tend to kill pest mites with little harmful effect on predaceous mites (e.g. cyhexatin and fenbutatin oxide).

A few pesticides are both insecticides and miticides (such as endosulfan, ethion, malathion and pyrethrins) or fungicides and miticides (such as chinomethionat). They are non-specific for mite control and therefore are not usually the most effective miticides. Note that some insecticides, particularly carbaryl, can cause mite pest 'flare-up'. It is thought that carbaryl kills beneficial insects that help to hold pest mites at low levels, allowing the pest species to multiply without control.

Frequent use of a miticide may cause mites to develop resistance. Such mites may be controlled by using a sequence of closely-timed treatments, or by alternating with miticides from different chemical groups. Commercial growers faced with the problem of resistant mites should call their district horticulturist for advice.

USEFUL PUBLICATIONS ON MITE CONTROL IN B.C.

See the B.C. Ministry of Agriculture and Fisheries Production Guides and general publications listed in Chapter 8, plus the following:

Downing, R.S. and J.C. Arrand. 1978. *Integrated Control of Orchard Mites on Apple Orchards in B.C.* BCMAF. Victoria. 8 pp.

REFERENCE LIST OF MITICIDES AND THEIR PROPERTIES

The following reference list includes a description of most miticides used in British Columbia when this text was published. Miticides are listed alphabetically by active ingredient with some examples of trade names. No endorsement of products is implied. Information contained in this list could become out-of-date and not represent current use recommendations. **The current registered label is the authority on a pesticide's registered uses, application methods and safety precautions.**

The relative acute mammalian toxicity is given for each active ingredient listed. LD_{50} values (mg/kg body weight) are listed where available and are derived from tests with rats unless indicated otherwise (Rb = rabbit). The lowest LD_{50} is listed for each miticide where several values are given in the literature reviewed.

carbophenothion *(Trithion)* — an insecticide and miticide registered for control of mites on some fruit trees, vegetable crops and ornamentals. (See reference list of insecticides for more information.)

chinomethionat *(Morestan)* — an organic hydrocarbon compound formulated as a dust and wettable powder. Chinomethionat is effective against some insects and several mite species, powdery mildew and pear psylla. It is registered for use on some fruit trees and ornamentals. It should not be used on bearing fruit trees after the calyx stage. It is phytotoxic to some varieties of apples, pears and ornamentals. It has a low mammalian acute toxicity (LD_{50}: oral = 1,100; dermal = 2,000), but may cause skin irritation. It is relatively non-toxic to bees, but toxic to fish.

coumaphos — an insecticide and miticide registered for control of mites on hogs and chickens and in poultry farm buildings. (See reference list of insecticides for more information.)

cyhexatin *(Plictran)* — an organic tin compound effective on apples against European red, McDaniel and rust mites. Its toxicity to insects and predaceous mites is low. Therefore, it has been used in integrated mite control programs. Cyhexatin is relatively nonphytotoxic except to pears in combination with an oil spray. It is slow-acting, but has a short residual life. It has a low mammalian acute toxicity (LD_{50}: oral = 540; dermal > 2,000), but recently registration of cyhexatin has been discontinued due to its possible teratogenic effects. It is toxic to fish.

diazinon — an insecticide with some miticide properties. It is registered for control of clover mites and spider mites on ornamentals and in buildings. (See reference list of insecticides for more information.)

dicofol *(Kelthane)* — this organochlorine material has been used against European red, McDaniel, and the apple and pear rust mites on fruit trees. It is now replaced by materials which are not as toxic to predaceous mites. It is still being used to control the two-spotted spider mite on small fruits and vegetables, and around houses to protect against invasions of the clover mite. Although dicofol is nonsystemic, it gives good initial kill. Where dicofol has been used for a number of years, mites may have developed resistance. An alternate registered miticide should be used in such situations. Treated crops should not be fed to dairy or slaughter animals. Dicofol has a low mammalian acute toxicity (LD_{50}: oral = 575; dermal = 1,000), but is toxic to fish.

dienochlor *(Pentac)* — an organochlorine miticide with long residual activity. It is useful for the control of two-spotted spider mites in greenhouses. Dienochlor has no insecticidal activity. It has a very low mammalian toxicity (LD_{50}: oral = 3,160; dermal > 3,160), but may be irritating to the eyes. It is toxic to fish.

dimethoate — an insecticide and miticide registered for mite control on some fruit trees, vegetable crops and ornamentals. (See reference list of insecticides for more information.)

DNOC (dinitrocresol, *Elgetol, Sodinoc*) — a dinitrophenol herbicide which was found to be useful as an insecticide and miticide. It is effective in the control of rust mites. DNOC is formulated as a soluble powder. DNOC is not compatible with lime sulphur, but sometimes is applied with dormant oil. It has a high mammalian acute toxicity (LD_{50}: oral = 24; dermal = 200).

dormant oil — is used on apples in the half-inch green to cluster bud stage against European red mite. Oil does not control rust mites and favours the survival of predaceous mites. It is important in integrated mite control. It has a very low mammalian acute toxicity.

endosulfan *(Thiodan)* — an organochlorine insecticide and miticide used on vegetables, fruit trees and various plants in greenhouses. It is particularly effective against aphids, rust mites, whiteflies, and cyclamen mites. (See reference list of insecticides for more information.)

ethion — an organophosphorous material available in emulsifiable concentrate, granular and wettable powder formulations. It is a contact material with extended residual action. Ethion is effective against a number of mite species, aphids, scales, and leafhoppers on grapes and fruit trees. It may be applied with oil as a commercial dormant spray for aphid and rust mite control. Ethion is only moderately toxic to predaceous mites and is used as a summer spray in integrated mite control programs. It has a high mammalian acute toxicity (LD_{50}: oral = 13; dermal = 62). It is toxic to bees, fish and wildlife.

fenbutatin oxide *(Torque, Vendex)* — an organic tin compound registered for use on ornamentals and nursery stock as well as greenhouse cucumbers and tomatoes. It will control two-spotted spider mites and spruce spider mites, but is relatively harmless to predaceous mites. It is also non-toxic to honey bees. The addition of a spreader-sticker will result in better mite control. It has a low mammalian acute oxicity (LD_{50}: oral = 2,630; dermal > 2,000), but is irritating to skin and eyes. It is toxic to fish.

formetanate hydrochloride *(Carzol)* — a contact carbamate material that has been used for control of European red, McDaniel, and two-spotted mites on apple and pear trees. It also kills predaceous mites and for this reason should not be used where integrated mite control is being practiced. Formetanate hydrochloride is compatible with most other pesticides. It is highly toxic to mammals (LD_{50}: oral = 15; dermal > 10,200 Rb) and is toxic to birds and fish.

lime sulphur *(Orthorix)* — an old-time inorganic fungicide which is also effective against blister and rust mites. It is used on fruit trees mainly during the dormant and prebloom stage. (See reference list of insecticides for more information.)

malathion *(Cythion)* — this organophosphorous material is active against a wide range of insects and mites. It is not effective enough to be a commercial miticide but is useful against two-spotted spider mites on fruit trees, vegetables and ornamentals in the home garden. Malathion is safe and effective against poultry mites and may be used on birds as well as on barn walls, barn floors and poultry house manure. (See reference list of insecticides for more information.)

naled *(Dibrom, Bromex)* — an insecticide and miticide registered for mite control on some vegetable crops and ornamentals. (See reference list of insecticides for more information.)

oxydemeton-methyl *(Metasystox R)* — an insecticide and miticide registered for mite control on non-bearing fruit trees and some berry crops, vegetable crops and ornamentals. (See reference list of insecticides for more information.)

phosalone *(Zolone)* — an insecticide and miticide registered for suppression of European red mites on peach and plum trees. (See reference list of insecticides for more information.)

phosmet *(Prolate, Imidan)* — an organophosphorous insecticide and miticide formulated as a wettable powder. It can be used to control a wide variety of insects and to suppress two-spotted spider mites and European red mites on fruit trees. It has a relatively long residual activity. Phosmet has a low toxicity to predaceous mites, so it can be used in integrated mite control programs. Phosmet is nonphytotoxic when used as directed. It has a moderate acute toxicity to mammals (LD_{50}: oral = 113; dermal = 1,550). It is toxic to bees as well as fish and wildlife.

propargite *(Omite)* — an organic sulphite compound that shows residual activity. It is formulated as a wettable powder. Used as a summer miticide on fruit trees, it is effective against the European red, McDaniel and rust mites, but is harmless to predaceous mites. Therefore, it is useful for integrated mite control on apple trees. It is not recommended for use on pear trees because it is phytotoxic. It has a low mammalian acute toxicity (LD_{50}: oral = 1,350; dermal = 5,000), but can cause eye damage and skin irritation. It is toxic to fish.

pyrethrins — botanical insecticide with some miticide properties registered for use against grain mites in food processing areas. (See reference list of insecticides for more information.)

soap *(Safer's Insecticidal Soap)* — an organic substance consisting of the salts of oleic acid — a natural constituent of oils and fats. It is registered for use on house plants, ornamental plants and food plants for the control of aphids and mites. Its toxicity is very low. Thorough coverage of all surfaces of the sprayed plants is essential as it kills only on contact at the time of application and has no residual effect.

sulphur *(Ortho Flotox, Magnetic 6)* — an inorganic fungicide which is also effective against mite pests. Registered for use against rust mites on apples, pears and cherries and the russet mite on tomatoes. Phytotoxic in dry, hot weather to some plants. Sulphur is relatively nontoxic to mammals, but may irritate eyes and skin.

tetradifon *(Tedion)* — an organochlorine miticide, effective on immature stages of mites. It is registered for control of spider mites on greenhouse cucumbers and ornamentals. Mammalian acute toxicity is low (LD_{50}: oral = 566; dermal = 10,000 Rb). It is only available as a smoke fumigator.

CHAPTER QUIZ

Questions

1. Name three ways mites are different from insects.

2. Given the length of the life cycle of most mites, would you expect many generations during a growing season?

3. On what agricultural crop(s) is integrated mite control frequently used? Why?

4. Why should one be careful using miticides on indoor plants?

5. Can some pesticides be both insecticides and miticides?

6. Can mites become resistant to miticides?

Answers

1. Mites are less than 1 mm long, most mite adults have four pairs of legs (eight legs), no mites have wings.

2. Yes, mite life cycle length is usually 2 to 3 weeks, producing many generations per growing season.

3. On fruit trees, greenhouse vegetables and strawberry plants where it is desirable to protect predaceous mites.

4. Miticides can damage tender foliage.

5. Yes, although some pesticides which are specific for mites are usually more effective.

6. Yes, this problem can occur after repeated use of the same miticide.

Chapter 10

PLANT DISEASES AND FUNGICIDES

CONTENTS

PLANT DISEASES

INTRODUCTION

Plants are said to be diseased when they develop abnormally as a result of a continuing irritation or an environmental deficiency. Diseased plants may have roots that are underdeveloped, stems that are stunted, leaves that are curled, fruit that fails to ripen or other abnormalities.

The causes of plant diseases can be divided into two categories: **parasitic** and **nonparasitic.** Parasitic diseases result from the effect of living agents (pathogens) which obtain their nutrition by invading the cells and tissues of susceptible plants. Most disease-causing organisms are microscopic (microbes) and include fungi, bacteria, viruses and nematodes. Often diseases are blamed on parasites when they are caused by nonparasitic factors. Nonparasitic diseases are caused by deficiencies or surpluses of nutrients, lack or excess of moisture, unfavourably low or high temperatures, or toxic chemicals in the air or soil. While most of this chapter is devoted to the recognition and control of parasitic diseases, it is important to appreciate the importance of nonparasitic diseases.

NONPARASITIC DISEASES

Nonparasitic diseases are a very common cause of plant disorders. Nonparasitic diseases often weaken plants so they are more likely to be attacked by fungi or bacteria. There are a large number of possible causes of nonparasitic diseases, some of the more common include the following:

Light. Light duration and intensity requirements differ with plant species. A shortage of light may produce 'lanky' plant growth. Many ornamental coniferous plants show leaf-browning due to crowding and shading of lower branches.

Temperature. Spring frosts and unusual cold spells can cause leaf or blossom damage to many ornamentals and food crop plants and may kill annual transplants. Frost damage to setting fruit frequently produces scar tissue on maturing fruit.

Water. Dry air (low humidity) may accelerate evaporation from plant leaves and cause wilting. Plants conditioned to shallow watering grow shallow roots which dry up when the water supply is suddenly withdrawn. Excess moisture in the soil (i.e. poor drainage) may produce an oxygen deficiency causing root hairs to die, reducing or preventing water and nutrient uptake.

Nutrient deficiencies and excesses. Nutrient deficiencies in plants may cause stunting, resulting in reduced yields or weak plants. Specific plant abnormalities often indicate which nutrient element is deficient. Some nutrients which are in sufficient supply in the soil may be unavailable because the soil is too acidic or basic. Nutrient excesses may be as harmful to plants as nutrient deficiencies. Some effects of nutrient deficiencies or excesses are listed in Table 10.

Table 10. Effects of various nutrient deficiencies or excesses causing nonparasitic diseases.

nitrogen deficiency — plants have stunted growth and are often spindly; leaves are small and pale to yellow (chlorosis). Yellowing starts on the lower leaves. In grasses, dieback starts at the tips of blades and progresses downward. On corn, yellowing shows in a typical V shape from the tip of leaf downwards. Continued severe deficiency may cause death of leaf tissue.

nitrogen excess — plants have highly succulent growth and increased susceptibility to disease. High nitrogen fertilizer deposits on leaves and roots cause burning of plant tissue.

phosphorus deficiency — plant growth and maturity are retarded. Reddening or purpling of leaves is common in some plant species. Dwarfing of plants also occurs. Peach trees show dark green leaves with gradual purpling of veins on the underside of leaves and bronzing of the topside of leaves. Downward curling of leaf tips and leaf margins may occur.

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potassium deficiency — leaves on many plants curl, followed by browning of leaf margins and appearance of pale spots on inner leaf portions. These disorders first appear on older leaves. Fruit on trees develops poorly or not at all. Weak growth is a common problem.

calcium deficiency — symptoms appear first in the growing tips and young leaves. Leaf growth is uneven and distorted. Leaf margins may be ragged and die. Pale leaves are also common. Blossom end rot of tomatoes is associated with calcium deficiency. Growing tips of celery, carrot, and parsley may be killed by calcium deficiency. Bitter pit of apple also is caused by calcium deficiency, as is internal tipburn of cabbages.

magnesium deficiency — magnesium deficiency leads to leaf yellowing and death and usually starts in the older leaves.

iron deficiency — Leaf cells between veins turn pale and even the smallest veins are bright green in contrast. Iron deficiency shows in young growth first. It is common in many fruit growing regions and is referred to as 'iron chlorosis'. Prolonged severe deficiency may lead to browning of the leaf margins and dieback of growing tips.

DISEASE-CAUSING ORGANISMS

The development of a parasitic plant disease depends on the life cycle of the parasite, susceptibility of the plant and environmental factors such as temperature and moisture. Some characteristics of parasitic disease causing agents are as follows:

Fungi. These are the largest group of plant disease-causing agents and include moulds, mushrooms and yeasts. These are simple plants which derive their food from other living organisms or decaying organic matter on which they live.

Most fungi reproduce by means of microscopic spores. When the spores germinate, they usually give rise to microscopic threadlike filaments. These filaments form the main body (mycelium) of the fungus and absorb nutrients and release chemical materials that induce disease. The parasitic fungi are transmitted from one plant to another by spores or fragments of mycelium. Movement of plants, plant parts, and soil from one area to another, may also spread the disease. Some examples of fungal diseases are:

- **cankers and diebacks**—e.g. apple anthracnose, *Coryneum* of peach.
- **galls**—e.g. azalea leaf gall, rust gall of pine.
- **leaf spots**—e.g. hawthorn leaf spot, blackspot of rose.
- **powdery mildew**—e.g. rose mildew, powdery mildew of blue grass.
- **rots**—e.g. *Phytophthora* root rot of Lawson's cypress, *Botrytis* rot of strawberries and conifer seedlings.
- **rusts**—e.g. white pine blister rust, snapdragon rust.
- **wilts**—e.g. *Verticillium* wilt of stone fruits, *Fusarium* wilt of cucumber.

Bacteria. Some major diseases of plants are caused by bacteria. These parasites are microscopic one-celled organisms that require an external source of organic matter for their food. Bacteria can reproduce very rapidly when conditions are favourable. They generally enter a plant through natural openings or through wounds. Bacterial plant diseases are often transmitted from plant to plant by the activity of people, by contaminated equipment, by wind and rain and by insects. Some examples of bacterial diseases are:

- **blights**—e.g. lilac blight, bacterial canker of cherry.
- **galls**—e.g. crown gall of rose, cane gall of raspberry.
- **rots**—e.g. bacterial ring rot of potato, soft rot of fruits and vegetables.

Mycoplasmas. These organisms are intermediate in size between bacteria and viruses. They have recently been discovered to be the cause of many plant diseases formerly attributed to viruses. These diseases are transmitted by sucking insects only and cannot be spread mechanically by contact. Included among the mycoplasma diseases are:

- **aster yellows** — e.g. aster yellows of wheat.
- **yellow edge disease** — e.g. yellow edge disease of clovers.
- **western-x disease** — e.g. western-x disease of peach.

Viruses. Viruses are extremely small living organisms that cannot be seen with an ordinary microscope. They only grow inside the cells of the living host. The viruses are transmitted by mechanical means during pruning or harvesting, or by insects, mites, nematodes, or fungi. Once introduced into the host plant, the virus may or may not cause visible symptoms. Some examples of virus-caused diseases are:

mosaics—e.g. gladiolus mosaic, lettuce mosaic.
ringspot—e.g. *Prunus* ringspot.
leaf roll—e.g. potato leaf roll.

Viroids. Viroids are the smallest self-replicating organisms yet discovered in plants. They are easily spread by propagating and cultivating procedures. They are not spread by insects. Disease examples include potato spindle tuber and chrysanthemum stunt.

DISEASE IDENTIFICATION

Before control measures can be taken, the cause of a suspected disease must be determined. Because of the microscopic size of most disease organisms, a diagnosis of a plant disease must usually rely on symptoms rather than on the identification of the causal organism. **Symptoms** are the visible expression of disease caused by the disease agent acting on plant cells and tissues. For example, cells and tissues die, leaves turn brown and fall, shoots enlarge abnormally or plants are stunted. Symptoms by themselves may not allow an accurate diagnosis of a plant disease because several distinctly different causal agents may produce similar symptoms. However, with experience, symptoms used with other evidence can often produce a satisfactory diagnosis.

Identifying the cause of a suspected plant disease should involve the following steps (Maloy, 1979):

Identify the plant affected. Determine both the species and variety whenever possible since differences in susceptibility to a plant disease may exist among varieties.

Examine the diseased area. Note how the diseased plants are distributed over the affected area. Parasitic diseases generally start in one location in a field or greenhouse and spread slowly in extent and severity. Such diseases rarely afflict all plants in a crop to the same degree. However, clumps of diseased plants, such as at the edge of a greenhouse bench, or along roadways or fences or in low spots in a field, frequently indicate nonparasitic causes such as soil condition or toxic chemicals. If all plants in a field are affected, the cause may also be a toxic chemical or unfavourable cultural practices or weather.

Determine the appearance of a "typical" diseased plant. Identification of the disease should not be based entirely on the appearance of plants with early symptoms nor on a plant that has deteriorated to a point that secondary organisms have obscured the primary cause of the problem. Note the parts of the plant affected. Are the roots, leaves, stem, flowers, fruit or entire plant involved?

Determine the primary symptoms of the condition under study. Symptoms are expressions of the affected plant that indicate something abnormal and are grouped into three general classes:

a) death of plant parts, e.g. shoot and leaf blights, leaf spots and fruit rots;
b) underdevelopment of tissues or organs, e.g. stunting of plants or failure of leaf pigments or flowers to develop; and
c) overdevelopment of tissues or organs; e.g. galls or witches'- broom.

Look for disease structures. Structures are sometimes produced by the causal agent of a disease and are more useful than symptoms in the accurate identification of a disease. The presence of mycelial mats of a root rot fungus, bacterial ooze from fire-blighted pears, masses of rust spores and the gray-white mycelium of powdery mildew are all structures produced by different disease organisms.

Isolate and identify the causal agent. Sometimes neither symptoms nor structures are specific or characteristic enough to pin down the cause of a disease. Additional specialized techniques are then required to isolate and identify the causal agent. Such problems can be reviewed with expert pathologists in the Ministry of Agriculture and Fisheries, Ministry of Forests and Lands or Pacific Forestry Centre.

DISEASE DEVELOPMENT

It is important to understand the life cycle of a disease-causing organism in order to develop an effective control program. The life cycles of all disease organisms follow the same general sequence. This sequence can be illustrated using a leaf fungus as an example (Figure 19). A diseased leaf carries the fungus over the winter. In the spring as the temperature becomes warmer, this fungus grows and develops spores. This mass of spores is called a **primary inoculum**.

As the fungus spores mature, they are discharged into the atmosphere where they are distributed by wind or water. Some eventually land on healthy leaves of a susceptible host plant. This step of moving the inoculum to a host plant is called **inoculation**. If conditions at the site of inoculation are adverse, the inoculum may die, it may be washed off by rain, or it may remain dormant. Until the inoculum begins to grow, it can be fairly resistant to pesticides.

If environmental conditions are favourable, the fungus spores will germinate. The disease has now entered the **incubation** stage and at this stage the disease organism is most vulnerable to pesticides or other unfavourable conditions.

At some point during incubation, the fungus may penetrate the plant's protective barriers and invade the plant tissues to begin the stage called **infection**. When the plant responds to the invasion of the fungus in some way, i.e. cells die or multiply abnormally, it is **diseased.**

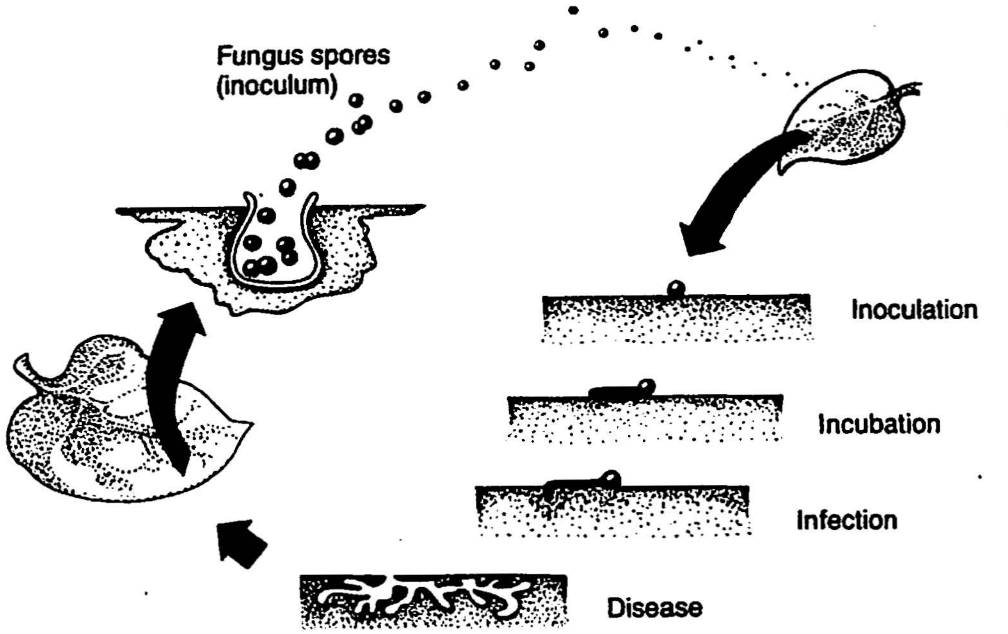

Figure 19. Example of a life cycle of a fungus in a plant leaf.

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Once the fungus is inside the plant, it is protected from outside influences. Most fungus diseases which reach the infection stage can not be controlled effectively unless a systemic fungicide is used before the infection is too severe. An exception is the infection stage of the powdery mildew fungi. This fungus remains confined to the surface (epidermal) cells where it forms specialized absorbing structures. Because the powdery mildews develop on the outside of plant surfaces they can often be controlled with pesticides after infection has occurred.

DISEASE CONTROL

PRINCIPLES OF DISEASE CONTROL

Three conditions must be present for a disease to develop:
- a causal agent,
- a host plant susceptible to the disease, and
- a favourable environment.

Elimination or altering any one of the three conditions will control disease development.

Methods for plant disease control can be divided into four general categories:

Exclusion. An area sometimes can be kept free of a disease by excluding plant material or soil containing disease organisms. Plant quarantines are one method of exclusion. Another method is to plant only certified disease-free seeds or plants. Once disease organisms have entered the soil or plants they are usually difficult to control.

Resistance. Strains of plants may be used which are least susceptible to the disease. Breeding programs have developed resistance in certain strains of plants. The level of resistance may vary depending on factors such as age of the host plant, aggressiveness of the disease-causing organism, or relative favourability of the environment.

Eradication. The attempted elimination of a disease organism is called eradication. Burning diseased plant material, eliminating alternate hosts and using eradicant fungicides are methods of eradication.

Protection. The host plant can sometimes be protected from a disease by providing conditions which are unsuitable for the disease organism. Examples of protection are controlling temperatures, providing good drainage and maintaining good cultural and sanitation practices. Fungicides are also used to protect against disease organisms. The treatment of seeds with a fungicide before planting is an example of this method.

Many diseases can be controlled by cultural practices alone. Such practices include:
- Selection of resistant or tolerant varieties of plants. Plants should be adapted to local conditions and planting stock should be vigorous.
- Proper establishment of plants. Ensure that soil, water, light and nutrient conditions are as favourable as possible to avoid development of disease.
- Rotating planting locations. Encourage the natural

decline of disease organisms specific to past crops, before they build up to nuisance levels.
- Maintenance operations. Rake and destroy fallen leaves and prune diseased growth to prevent nuisance infestations.

FUNGICIDES

Fungicides are chemicals used to prevent or eradicate diseases caused by fungi. Fungicides are generally not effective in preventing or eradicating bacterial or virus diseases. Many virus diseases are transmitted by insect, mite and nematode pests, hence virus disease control is sometimes possible by using insecticides, miticides or nematicides.

Fungicides can be divided into two types:

Protectant Fungicides. These provide a film of fungicide to prevent fungus spores from germinating. Protectants must be applied before infection occurs to 'protect' the plant from invasion by a pest. Seed protectants such as captan or thiram are used to prevent seedling blights, root rots and dampening-off. Foliage and blossom protectants such as benomyl, captan or maneb are used to prevent leaf spot and blossom blight diseases. Fruit protectants such as benomyl, captan or chlorothalonil are used to prevent fruit blemishes and harvest rots of fruits and vegetables.

Eradicant Fungicides. These are applied to destroy established disease organisms. Eradicant fungicides have limited use in destroying fungi that have already penetrated and infected plant material. Only a few fungicides are classed as eradicants, e.g. dichlone, dodine and liquid lime sulphur.

The basis for most fungicide disease control programs is to apply a protective film of chemical to plant surfaces before the disease organism has a chance to invade plant tissues. Such fungicides require good spreading properties and are often used with a wetting agent.

Most fungicides remain at the point they are applied and do not move in the plant. However, recently a number of **systemic fungicides** have been developed. They are absorbed by foliage or other plant parts and move within the plant. They may be protectants, eradicants or both. Advantages of systemics are that they are not quickly washed off plant surfaces and they may be transported to areas of new plant growth. Disadvantages of systemics are their higher costs and the resistance that some fungi develop to these chemicals. Also, most systemic fungicides do not kill, but only suppress disease-causing organisms which frequently recover as the chemical breaks down. The disease organism may continue to reproduce while its growth is suppressed.

Fungicides should remain active during the period of possible infection. Many disease fungi have reproductive cycles only a few days long and a crop plant may be exposed to as many as 10 to 25 generations of a fungus during the growing season. The protective covering provided by a fungicide may be lost because the chemical is broken down, the chemical is washed off, or new growth produces unprotected plant surfaces. Most fungicides are not effective for longer than 10 to 14 days. Thus repeated applications of fungicides are often required. Some plants only require treatments after each period of wet weather. Some susceptible plants require frequent chemical applications from the time leaves start to develop until growth stops. While most diseases are controlled during the active growing period of the plant, a few diseases, such as peach leaf curl, can be controlled effectively only by spraying when the tree is completely dormant in December or January.

Fungicides are available as liquid sprays or dusts. Usually, sprays are cheaper, easier to apply and more effective than dusts, but some diseases, such as powdery mildew, are better controlled by dusts. Regardless of whether a dust or spray is used, it is important to completely cover the plant part being protected.

Fungicides are also classified according to their chemical structure. They are either organic or inorganic. They are further categorized by the element(s) in inorganic fungicides or by the class of chemical compounds in organic fungicides. The major types of fungicides include the following:

Inorganic Fungicides

Sulphur. Probably the oldest pesticides known to man are various sulphur compounds. Sulphur is still used to control powdery mildews.

Copper. These compounds are wide-spectrum protectants. The combination of copper sulfate and hydrated lime to form Bordeaux mixture reduces the phytotoxicity of the copper sulfate. In general, copper compounds are relatively insoluble in water and are not easily washed from the leaves by rain. A very small portion of the copper goes into solution. Plant cells may eventually accumulate enough so that they are poisoned. Thus copper compounds can be phytotoxic with repeated applications.

Mercury, Cadmium and Other Heavy Metals. These are broadly toxic to fungi but also to warm-blooded animals. Many of the heavy metal compounds have now been banned for use because of their persistence in or on treated plants, leading to pesticide poisoning of man and animals, or because of the buildup of toxic residues in the soil.

Organic Fungicides

Dithiocarbamates. Most were developed in the 1930's and 1940's and are still widely used on fruit and vegetable crops. These have various properties depending on the metallic element associated with them. Ferbam is an iron salt, zineb and ziram are zinc salts, and maneb contains manganese. Thiram and metiram are nonmetallic carbamate fungicides.

Dicarboximides. These are widely used as protective sprays or dusts for fruits, vegetables, ornamentals and turf, and as seed treatments (e.g. captan, folpet and captafol).

Oxathiins. Two of these compounds, carbathiin and oxycarboxin, were introduced in 1966 as systemic fungicides. They are selectively toxic to some of the smut and rust fungi.

Benzimidazoles. These compounds were first introduced in the late 1960's and have been used as systemic fungicides against many types of diseases. One of the most widely used is benomyl, for control of diseases on fruits, vegetables, ornamentals and turf. Two others are thiabendazole and thiophanate-methyl, used as foliar fungicides, seed treatments, soil drenches, and as dips for fruit or roots.

Dinitrophenols. As a group, these compounds are usually toxic to mammals and phytotoxic. DNOC can only be used as a dormant spray. Dinocap is no longer registered because of chronic health effects in test animals.

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Organochlorines. This group contains fungicides with limited uses. Quintozene (PCNB) was introduced in the 1930's as a seed treatment, as a foliage fungicide and as a soil treatment to control damping-off fungi, but use on food crops is now very restricted.

Antibiotics. Antibiotics are toxins produced by microorganisms to kill other microorganisms. One such compound is streptomycin used for control of bacterial diseases on pears and potatoes. Another compound, cycloheximide, has antifungal properties but has limited use because of its high mammalian toxicity.

USEFUL PUBLICATIONS ON PLANT DISEASE CONTROL

For recommendations on control of specific diseases in British Columbia, see the Ministry of Agriculture and Fisheries Crop Production Guides listed near the end of Chapter 8 for field crops, tree fruits, grapes, berries, nurseries, vegetables, mushrooms and the home and garden. More general references include the following:

Maloy, O.C. 1979. Plant Diseases. *In*: Pacific Northwest Pest Control Handbook. State of Washington, Department of Agriculture. Olympia, Washington. p. 347 - 382.

Martens, J.W. *et al*. 1984. *Diseases of Field Crops in Canada.* The Canadian Phytopathological Society. Harrow, Ontario. 160 pp.

Pirone, P.P. 1978. *Diseases and Pests of Ornamental Plants.* Fifth Edition. John Wiley & Sons. New York. 565 pp.

REFERENCE LIST OF FUNGICIDES AND THEIR PROPERTIES

The following reference list includes a description of most fungicides used in British Columbia when this text was published. Fungicides are listed alphabetically by active ingredient with some examples of trade names. No endorsement of products is implied. Information contained in this list could become out-of-date and may not represent current use recommendations. **The current registered label is the authority on a pesticide's registered uses, application methods and safety precautions.**

The relative acute mammalian toxicity is given for each active ingredient listed. LD_{50} values (mg/kg body weight) are listed where available and are derived from tests with rats unless indicated otherwise (Rb = rabbit). The lowest LD_{50} value is listed for each fungicide where several are given in the literature reviewed.

anilazine *(Dyrene)* — a foliage protectant triazine fungicide. It is formulated as a wettable powder for use on turf, vegetables and berries. Nonphytotoxic when used at recommended dosages. It is compatible with most insecticides and fungicides except those which are alkaline. It has a low mammalian acute toxicity (LD_{50}: oral = 2,700; dermal ▷ 9,400), but may cause skin irritation and is toxic to fish.

benomyl *(Benlate, Tersan 1991)* — a benzimidazole compound with residual systemic activity. It is a broad-spectrum fungicide used as a foliar, seed, soil or turf treatment. Benomyl acts as both a protectant and eradicant fungicide. It is formulated as a wettable powder or dry flowable. Benomyl is used for the control of apple scab, powdery mildew, brown rot, *Fusarium* wilt, and numerous other diseases. It is nonphytotoxic. It has a low mammalian acute toxicity (LD_{50}: oral ▷ 9,600), but may cause irritation to eyes, nose, throat and skin. It is toxic to fish.

borax — a fungicide used as a wood preservative. See reference list in chapter on wood preservation.

Bordeaux mixture — a broad-spectrum, long-lasting protectant fungicide which is used as a dormant spray for fruit and other ornamental trees. It consists of a mixture of copper sulphate and hydrated lime. Bordeaux mixture is phytotoxic to plum and peach tree foliage, especially at low temperatures. Since it is corrosive, it should not be stored in iron or steel containers. A typical formula for mixing is expressed as 2-6-1000 which means 2 kg of powdered copper sulphate and 6 kg of lime in 1,000 L of water. Bordeaux mixture is incompatible with most other pesticides. It has a low mammalian acute toxicity.

cadmium compounds *(Cadminate, Caddy, Ortho Lawn and Turf Fungicide)* — are inorganic compounds registered in Canada as cadmium chloride, succinate and sebacate. They are broad-spectrum turf fungicides. Cadmium compounds are no longer recommended in British Columbia because of possible cumulative effects in nontarget species. Their acute toxicity to mammals varies from low to moderate (cadmium chloride oral LD_{50} = 88; cadmium succinate oral LD_{50} = 660).

captafol *(Difolatan)* — a dicarboximide compound which is a powerful foliar, turf and seed protectant fungicide closely related to captan and folpet. It is formulated as a flowable suspension. Captafol has a very long residual activity on tree fruit and blueberry plants and is used for control of potato and tomato blights. During high temperatures and high humidity it may be phytotoxic to some plants. Captafol has a low acute toxicity to mammals (LD_{50}: oral = 2,500) but skin and eye contact should be avoided as skin irritation and allergic reactions have been reported by some applicators. It is toxic to fish.

captan *(Captan, Orthocide)* — a dicarboximide compound which is a broad-spectrum protectant and eradicant fungicide available in a wide variety of formulations and mixtures with other fungicides and insecticides. Captan controls a wide range of leaf spots, blights, rots, scabs, blotches, as well as seed and soil-borne diseases. Captan is used for control of *Botrytis* and other fruit rots of berry crops, tree fruits and grapes. It is used as a seed treatment and to control bedding plant and forest nursery diseases. It may be phytotoxic to some varieties of apples. Captan has a low mammalian acute toxicity (LD_{50}: oral = 8,400) but has caused skin irritation. Also, chronic health effects developed in test animals after long-term exposure to captan. Use guidelines have recently been modified to reduce operator exposure and crop residue levels. It is toxic to fish.

carbathiin *(Arrest, Pro Gro, Vitaflo, Vitavax)* — a nonpersistent oxathiin compound available as a dust, solution, suspension and wettable powder, usually in combination with other fungicides and insecticides. It is a systemic fungicide effective against seed and soil-borne smuts, *Rhizoctonia*, and damping-off disease when applied to seed or soil. Treated seeds should not be used for food or feed, and livestock should not be grazed on areas sown with treated seed for four weeks after planting. Carbathiin has a low mammalian acute toxicity (LD_{50}: oral = 3,200; dermal > 8,000 Rb), but is toxic to fish.

carbendazim-phosphate *(MBC-phosphate, Lignosan-P)* — a benzimidazole systemic fungicide similar to benomyl and thiophanate methyl registered for Dutch elm disease. It has a low mammalian acute toxicity (LD_{50}: oral = 1,500).

chinomethionat *(Morestan)* — an organic hydrocarbon effective as a protectant and eradicant fungicide against powdery mildew. Available in dust and wettable powder formulations. Registered for use on non-bearing fruit trees or as a pre-bloom or post-harvest application only on bearing trees. Not registered for vegetable crops. It has a low mammalian acute toxicity (LD_{50}: oral = 1,100; dermal = 2,000), but may cause skin irritation and is toxic to fish.

chloroneb *(Demosan)* — a chlorinated hydrocarbon, soil fungicide useful against damping-off organisms such as *Pythium* and *Rhizoctonia* in turf. It has a low mammalian acute toxicity (LD_{50}: oral > 5,000; dermal > 5,000).

chlorophenates — fungicides used for wood preservation. See reference list in chapter on wood preservatives.

chloropicrin *(Larvacide, Picfume, Tear-Gas)* — a liquid which produces a highly poisonous but nonflammable gas, used to fumigate soil. Phytotoxic to all plants. Persists in the soil for about two weeks. Effective against a wide range of soil-borne diseases. It is added in a small quantity to methyl bromide to serve as a warning agent. Extremely irritating to the eyes and skin. Highly toxic to all animal life.

chlorothalonil *(Daconil 2787, Bravo, Exotherm Termil, Termil)* — a chlorinated hydrocarbon compound which is a broad-spectrum, foliar, protectant fungicide for turf, vegetables and ornamentals. Available in a wide variety of formulations. It has a very low mammalian acute toxicity (LD_{50}: oral = 10,000), but it causes allergic side effects in some people. Commonly used in commercial vegetable production. Toxic to fish.

coppers, fixed (copper oxychloride, copper hydroxide, tribasic copper sulphate, *Basico, Coprantol, Neutro-Cop, Tri-Cop)* — these insoluble materials are substitutes for Bordeaux mixture and are more widely used today than Bordeaux mixture. Effective for control of bacterial blights, and some fungus blights of trees, shrubs, and vegetables, and a wide range of other plant diseases. They have low mammalian toxicity.

cycloheximide *(Acti-Dione)* — an antifungal antibiotic for use on turf and ornamentals. Available in very dilute wettable powder formulations. Not recommended for use in the home garden due to its high toxicity. Occasionally used for rust and powdery mildew control in ornamentals. It has an extremely high mammalian acute toxicity (LD_{50}: oral = 1.8) and may cause skin irritation. It is toxic to fish and wildlife.

dichlone *(Phygon)* — a quinone compound used as a foliar, protectant fungicide for a variety of diseases on tree fruits and roses. Dichlone has a low mammalian acute toxicity (LD_{50}: oral = 1,300), but may cause skin irritation. It is toxic to fish.

dichloran *(Botran)* — a chlorinated nitroaniline compound used as a soil and foliar fungicide. It is available as a wettable powder and is effective against sclerotia-forming fungi and some other plant diseases. It is also used as a cut flower spray or dip for *Botrytis* control. It is phytotoxic to some seedlings, transplants, and greenhouse ornamentals, especially when mixed with certain organophosphorous pesticides It has a low mammalian acute toxicity (LD_{50}: oral = 1,500).

DNOC (dinitro compounds, *Elgetol)* — related to the dinoseb herbicides, used as a dormant spray to control overwintering fungi, insects and mites on tree fruits. Extreme care must be exercised with its use. It is not normally recommended due to its high mammalian toxicity (LD_{50}: oral = 20; dermal = 200).

dinocap *(Karathane, Mildex)* — a protective dinitrophenol fungicide specific for powdery mildews, although some other plant diseases and mites are also controlled. Dinocap acute toxicity to mammals is moderately low, but its use registration has recently been withdrawn due to chronic toxicity effects in test animals.

dodemorph-acetate *(Meltatox)* — is an organic compound used as a systemic, foliar protectant and eradicant fungicide for the control of powdery mildew on roses in nurseries and greenhouses. Formulated as an emulsifiable concentrate, it is nonphytotoxic when used as directed. It has a low acute toxicity to mammals (LD_{50}: oral = 2,500), but it may cause eye and skin irritation. It has a low toxicity to bees.

dodine *(Cyprex)* — is an aliphatic nitrogenous compound used as a foliage protectant fungicide. It has some eradicant properties. It gives residual control of apple and pear scab, brown rot of stone fruits and cherry leaf spot. Dodine is available as a solution, emulsifiable concentrate or wettable powder. Phytotoxicity has been reported with some varieties of apples, peaches and plums. It has a low mammalian acute toxicity (LD_{50}: oral = 566), but may be irritating to the skin. It is nontoxic to bees.

ethirimol *(Milgo-E)* — a pyrimidine compound effective against powdery mildew of wheat when applied as a foliar protectant. Systemic but rapidly degraded in plants. It has a low mammalian acute toxicity (LD_{50}: oral = 4,000).

etridiazole *(Truban)* — a selective thiazole soil fungicide registered for use against water moulds such as *Pythium* and *Phytophthora* on certain ornamental plants. It has a low mammalian acute toxicity (LD_{50}: oral = 1,077).

fenaminosulf *(Dexon, Lesan)* — an organic hydrocarbon which is effective against certain water moulds and damping-off fungi in soils. It is sometimes combined with quintozene *(PCNB, Terraclor)* for use in greenhouses. Not recommended for home garden use. Solutions decompose rapidly when exposed to sunlight. Nonphytotoxic. It has a high mammalian acute toxicity (LD_{50}: oral = 60; dermal = 100).

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fentin hydroxide *(Du-ter)* — an organic tin compound used as a protectant and eradicant for the control of late blight on potatoes. It is formulated as a wettable powder. It has a moderate acute toxicity to mammals (LD_{50}: oral = 108; dermal = 5,000), but may cause skin irritation. It has no known specific antidote. It is toxic to fish and wildlife.

ferbam *(Fermate)* — one of the original carbamate fungicides used as a broad-spectrum foliar protectant. It is formulated as a dust, pressurized spray and wettable powder. It leaves a black spray residue and has an unpleasant odour. It is nonphytotoxic. It has a low mammalian acute toxicity, (LD_{50}: oral = 1,000), but it causes irritation to the nose and throat. It is highly toxic to fish.

fixed copper — see copper, fixed

folpet *(Phaltan)* — a dicarboximide compound closely related to captan. It is used for many of the same purposes as captan. Available in a variety of formulations, it is used mainly in home garden mixtures. Folpet gives fair control of many powdery mildews. Phytotoxic to some varieties of pears, apples, and cherries. Mammalian acute toxicity is very low (LD_{50}: oral > 10,000) but it may be irritating to the mucous membranes. It is toxic to fish.

formaldehyde *(Formalin)* — a general disinfectant for soil, benches, tools and storage areas. A gas mask is required in confined areas. Available as a solution. Formaldehyde is also used against a wide variety of plant diseases, as a seed treatment, and hot or cold treatment for tubers and bulbs. It has a low mammalian acute toxicity (LD_{50}: oral = 800) but its fumes are very irritating to eyes and lungs.

glyodin *(Glyodine)* — an organic heterocyclic compound used as a protectant fungicide. It controls apple scab and suppresses mites and has excellent wetting and sticking properties. It has a low mammalian acute toxicity (LD_{50}: oral = 3,200).

iprodione *(Rovral)* — a broad-spectrum systemic imide fungicide, with protectant and eradicant properties, registered for use against grey mould of vegetables, berries, grapes, and ornamentals, *Botrytis* bunch rot in grapes, grey mould in strawberries, brown rot of stone fruits, white mould of beans and several diseases of turf. It has a low mammalian acute toxicity (LD_{50}: oral = 3,700).

lime sulphur (calcium polysulfide, *Orthorix)* — an old time inorganic fungicide, miticide and insecticide. Still useful as a dormant or delayed dormant spray for certain fruits and other woody plants. Lime sulphur is incompatible with most pesticides. It is commonly used for control of pear scab and peach leaf curl. Lime sulphur may burn foliage when used during the growing season. It has a low mammalian toxicity, but may cause skin irritation.

mancozeb *(Dithane M-45, Manzate 200)* — a broad spectrum carbamate foliage protectant fungicide. It is available in wettable powder and dust formulations. Mancozeb is particularly useful for foliar diseases of vegetables, ornamentals and tree fruits. It is similar to maneb, but with the addition of zinc. Nonphytotoxic when used as directed. Compatible with most commonly used pesticides. It has a very low mammalian acute toxicity, (LD_{50}: oral = 7,500), but may cause skin irritation.

maneb *(Dithane M-22, Manzate-D, Mantox, Agrox Seed Treatment Fungicide, Tersan LSR)* — a broad-spectrum carbamate foliage fungicide similar to mancozeb, available in dust, suspension and wettable powder formulations. May be phytotoxic to some seedlings and to some varieties of cherries and apples. Compatible with many insecticides and fungicides. It has a low mammalian acute toxicity (LD_{50}: oral = 1,000), but may cause skin irritation.

metalaxyl *(Ridomil, Subdue, Apron)* — an acylalamine compound with systemic fungicide properties specific for water moulds. It is used for foliage, soil or seed treatments. Metalaxyl is often mixed with other fungicides in an attempt to avoid fungus resistance. It has a low mammalian acute toxicity (LD_{50}: oral = 670), but may cause skin irritation.

methyl bromide *(Dowfume MC-2, Brom-O-Gas, Meth-O-Gas, Terr-O-Gas)* — a highly poisonous gas used for fumigation of greenhouse soils and seed beds to prevent damping-off and root diseases and to kill weed seeds and nematodes. (See reference list in chapter on fumigants).

metiram *(Polyram)* — a carbamate compound used as a protective foliage fungicide. Formulated as a wettable powder or solution. Metiram is a broad-spectrum fungicide registered for control of rusts, scabs, rots, downy mildew, early and late blights, leaf spots, smuts and other fungi on vegetable crops, cereals, potatoes, tomatoes, grapes and turf. Metiram must be stored cool and dry to avoid release of flammable vapours. It is nonphytotoxic. Mammalian acute toxicity is very low (LD_{50} = 6,200), but it is a skin irritant. It has a low toxicity to fish.

oxine benzoate *(No Damp)* — an organic compound used for control of damping-off diseases on seedlings and cuttings of ornamentals and vegetables. It can be applied to seedlings or to the soil.

oxycarboxin *(Plantvax)* — an organic compound effective as a systemic fungicide. Available in a solution and a wettable powder. It is used for rust control on carnations in greenhouses, or in a mixture with other fungicides for control of several snow moulds on turf. Although mammalian acute toxicity is low (LD_{50}: oral = 2,000), it is not registered for use on food or feed crops.

quintozene *(Terraclor, PCNB)* — an organochlorine compound. Quintozene is a long lasting soil and turf fungicide formulated as a wettable powder. It is effective against sclerotia-forming, soil-borne fungi such as *Rhizoctonia*. Not recommended for use in food crop production except for club root of crucifers. Useful for root rots of potted plants in greenhouses. Nonphytotoxic at recommended rates of application. Quintozene has a low mammalian acute toxicity (LD_{50}: oral = 1,650), but may cause skin irritation.

streptomycin sulphate *(Agrimycin, Agristrep)* — is an antibiotic used in controlling certain bacterial diseases such as fire blight, soft rot and black leg. It is formulated as soluble and wettable powders. It has a low mammalian acute toxicity (LD_{50}: oral = 9,000), but may cause skin irritation.

sulphur *(Ortho Flotox, Magnetic 6)* — is an element long used as a combination fungicide-miticide-insecticide, available in a variety of formulations for the control of a wide range of plant diseases. May injure plants during hot, dry weather. It is phytotoxic to certain sulphur-sensitive plants such as pears, apricots, raspberries and cucurbits. Relatively nontoxic to man, animals and bees, but may be irritating to the eyes and skin.

thiabendazole *(Mertect)* — a benzimidazole compound used as a protectant and eradicant fungicide. It is formulated as a dust, suspension and solution. Used for the control of moulds and rots in apples, bulbs and potatoes. It is not effective against bacterial infections. Nonphytotoxic when used as directed. Incompatible with numerous other pesticides. It has a low acute toxicity to mammals (LD_{50}: oral = 3,100).

thiophanate-methyl *(Easout, Scotts DSB)* — is a benzimidazole compound similar to benomyl used as a systemic, protectant and eradicant fungicide with long residual activity. It is formulated as a dust, granules or wettable powder. It is used in the control of a number of diseases of fruit, vegetables, turf, greenhouse and nursery ornamentals. It is nonphytotoxic. Mammalian acute toxicity is very low (LD_{50}: oral = 7,500, dermal > 10,000). It is toxic to fish.

thiram *(Arasan, Thiram 75, Tersan 75, Vitaflo, Pro Gro)* — a broad-spectrum carbamate compound used as a turf, foliar, soil and seed protectant fungicide. Available in a variety of formulations for use against a wide range of plant diseases. It has a moderate mammalian acute toxicity (LD_{50}: oral = 375; dermal > 2,000). It may be irritating to the skin and must not be used while consuming alcoholic beverages.

triforine *(Funginex)* — a systemic piperazine fungicide currently registered in Canada for the control of mummyberry on blueberries, for cottonball on cranberries, for blossom blight stage of brown rot on peaches, cherries and plums, and powdery mildew and black spot on roses and ornamentals. It has a low acute toxicity to mammals (LD_{50}: oral = 6,000). It also has a low toxicity to fish and bees.

zineb *(Dithane Z-78, Blightox, Thiogreen 80)* — a carbamate compound containing zinc. Zineb is a protective multi-purpose foliage and soil fungicide for use on many types of plants. It is formulated as a dust and a wettable powder. It may be phytotoxic to zinc sensitive plants. A widely used fungicide, zineb was replaced by maneb and mancozeb for some uses. Mammalian acute toxicity is low (LD_{50}: oral = 1,000; dermal > 2,500). It may cause irritation to the nose, throat and skin.

ziram — a carbamate compound containing zinc. It is used as a general protective foliage and soil fungicide. It is good for tender flowers and vegetable seedlings. Formulated as a wettable powder or spray. It is incompatible with many inorganic materials. It is nonphytotoxic, except to zinc-sensitive plants. It has a low mammalian acute toxicity (LD_{50}: oral = 1,400), but may cause skin irritation.

CHAPTER QUIZ

Questions

1. Name three causes of nonparasitic diseases.
2. Name three parasitic disease-causing organisms.
3. How are virus diseases transmitted from one plant to another?
4. Give several examples of symptoms of plant diseases.
5. Name possible causes of diseases with the following characteristics:
   (a) develops in a low spot in a field
   (b) all plants in a field are affected
   (c) develops very rapidly
   (d) started from a localized area, spreading slowly in extent and severity.
6. What are 3 categories of disease symptoms to look for in disease identification?
7. At what stage in the life cycle of a fungus is it usually most vulnerable to fungicides? Describe this stage.
8. Name four cultural control practices to protect against parasitic diseases.
9. Explain the difference between protectant and eradicant fungicides — which are most commonly used?
10. What are two major disadvantages of systemic fungicides?

Answers

1. light, temperature, water or nutrient deficiencies or excesses.
2. fungi, bacteria, mycoplasmas, viruses, viroids.
3. by mechanical means — on pruning equipment or by insects.
4. leaf browning, leaf or blossom damage, wilting, yellowing of leaves.
5. (a) soil condition but could be parasitic disease
   (b) soil condition, adverse climate, toxic chemical
   (c) climate, toxic chemicals
   (d) parasitic disease
6. death of plant parts, underdevelopment of tissues, overdevelopment of tissues.
7. incubation stage — when fungal spores start to germinate on the plant surface, but before they penetrate.
8. select tolerant plants, select plants suited to growing conditions, rotate plant crops, remove plant debris.
9. protectant sprays prevent a fungus from infecting a plant; eradicant sprays eliminate established infestations or prevent further development. Protectant sprays are most commonly used.
10. Resistance may develop to systemic fungicides and fungal organisms may recover quickly after the chemical breaks down.

Chapter 11

NEMATODES, NEMATICIDES AND SOIL FUMIGATION

CONTENTS

NEMATODE CHARACTERISTICS

STRUCTURE AND LIFE CYCLE

Nematodes are small, slender, colourless round worms. They are microscopic, and range in length from 0.2 to 0.4 mm. Various species of nematodes are parasites, living in or on plants, animals, insects and fungi; others feed only on decaying organic matter. A small fraction of the several thousand species known to man are plant pests, causing diseases in desirable plants.

The life cycle of most plant-feeding nematodes is simple. The female lays eggs that hatch into larvae which pass through four moulting periods to become adults. The average life cycle takes 20 to 60 days, during which the females of some species may produce more than 500 eggs. Figure 20 illustrates a life cycle which includes stages in the soil and in plant tissues.

Most plant-feeding nematodes spend their life in the soil. However, some species live part of their life inside plant roots. Others move from the soil up into stems, bulbs and leaves of certain plants. The symptoms of nematode attack are often the same as those caused by other diseases which damage the root system. Typical symptoms above ground are stunting, yellowing, loss of vigour and eventual death of plants, when nematode populations are large.

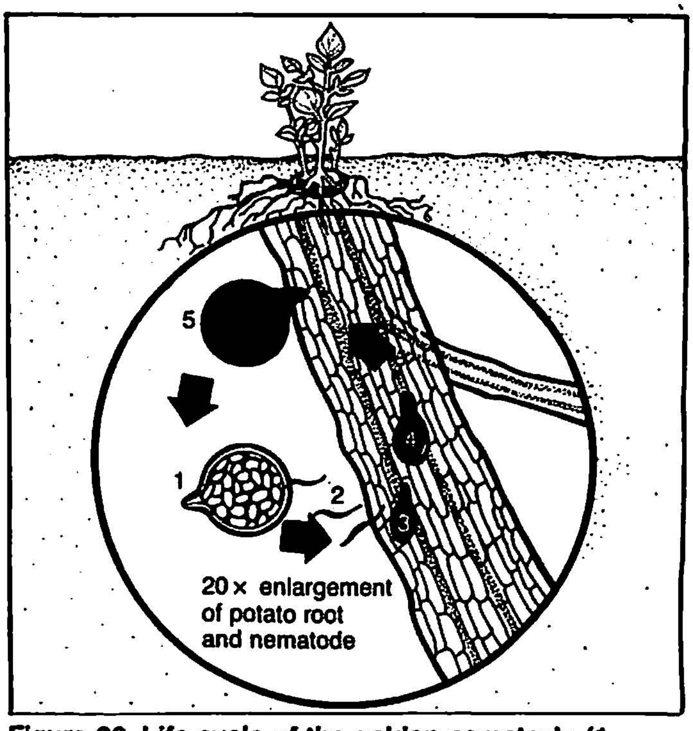

Figure 20. Life cycle of the golden nematode (1 — the cyst, smaller than a pinhead may contain several hundred eggs. A chemical produced by potato or tomato roots causes larvae to hatch from the egg. 2 — larvae entering root. 3 and 4 — swollen females feeding in root. 5 — mature female breaking through surface of root into soil).

TYPES OF NEMATODES

Most nematodes that are pests in British Columbia are widespread in the province. They can become a problem in nearly any location if a cultivated crop is susceptible to nematode infestation and if nematode control is not practiced. The main pest species in British Columbia can be divided into six categories:

The bulb and stem nematode *(Ditylenchus dipsaci).* Only the species which attack narcissus appears to be economically important in British Columbia. The nematodes usually enter the bulbs from the soil in the region of the neck and are eventually found throughout the plant. Infected plants have characteristic small, pale swellings or 'spickles' on the growing leaves. Rings of brown decay can be seen in badly infested bulbs when they are cut in cross section. The older larvae, when gradually dried, enter a dormant condition known as 'nematode wool', in which they can remain alive for several years, becoming active again only when moistened. This wool is easily transported to clean bulbs and fields through the use of contaminated equipment and clothing.

Spiral nematodes *(Helicotylenchus spp.).* These nematodes live on the outside of the roots and underground parts of plants. They are especially prevalent in lawns, golf greens and pastures. Many common field and vegetable crops, as well as ornamental shrubs, fruit and forest trees, and weeds, can also serve as hosts.

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Needle nematode *(Longidorus spp.).* This nematode has a limited distribution and causes damage primarily to strawberries. It feeds from the outside of the roots, causing a stunted, distorted root system with slight terminal swellings. Certain viruses are transmitted by this nematode.

Root-knot nematodes *(Meloidogyne spp.).* These nematodes reproduce on a wide variety of plants, including many weeds. Damage to economic crops is greatest on ornamentals and vegetables in British Columbia. The most obvious damage is the formation of knots or galls on the roots of host plants. Symptoms above ground vary with the plant and the environment, but generally the plant becomes stunted, turns yellow, and may eventually die. The root-knot nematode spends most of its life inside plant roots. It is therefore easily spread from place to place when plants are moved from one location to another.

Root lesion nematodes *(Pratylenchus spp.).* These are the most common nematodes in British Columbia. One species or another is found throughout the province on almost every crop. They often cause severe injury, particularly on raspberries and strawberries. Direct damage is caused by the nematode penetrating, feeding and migrating throughout the roots. Fungi and bacteria often invade these nematode wounds, and the combination of organisms eventually results in extensive root decay. Since these nematodes spend a portion of their life inside roots, they are difficult to control and easily spread by transplanting infected plant material.

Dagger nematodes *(Xiphinema spp.).* The American dagger nematode attacks ornamentals, raspberries, strawberries and certain fruit trees. Its feeding causes eventual destruction of the root system and may also transmit plant viruses to these crops. The Baker dagger nematode causes damage to small fruits (e.g. strawberries and raspberries), forest and ornamental trees, tomatoes and potatoes. This species causes terminal root swelling and a characteristic curling of the root tip. Dagger nematodes remain free in the soil most of their life and are more easily controlled than nematodes that live inside roots.

SAMPLING FOR NEMATODES

The effects of nematode damage can be distinct, but more often are difficult to distinguish from other plant disease symptoms. Nematode damage to field crops usually appears as an area of depressed growth with a gradual improvement outward from the centre. Nematode populations may be low in the centre of the depressed growth area, but high around the edge of this area where food is abundant. Sampling may be required to determine whether poor plant growth is the result of nematode injury.

A plant parasitic nematode causes economic damage only when the population density exceeds the tolerance level of the crop. This tolerance level varies according to the host crop and factors such as moisture, temperature, soil fertility, and soil type. These conditions vary from season to season and field to field. The need for nematode control should be determined from a careful assessment of nematode abundance and the susceptibility of the crop to nematode damage.

If a nematode problem is suspected in a commercial crop, growers should consult a District Horticulturist of the Ministry of Agriculture and Fisheries. If sampling is recommended, the grower should obtain advice on the number, size and depth of samples which should be taken to look for nematodes in a particular planting.

METHODS OF NEMATODE CONTROL

NON-CHEMICAL CONTROL

There are several ways in which a nematode problem may be solved. Control often involves the integration of different methods. Sound practices which prevent introduction and spread of parasitic nematodes must be incorporated into a control program, otherwise chemical treatment may be useless and costly.

It is most important to purchase plant stock certified to be free of plant-parasitic nematodes. Crop rotation can sometimes be used to prevent buildup of damaging nematode numbers. The design of crop rotation schemes for this objective requires considerable knowledge. Advice can be obtained from Ministry of Agriculture and Fisheries district offices. Good weed control around crop plants in conjunction with periodic summer fallow can reduce nematode numbers. Summer fallow can be beneficial if the soil is left to dry out, but is only of limited value where there are heavy nematode infestations.

SOIL FUMIGATION

Nematodes are covered with a tough outer skin which provides them with considerable protection. Pesticides with outstanding penetration characteristics are therefore required for their control.

Most pesticides used in nematode control are fumigants. They move through the soil as a gas and depend on the presence of air spaces in the soil for their distribution. It is critical that the soil contains sufficient air spaces for this gas movement in order to obtain adequate control. A few nematicides are applied as liquid or granular formulations and are not fumigants (e.g. oxamyl). They have limited uses.

There are a small number of fumigant nematicides used in British Columbia, and the following discussion applies to these chemicals.

HOW SOIL FUMIGATION WORKS

Soil fumigation is used to control many pests, including insects, weeds and disease organisms, such as nematodes, fungi and bacteria. Soil fumigation is the application of a toxic gas or a liquid or granular material which converts to a toxic gas in the soil. This gas moves through the air spaces in the soil and is absorbed in the water film surrounding soil particles. Eventually the gas escapes from the soil, otherwise the succeeding crop would be damaged. However, if the gas escapes from the soil too soon, the pest species will not be killed.

Several factors influence the movement of a fumigant through the soil. Gases move much faster through air than through water, so the soil must have the right proportion of air space to water. If the soil is too wet, there will not be enough air space for the fumigant to disperse through the soil. If the soil is too dry, there will be too little moisture around the soil particles to absorb the fumigant, and it will escape from the soil too quickly.

Heavy or compacted soils do not allow the fumigant to disperse, and cultivation is usually required to bring the soil to a loose condition before fumigation. Light sandy soils often have too much air space and the fumigant will escape quickly unless the soil is sealed or compacted immediately after fumigation.

Soil temperatures directly influence the effectiveness of a fumigant. When soil temperatures at a depth of 15 to 20 cm are near or below 4°C, the fumigant converts to a gas slowly and spreads very gradually. If the soil temperature is above 24°C, the fumigant converts to a gas rapidly and moves out of the soil too quickly.

Organic matter readily absorbs fumigants and may prevent the gas from dispersing evenly. If the soil organic matter is high or too much crop residue is in the soil, higher rates of fumigant will be needed to do an effective job. The presence of materials such as stems or stubble will provide 'chimneys' through which the fumigant can rapidly escape from the soil. Crop remnants also provide protection for various pests.

SELECTING THE RIGHT FUMIGANT

Considerations for fumigant selection are the purpose, cost and equipment available for application. Fumigant costs vary considerably. Some fumigants require considerable field preparation and/or elaborate application equipment. Some fumigants such as 1,3-dichloropropene control mainly nematodes and insects. Others, such as methyl bromide, methyl isothiocyanate-dichloropropene mixtures, and metam-sodium have a wide spectrum of activity and control many soil insects, nematodes, weeds and plant disease organisms.

In deciding on fumigant use, one must consider the value of the crop, cost of the fumigant and its application, impact of the nematode disease, other diseases or weeds that might be controlled at the same time as well as safety precautions. Advice can be obtained from a District Horticulturist.

APPLYING THE FUMIGANT

The best time to apply chemical controls is in the late summer or early fall when soil temperatures are high, moisture is moderate, and there is sufficient time for control and the release of the nematicide from the soil before planting the next spring. A good practice, where possible, is to plough out the roots of susceptible plants immediately after harvest. This prevents additional nematode buildup, exposes roots to the drying sun and wind, and breaks down roots where nematodes may be living. Then work the ground to seed bed condition which will permit thorough diffusion of the fumigant.

The soil should contain a moisture content so that, when a handful of soil is squeezed, it will barely retain its shape. In drier areas or on sandy soils, water may have to be applied prior to fumigation to get the desired soil moisture.

Soil temperature usually should be between 10° and 20°C at the application depth. Check label directions.

Soil fumigants are sometimes applied to small areas such as greenhouse soil or topsoil, seed beds or sites where individual trees are to be planted. Gaseous fumigants such as methyl bromide can be applied under a polyethylene cover. Liquid fumigants can be applied by injection with hand applicators or by mixing with water and drenching the area.

Soil fumigants may be applied to large areas by the use of tractor-drawn injection equipment or by application in irrigation systems. Fumigants may be injected by chisels or ploughs at a depth of at least 15 to 20 cm. The applicator shanks should be spaced no more than 30 cm apart. Row or strip application reduces fumigation costs, since only that portion of the field where plants will be grown is treated. However, this method can be less effective than broadcast treatment.

Immediately after fumigation the soil surface should be sealed to delay the escape of the fumigant from the soil. For most fumigants, simply compressing the surface with some device, such as a roller, is sufficient. For more volatile materials like methyl bromide, a plastic cover is necessary. A water seal may be used with the application of certain fumigants.

The soil should be exposed to the fumigant for periods ranging from two days to two weeks, as recommended for the product used. Longer exposure periods are usually required for cooler soils. Following the exposure period, the soil should be left to aerate so that no phytotoxic concentrations of fumigant remain at planting time. Two weeks to several months may be required. With some fumigants, the soil is free of damaging fumigant levels when the odour of the fumigant can no longer be detected. When soil fumigants are applied in spring, the soil may have to be cultivated one or more times to speed up aeration prior to planting.

Since many fumigants are corrosive, equipment should be cleaned thoroughly after use by flushing with fuel oil or kerosene.

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SAFETY PRECAUTIONS

Note that the production of a toxic gas during or following *fumigant* application considerably increases the risk of human exposure to these pesticides compared to solid or liquid pesticides. In addition, the toxicity of most fumigants is relatively high. Therefore, it is essential to follow the safety precautions described on the label. Fumigant applicators must have knowledge of the properties of the fumigant chemicals and safety requirements for their use.

The following procedures should be observed when working with fumigants:

- Do not work alone.
- Ensure you have the required and correct protective gear.
- A *respirator must* be worn if fumigants are used in enclosed places and when aerating treated areas.
- When dealing with a spill in an enclosed area, use an approved full-face, air-supplied respirator.
- Many liquid fumigants can penetrate leather and rubber boots or gloves. Polyethylene gloves and wrapping around boots provides better protection.
- When working with methyl bromide, gloves should not be worn. If the liquid is held in contact with the skin by gloves, burns can result. If the liquid is spilled on bare hands it will evaporate quickly, but wash with soap and water immediately.
- Do not apply fumigants immediately adjacent to human dwellings or livestock.
- Prevent access to treated areas by people without knowledge of the danger, especially children.
- Do not store fumigants near human dwellings or livestock.

USEFUL PUBLICATIONS ON NEMATODES AND SOIL FUMIGATION

Information on nematode control is contained in the B.C. Ministry of Agriculture and Fisheries Crop Production Guides for Berries, Nurseries, Vegetables, Tree Fruits and Grapes.

REFERENCE LIST OF NEMATICIDES AND THEIR PROPERTIES

The following reference list includes a description of most nematicides used in British Columbia when this text was published. Nematicides are listed alphabetically by active ingredient with some examples of trade names. No endorsement of products is implied. Information contained in these lists could become out-of-date and may not represent current use recommendations. **The current registered label is the authority on a pesticide's registered uses, application methods and safety precautions.**

The relative acute mammalian toxicity is given for each active ingredient listed. LD_{50} values (mg/kg body weight) are listed where available and are derived from tests with rats unless indicated otherwise (Rb = rabbit). The lowest LD_{50} value is listed for each nematicide where several are given in the literature reviewed.

Non-Fumigant Nematicides:

oxamyl *(Vydate L)* — a carbamate compound that is used for control of nematodes and insects. Its registered use is restricted to root-lesion nematodes on non-bearing apple trees. It is applied as a liquid drench or foliar treatment or both. It has moderate residual activity. It is highly toxic to mammals (LD_{50}: oral = 5.4) and highly toxic to fish and birds.

Fumigant Nematicides:

dazomet *(Basamid)* — is a granular soil fumigant which is applied dry and needs no plastic cover or complicated application equipment. It controls unencysted nematodes, soil fungi and most weeds and weed seeds commonly found in soil and mixtures of soil and peat used in propagation beds. Granules are applied to moist, well prepared soil when the soil temperature is above 6°C. Following incorporation to a depth of 20 to 25 cm, the soil surface must be sealed by rolling or packing and possibly light irrigation. After 7 to 10 days the soil is cultivated to allow phytotoxic gases to escape. Depending on soil temperatures, 2 to 6 weeks must pass before any crop can be safely planted. If very early spring planting is anticipated, dazomet is best applied in September or October of the preceding year when the soil is warm. Dazomet has a moderate acute toxicity to mammals (LD_{50}: oral = 320) and may be irritating to skin. It is toxic to fish.

dichloropropene fumigants *(Telone, Vorlex)* — these products contain 1,3-dichloropropene alone or in combination with 1,2-dichloropropane and small amounts of other chlorinated hydrocarbons including chloropicrin or methyl isothiocyanate. They are used for preplant treatments in both field and greenhouse soils to be planted with some ornamental plants, vegetables, berries, fruit trees and nursery crops. They kill nematodes and can control some fungal diseases and wireworms and suppress germination of some seeds. They can be phytotoxic to crops if planted too soon after the fumigants are applied. After the soil is exposed to the fumigant for a minimum of 4 to 7 days, the soil should be cultivated, then left to aerate for a minimum of one week — longer if high application rates are used, soil temperatures are below 15.5°C, the soils are very wet or are organic (muck). After fall or winter applications, the aeration period should extend until spring. The active ingredients have a moderate acute toxicity to mammals as liquids (LD_{50}: oral = 100—500; dermal = 2,000), but they are hazardous to use because of the gas they produce (LC_{50}: inhalation = 9 mg/L). 1,3-dichloropropene has a relatively low toxicity to birds but is highly toxic to fish.

metam-sodium *(Metam-Sodium, Vapam)* — a liquid soil fumigant which may be injected into the soil, applied to the soil surface as a drench, or metered into irrigation systems. In the presence of water, it breaks down into the more toxic methyl isothiocyanate which is then lost to the atmosphere by vaporization. Certain weeds and fungi may be controlled as well as nematodes. Metam-sodium has a low mammalian acute toxicity (LD_{50}: oral = 820; dermal = 2,000 Rb) but it may be irritating to the eyes, nose, throat and skin. It is hazardous to use because of the gas it produces. Note that the oral LD_{50} for methyl isothiocyanate = 97.

methyl bromide *(Dowfume MC-2, Terr-O-Gas)* — a colourless, nearly odourless gas, available in pressurized cans or cylinders, or as solutions containing various percentages of methyl bromide. The tear gas, chloropicrin, is usually added as a warning agent. The area to be treated must be covered with a plastic tarp or other suitable gas-proof material. Although normally used in small areas, equipment is available for field-scale application. The material is injected into the soil and immediately sealed with polyethylene in one operation. When the soil has been properly prepared, methyl bromide will kill nematodes and insects to a depth of 30 cm or more and fungi and weed seeds to a lesser depth. The minimum soil temperatures for treatment is 4.5°C at 15 cm. When the tarp is removed, the material escapes rapidly and the soil is ready for planting within two to five days. Methyl bromide has a high mammalian toxicity. The liquid has an LD_{50} of about 1 mg/L and can cause severe eye and skin burns. The gas is very hazardous due to the potential for inhalation. The threshold level of toxic effects in humans is about 20 ppm for the gas.

CHAPTER QUIZ

Questions / **Answers**

1. How large are adult nematodes? Summarize their life-cycle.
   - The adult size is 0.2 to 0.4 mm long. Larvae hatch from eggs and moult about 4 times during development to the adult stage which usually takes 20 to 60 days.
2. What are symptoms of nematode damage in plants?
   - Stunting, yellowing, loss of vigour, death of plant.
3. What are 4 types of plants that are susceptible to nematode damage in B.C.?
   - Narcissus bulbs, vegetable crops, ornamental shrubs, fruit trees, berry crops.
4. Who would you consult about the need to sample for nematodes?
   - District Horticulturist of the Ministry of Agriculture and Fisheries.
5. What are 3 non-chemical ways to control nematodes?
   - Purchase nematode-free plant stock, practice crop rotation and practice good weed control with periodic summer fallow.
6. Name 4 soil conditions that must be considered when using a fumigant and indicate why.
   - **Water content** — not enough air spaces if too wet; gas moves out too quickly if too dry.
     Compaction — does not distribute well if too compact, moves out too quickly if too sandy.
     Soil temperature — fumigant doesn't become a gas if too cold, converts to gas too quickly if too warm.
     Organic matter — gas binds to organic matter.
7. What are 2 reasons fumigants are dangerous to workers?
   - Increased risk of exposure to gas; they are highly toxic.
8. Name at least 4 safety precautions in working with fumigants.
   - Don't work alone, wear correct protective gear, don't store or apply near human dwellings or livestock, have a gas mask for emergencies if not used in treatment, prevent access to treated areas by unauthorized people.

Chapter 12

WEEDS, HERBICIDES AND PLANT GROWTH REGULATORS

CONTENTS

WEED CHARACTERISTICS

INTRODUCTION

A weed is a plant growing where it is not wanted. A plant may be a desirable species in one location and a weed in another. Rye, for example, is a desirable crop plant when grown for its seed, but becomes a troublesome weed when it invades wheat fields. A Douglas fir tree near a power line is a weed, as is common chickweed in a vegetable garden.

Weeds need to be controlled for many different reasons. They compete with cultivated plants for light, water and nutrients and reduce crop yields. Weeds may be poisonous to people and livestock or taint dairy products. Some weeds serve as alternate hosts for insects and plant diseases which attack crops. Weeds suppress the growth of coniferous seedlings in logged forest areas. Weed growth along roads can reduce the visibility around corners and eventually grow through and break up pavement. Uncontrolled weeds in industrial areas increase the fire hazard.

Some weed species are designated as **noxious** under the provincial Weed Control Act. Noxious weeds are particularly troublesome species in certain locations and must be controlled in order to reduce their nuisance and to prevent their spread. Under authority of this Act, government agents can instruct landowners to control those weeds designated as noxious in a particular area. Some weeds are designated as noxious for the entire province, while other species are designated as noxious within some regional districts. The noxious weeds for British Columbia are listed in Chapter 3.

WEED CLASSIFICATION

Weeds can be classified (grouped) according to such characteristics as lifespan, season of growth and type of reproduction. A knowledge of these characteristics is important when deciding how and when to control specific weeds. Herbicide product labels may include directions for use on specific types of weeds.

All plants can be divided into three types: annuals, biennials and perennials.

Annuals

Annual plants complete their *life cycle* in less than one year. They are often considered easy to control in the short term (i.e., for one crop of weeds). However, most annuals produce many seeds and have rapid growth rates. They may require more effort to control over a period of years than perennial weeds. There are two kinds of annuals:

- **Summer annuals.** These plants germinate in spring, produce most of their growth during the summer and mature, produce seed and die in the fall. Some summer annuals are lambsquarters, pigweed, foxtail and common ragweed.

- **Winter annuals.** These plants germinate in the fall or winter, produce most of their growth during the spring, and mature, produce seed and die in summer. Some winter annuals are chickweed, shepherd's purse, groundsel and black medick.

Biennials

Biennials live for more than one year but less than two years. They grow from seed which usually germinates in the spring. The first year, the plant usually forms a rosette of basal leaves and a tap root. The following spring the plant draws upon food stored in its root and grows vigorously. It produces seed and dies in the summer or fall. Some examples of biennials are wild carrot, bull thistle, foxglove, common mullein and burdock. The best time to control biennials is in their first year of growth.

Perennials

Perennials live for more than two years. Seed may be produced during the second year and in each succeeding year of the plant's life. There are three types of perennials:

- **Simple perennials.** These plants spread mainly by seed. Large pieces cut from these plants can sometimes grow into new plants. For example, a dandelion or dock root cut in half may produce two plants. Other simple perennials are plantains and spotted cat's ear.
- **Bulbous perennials.** These plants reproduce by underground bulbs as well as by seed (e.g. wild garlic).
- **Creeping perennials.** These plants reproduce by seed and also by creeping roots, creeping above-ground stems (stolons), or creeping below-ground stems (rhizomes, tubers or corms). Small pieces of creeping perennials can grow into new plants. Examples of creeping perennials include red sorrel, perennial sow thistle, field bindweed, wild strawberry, mouse-ear chickweed, quack grass and Canada thistle. Once a field is infested, creeping perennials are difficult to control. Cultivators and plows move pieces around fields spreading the weeds. Control often requires frequent repeated cultivation or mowing, or several herbicide applications.

Conifers, Narrowleaved and Broadleaved Plants

Plants are also classified according to structural similarities. Three commonly recognized classes of plants are conifers, and the narrowleaved and broadleaved flowering plants (Figure 21).

- **Conifers** (gymnosperms) are characterized by needle or scale-like leaves and production of seeds in cones. Most are evergreen. Conifer trees are generally called soft-wood trees in contrast to hard-wood broadleaf trees.

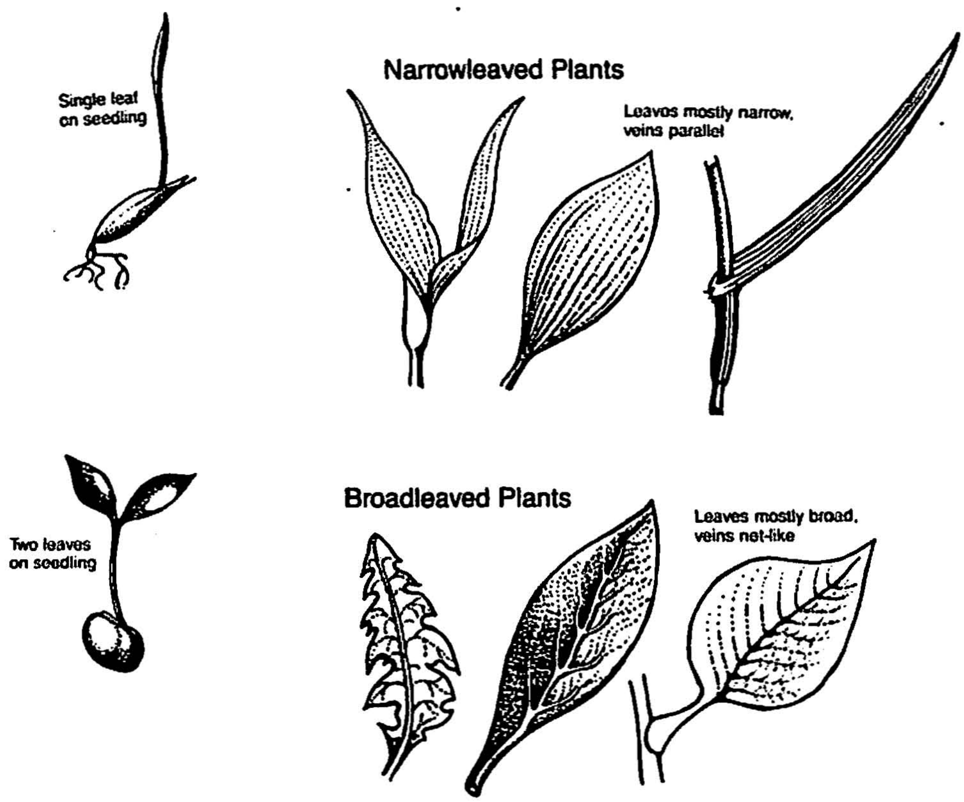

Figure 21. Comparison of narrowleaved and broadleaved plant leaves and seedlings.

- **Narrowleaved plants** (monocotyledons). Plants in this group typically have long, narrow, upright leaves and leaf-veins which run parallel to leaf margins. Seedlings have only one seed leaf (Figure 21). These narrowleaved plants are usually herbaceous, lacking woody tissues. They include grasses, rushes, sedges and bamboo which can be problem weeds, and plants such as lilies, irises and corn which are generally not weeds. Some herbicides have been developed which are selective for narrowleaved plants.
- **Broadleaved plants** (dicotyledons). Plants in this group usually have broad leaves and their leaf-veins are net-like, not all parallel. Seedlings have two seed leaves (Figure 21). They may be either evergreen or deciduous (lose their leaves in winter). They may be either herbaceous (soft-stemmed) or woody (hard-stemmed). Woody plants (e.g. brush, shrubs and trees) usually live longer and are often more resistant to herbicides than herbaceous plants.

WEED IDENTIFICATION

It is usually necessary to identify the name of a weed before a control program is selected. When a weed is identified, information can be obtained on its growth characteristics and control recommendations.

Plants have both scientific and common names. The scientific (botanical) name always consists of two parts and is written in Latin. The first part identifies the **genus** of the plant. The second part identifies the **species** of the plant. For example, the scientific name of Canada thistle is *Cirsium arvense*. This is the most accurate way to name a plant, as the scientific name is used for the same plant species around the world. Common names for plants (such as Canada thistle) may vary from region to region, causing confusion. If you refer to a weed by its common name, be sure that the same name is used by weed control specialists in your area.

Various illustrated publications by Agriculture Canada and the British Columbia Ministry of Agriculture and Fisheries are available to help identify weeds (see list of publications toward the end of this Chapter). Weed specialists may be able to help when identification is difficult.

WEED CONTROL AND HERBICIDE USE

WEED CONTROL METHODS

Weed control methods can be divided into five categories: prevention, mechanical, cultural, biological and chemical. A well-planned weed control program will often combine two or more of these methods.

Prevention

Prevention is the attempt to keep weed species out of a specific area and should be the first consideration for effective, long-term weed control. Once weeds infest an area and produce seeds, they are difficult and costly to control. A single weed has the potential to cause a widespread infestation if permitted to produce the enormous number of seeds typical of many weed species (Table 11). Some desirable practices to prevent weed introduction include the following:

- Control noxious weeds along roads and railways to prevent their transport to uninfested areas.
- Keep areas near cropland and landscaped areas as free of weeds as possible. Clean along fencelines, irrigation ditches, roadsides and other areas that may harbour weeds.
- Use seed certified to be clean, i.e. free of weed seeds.
- Cut weed-infested crops prior to seed production.
- Avoid use of soil from infested areas.
- Make sure machinery such as harvesting equipment is free of weed fragments and seed before moving to clean areas.
- Clean livestock before moving from infested to clean areas.
- Use only well-rotted manure (at least 4 to 5 months old). Many weed seeds pass unharmed through the gut of grazing animals.

Table 11. Seed production estimates of individual plants of some common weed species.

Weed Species	Seeds Per Plant
wild buckwheat	11,900
burdock	31,600
dandelion	15,000
curled dock	29,500
lambsquarters	72,450
mullein	223,200
common mustard	2,700
wild oats	250
shepherd's purse	33,500
Russian thistle	24,700

Physical Control

Objectives of physical control may include removing, covering or stressing weeds or preventing seed production.

Tillage is probably the most common method of physical weed control. Most annual broadleaf weeds are killed by tillage if all growing points are buried. Burial is only partly effective on weeds with underground stems and roots that are capable of sprouting. Tillage can also be used to disturb root systems. The objective is to dislodge or cut the root system so the plant dies from drying out or from frost damage before it can re-establish its roots. Repeated tillage operations are usually required to effectively control perennial weeds.

Mowing can be an effective way to control annual weeds if done often enough to prevent flowering and seeding. Some perennial weeds can be killed by mowing. However, most perennials require several cuttings to expend food reserves in their roots, before they are killed.

Burning can be used to remove undesirable plants and to kill some of their seeds. Although intense heat from burning will destroy most seeds on plant stalks, only a small number of seeds below the soil surface can be killed.

Mulching can be an effective way to eliminate weed growth from small areas. Mulching materials such as straw, manure, sawdust or black plastic exclude light from weeds and they eventually die.

Cultural Control

In cultural control, plant competition or cropping practices are used to suppress weeds. Such techniques require knowledge about the growth requirements of desirable plants in relation to weeds.

It is important to establish a vigorous, dense growth of cultivated plants to reduce competition with weeds. For example, good growing conditions should be provided for lawn areas by aeration, top dressing, re-seeding, good watering practices and correct mowing heights. Bare areas normally requiring weed control can often be planted with desirable perennial ground cover to inhibit annual weed growth. It may be possible to promote the development of desirable plant communities along rights-of-way or in landscaped areas to suppress weed species which grow too high or spread too quickly.

Nurse or companion crops are sometimes planted to reduce weed growth before the main crop is well established. These companion crops may be controlled with chemicals or they may be annuals in a perennial crop. They are usually quick to germinate and have rapid early growth to compete with weed species.

Crop rotation is a good method to prevent or reduce the buildup of high populations of certain weeds common to a particular crop. When the same crop and cultural procedures are followed year after year, crop-associated weeds tend to multiply rapidly and compete successfully with the crop plants. Rotation of crops or land-use will reduce this weed growth and, combined with chemical control, is an effective way of controlling most weeds.

Biological Control

Biological control is the use of insects or disease-causing organisms such as fungi, bacteria or viruses for the control of weeds. Most common weed species are not native plants, but were introduced from elsewhere, mainly Europe and Asia. Weeds in their native habitat often have natural enemies that keep their numbers in check. Introduced weeds may increase rapidly since their natural enemies are often absent in their new environment. Thus biological control usually involves importing natural enemies from areas where the weeds are native. These enemies must be tested to make certain that they affect only the weed species and not any other important animals or plants.

Biological control can be effective, but has a number of limitations. Testing the effectiveness and safety of a new control organism usually takes several years. Biological controls are meant to be specific to one or several closely-related weed species and cannot be used to control a complex of unrelated species. Also, biological control is generally a slow process and does not provide immediate weed control. Typically 3 to 10 years are required before a weed population is reduced to a non-economic level.

Some investigations of biological control agents in British Columbia are listed in Table 12.

Chemical Control

Chemicals used to kill, inhibit or change plant growth are called herbicides. They are "phytotoxic", meaning injurious or toxic to plants. There are over 100 herbicide active ingredients presently registered for use in Canada and there are over 600 registered products which contain one or several of these active ingredients. There is a continuing attempt to develop herbicides that

Table 12. Some attempts at biological control of weeds in British Columbia.

Diffuse knapweed —	two fly species were released which lay eggs in the seed heads. The plant forms a gall around the resultant larvae and seed production is reduced. First releases were made in 1970 at Pritchard. In 1976, a root-boring beetle was released near Penticton and in 1983-84 two root feeding moth species were released at Summerland
Spotted knapweed —	two fly and one moth species were released that attack the seed heads and two moths species were released that feed on roots.
Canada thistle —	a stem-miner weevil and shoot gall-forming fly were released in 1975.
Bull thistle —	a fly species which attacks seed heads was released in 1975 at Cloverdale and Cranbrook and in 1978 in the Cariboo.
St. Johnswort —	two leaf-eating beetle species have been very effective against this poisonous range weed in B.C. Another leaf-eater and root-borer were released in 1977 at Elko.
Toadflax —	a defoliator moth did not survive introduction.
Tansy Ragwort —	a defoliator moth established in the Lower Mainland was partially successful.

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will be more effective against specific weeds. However, testing new chemicals for effectiveness and environmental safety is extremely costly.

Herbicides can be used to prevent seed production, remove above-ground leaves, kill entire plants or sterilize the ground for several years. The different ways they affect plants is discussed in the following sections.

HERBICIDE MODES OF ACTION

Herbicide mode of action is the way in which herbicides affect plants. Herbicides can be divided into two groups: those which are taken up primarily by foliage and stems (foliar herbicides) and those taken up primarily by plant roots and germinating seeds (soil-applied herbicides).

Foliar Herbicides

These herbicides act on or through plant leaves and/or stems. They are either contact herbicides or translocated herbicides depending on whether damage is localized to the area sprayed or appears in other parts of the plant.

Contact herbicides. These kill plant parts directly contacted by the herbicide. They generally cause a rapid weakening and disorganization of plant cell membranes to the point where there is a loss of cell contents by leakage. There is little or no movement of the herbicide through the plant.

Contact herbicides are effective against annual weeds, but they only "burn off" the tops of perennial weeds, chemically mowing them. This may be useful to prevent seed production. Recovery of plants following top-growth removal will depend on whether the plant has a protected growing point. Perennials usually have underground buds that will regrow. Some contact herbicides can be somewhat selective. An example is dinoseb which can be used to control annual mustards or chickweed in some agricultural crops. Other contact herbicides, such as paraquat, are non-selective and will remove top growth of most plants.

Translocated herbicides. These herbicides (sometimes called systemics) are absorbed by leaves, stems or roots and translocated (carried along with other nutrients) throughout the plant. Their mode of action is generally to disrupt chemical processes critical to plant growth and nutrition. Effects may not be seen for a week or more after treatment. Translocated herbicides can be selective as in the case of 2,4-D, MCPA, dicamba and picloram (Tordon) or non-selective such as glyphosate (Roundup) and amitrole.

Note that correct application rates are critical with translocated herbicides. An overdose may kill plant parts first contacted by the herbicide and prevent further absorption and translocation. With an overdose to foliage, the tops of perennial plants may die quickly, but new shoots will generally develop from below ground.

Correct application rates of translocated herbicides allow movement throughout the plant before *it is killed*. Rapidly growing plants usually show phytotoxic effects more quickly than slow-growing plants. Herbaceous plants usually are affected more quickly than woody plants. Correct application rates used on woody plants may not cause toxic effects for a number of weeks. For example, application of 2,4-D to woody plants in favourable growing conditions should result in little or no yellowing one week after foliar treatment, some yellowing after two to three weeks, and dead leaves after four weeks.

Soil-Applied Herbicides

Soil-applied herbicides are used to control germinating or emerged weeds, or to sterilize soil. Many soil-applied herbicides are absorbed by roots, translocated upward and act on foliage. However some (e.g. trifluralin) act on the roots and are translocated little, while others (e.g. EPTC) act on the emerging shoots of seedlings. Soil-applied herbicides may be classified as non-residual, temporary residual or long-term residual.

Non-residual herbicides. These herbicides are effective for less than one to two weeks. The fumigant methyl bromide is a non-residual herbicide when used to kill weed seeds and other organisms in seed beds for nursery stock. It is applied as a gas under a cover placed over the treatment area for about 24 hours. The gas escapes quickly when the cover is removed. Some foliar herbicides are non-residual because they are quickly adsorbed to soil particles and rendered inactive (e.g. diquat, glyphosate).

Temporary residual herbicides. These herbicides are usually effective for less than one year. Some of these herbicides persist in soils for only a few weeks, others remain phytotoxic to sensitive plants for six months or more depending on soil and weather conditions. Most are used for selective control of germinating weed seeds and seedlings growing among crops or ornamentals. Examples are:

- — triallate (Avadex): used for control of wild oats and foxtail germinating in cereal, oil seed and legume crops.
- — metolachlor (Dual): used for control of some grasses and broadleaf weeds in corn crops.

Long-term residual herbicides. These herbicides may remain phytotoxic for a year or longer. Some are selective if used to control shallow-rooted weeds among deep-rooted crops or ornamentals. Such selective herbicides must remain in the upper layer of soil and may be effective for about a year (e.g. simazine applied at low application rates). Other long-term residual herbicides are non-selective and are used in areas where no vegetation is wanted. These non-selective herbicides are sometimes called **soil sterilants**, although the name is misleading. Soil sterilants are used to kill only plants rather than all organisms in the soil. These herbicides may be phytotoxic for one to five years.

HERBICIDE SELECTIVITY

Herbicide selectivity is required to kill weeds growing among desirable plants. A non-selective herbicide will kill or injure a wide range of plant species in a treated area. Selective herbicides will kill specific plant species while not significantly injuring others. Most herbicides do not fall rigidly into either selective or non-selective categories since they may be selective under some conditions and non-selective under other conditions. There are a number of factors which influence the selectivity of a specific herbicide. These are discussed briefly here.

Leaf Shape

Retention of spray solution on leaf surfaces is important for herbicide effectiveness and may vary with leaf shape (Figure 22). A herbicide spray tends to bounce or run off plants such as grasses with narrow vertical leaves. In contrast, the spray is generally retained on flat, wide leaves of broadleaf plants. Phenoxy herbicides will control broadleaf plants but not grasses due partly to this principle.

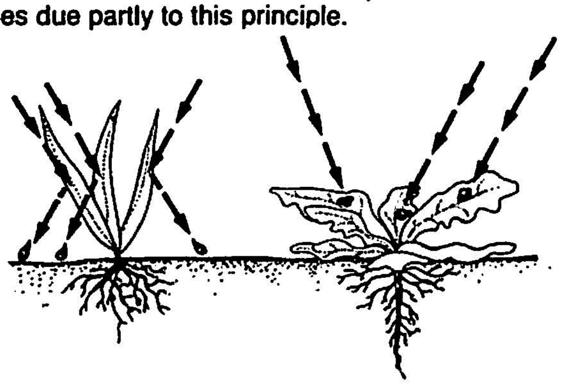

Figure 22. Herbicide retention is affected by leaf shape (after Pasic *et al.*, 1984).

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Leaf Surface

Type of leaf surface hairs and thickness of wax layer affect herbicide retention and penetration into the leaf (Figure 23). A dense layer of leaf hairs holds the herbicide away from the leaf surface allowing less chemical to be absorbed into the plant. A thin layer of leaf hairs may actually reduce herbicide runoff and increase the chemical in contact with the leaf surface. Some weeds are hairless, others have various numbers and kinds of hairs. Generally there are fewer and shorter hairs on seedling weeds than on more mature weeds.

A thick wax layer may be a barrier to herbicide penetration into some plant leaves. Many herbicides are selective for weeds at an early growing stage, partly because they have a thin wax layer. Penetration of the wax layer can sometimes be increased by adding a **wetting agent** to the herbicide. Wetting agents will also reduce the selectivity of a herbicide.

Plant Physiology

Plant physiology is the term for a plant's chemical processes that carry out life functions such as cell growth and reproduction, transport of food around the plant, use of sunlight to convert water and carbon dioxide into essential materials (photosynthesis) or breakdown of complex chemicals to produce energy (respiration). These processes consist of hundreds of complex biochemical reactions which vary from one plant species to another.

Herbicides are toxic to certain plants because they interfere with one or more physiological processes. Some herbicides are selective because of the differences in plant physiology among species. Other herbicides are selective because resistant plants can quickly break down the herbicide to non-toxic components. Susceptible plants are unable to detoxify the herbicide as it is absorbed.

Growing Sites

Many herbicides interfere with plant processes at sites of active growth (buds, shoot tips and regions of cell elongation). Some herbicides are selective due to differences in location of these growth sites in different plant species. This is one reason for the selective control of some broadleaf weeds among grasses. In grasses, the area of active growth is often near ground level or partway up the stem and is usually protected by a leaf sheath. Broadleaf plants typically have an area or areas of active growth at stem tips, often exposed to herbicide sprays. However, some perennial broadleaf weeds may also have protected buds on underground roots or stems, which makes them hard to control.

Growth Stages

The effectiveness of some herbicides may vary with a plant's growth stage. The seedling stage, when rapid plant growth occurs, is usually the most vulnerable to herbicide treatment. Thus herbicides may be applied which are selective for seedling plants.

Annual plants become less susceptible to herbicides as they near their flowering stage. Usually more herbicide is required. Herbicides are usually applied during flowering only to prevent seed production.

Biennials have a somewhat similar susceptibility to herbicides as annuals. They are most easily controlled in the seedling or rosette stage in their first year of growth. During winter they may be difficult to control because of their slow growth. As the biennial bolts to product flowers and seed in the second year, it becomes less susceptible to herbicides.

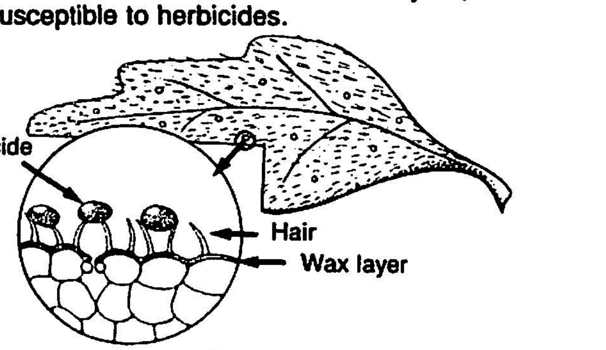

Figure 23. Leaf surface hairs and wax layer (after Pasic *et al.*, 1984)

Perennial weeds become more resistant to herbicide after their seedling stage. However, they become more susceptible again at the bud or early flower stage when food produced in the leaves is being transferred to roots to replenish depleted reserves. Herbicides are moved to the roots at this time, which is most important for control of perennials with underground growing tips. When perennial plants are in full flower and are producing seed they again tend to be less susceptible to herbicides. Many perennials show a period of regrowth in the fall, after seed production. Control with herbicides such as 2,4-D is effective at this time because the herbicide is translocated readily into the roots along with food reserves. Herbicide treatments in fall may also be effective as the plants will be subject to the additional stress of winter.

Application Rate

The rate at which herbicides are applied will often determine their degree of selectivity. For example, diuron may be used at low application rates for selective control of seedling weeds in several field crops, but at high application rates it is a soil sterilant. Atrazine may be used at low application rates for selective control of broadleaf weeds in corn, but at high application rates it is also a soil sterilant.

Formulation

Selectivity can be influenced by the type of herbicide formulation. One example is the selectivity obtained with granular formulations for control of emerging weeds. The granules fall off existing plants, landing on the soil. Pesticides are then washed into the zone of germinating weed seeds but may not penetrate as deep as the roots of established plants.

Application Timing

Many herbicides are selective if applied at the proper time with respect to weed growth or crop growth. Three categories of herbicides are recognized in relation to the time of application: preplant, preemergence and postemergence. These terms are often used in the directions given on the herbicide product label.

Preplant treatment is any application made before seeding or transplanting. Such applications might be in the fall to prepare the ground for spring-sown crops. For example, dalapon controls couch grass and 2,4-D controls bindweed when applied to cereal stubble. Grassland is treated with MCPA shortly before ploughing to reduce perennial weeds such as Canada thistle or rushes in the following crop. Preplant treatments are also made after seedbed preparation but before sowing the crop.

Preemergence treatment is made prior to the emergence of a specific crop and weed, usually after seeding. There should be a statement on the herbicide product label which specifies whether the herbicide is to be applied "preemergence to the crop", "preemergence to the weeds", or "preemergence to the crop and weeds" in order to clearly establish the timing of the treatment. These herbicides usually remain in the surface layer of the soil where they are absorbed by germinating weeds. It is necessary that the crop seeds are sown below the depth of herbicide penetration in the soil, or that the young crop plants are tolerant to the particular herbicide. Some moisture after application is generally required to move the herbicide into the weed germination zone, but heavy rains may cause injury to the crop.

Postemergence treatment is any treatment made after the emergence of a specified weed or crop. Some postemergent treatments of weeds in crops must be made when weeds are at a specific size for effective control. This size is usually specified by the number of weed leaves, such as a weed's 2 to 5 leaf stage (Figure 24).

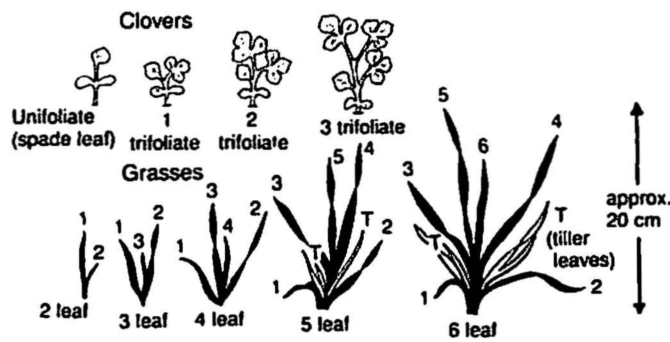

Figure 24. Examples of plant leaf stages. Herbicide use recommendations may specify the weed leaf stages when a treatment will be effective.

Soil Properties

Herbicides applied to the soil are directly affected by soil properties. Soil type determines how long a herbicide will remain phytotoxic and the depth that a herbicide will penetrate. Some preplant herbicides remain active in the soil for a short period so they can be used to control weeds shortly before planting. The success of a preemergence herbicide depends largely on the presence of a high concentration in the upper 2 cm of soil. This is where most annual weeds germinate. There must be relatively low concentrations of herbicide deeper in the soil where crop seeds germinate. Some postemergence herbicides are used to control weeds among deep-rooted plants such as fruit trees because the herbicide is not active around the deeper tree roots.

The action of a herbicide in the soil is affected by three main factors: adsorption, leaching and decomposition.

Adsorption is the attraction of soil particles for the herbicide active ingredient. When a herbicide is adsorbed, it is taken out of solution and made unavailable for uptake by the plant. Some herbicides are adsorbed by soil particles much more readily than others. Also, the content of organic matter and clay in soils greatly affects herbicide adsorption. Sandy soils have few adsorption sites and herbicides can be washed through quite readily. Soils with clay and organic matter have many adsorption sites, making some herbicides less available to plant roots. Often herbicide labels require application rates to be adjusted to match soil types. Higher rates are often required for soils high in organic matter or clay.

Leaching is the movement of herbicides through the soil. Leaching may occur in any direction (downward, sideways or upward), depending on water flow through the soil. Herbicides vary from being non-mobile (non-leachable) to very mobile (highly leachable). Most soil-applied herbicides require some moisture in the soil to be effective. Too much water, either as rainfall or irrigation, can leach herbicides out of the zone of weed roots resulting in poor control and possible toxicity to desirable plants.

Decomposition is the breakdown of herbicides into non-toxic compounds. Decomposition occurs by a number of processes including micro-organisms, chemical decomposition and photo-decomposition. Soil conditions which favour micro-organisms such as bacteria and fungi are most favourable to herbicide decomposition. These conditions are warm, moist, well-aerated soils. Herbicides may remain toxic in the soil for a considerable time if the soil is cold, dry and poorly aerated.

Chemical decomposition occurs from the reaction of soil constituents such as oxygen, hydrogen and water with a herbicide active ingredient. Some herbicides are more prone to chemical breakdown than others.

Photo-decomposition is the action of ultraviolet light from the sun which decomposes many herbicides applied to the soil surface. Some herbicides such as trifluralin are recommended for mechanical soil incorporation as they break down quickly if exposed to sunlight on the soil surface.

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Application Methods

The method of application can be an important factor influencing herbicide specificity. There are a number of terms that relate to herbicide application methods.

- **Broadcast treatment** is a uniform application to an entire area.
- **Directed sprays** are applications in a particular pattern or to a specific part of a plant. Such sprays are usually applied at or just above ground level, directed to the leaves of small weeds but away from taller desirable plant leaves. Sometimes directed sprays are used with shields to keep most spray off desirable plants.
- **Spot treatment** is the treatment of a restricted area, usually to control an infestation of a weed species requiring special treatment. Non-selective, residual herbicides are sometimes applied as spot-treatments to control small clumps of serious perennial weeds. Liquid or granular formulations may be used.
- **Wiper treatment** is a technique of applying herbicides selectively to weeds without the hazard of spray drift. Wicks made of rope, fabric rollers or absorbent pads are kept wet with herbicide solution and wiped against the weeds. The wick may be directed by hand to specific weeds or may be drawn over the ground in a way to maximize contact with weeds but avoid non-weed species. Treatment may be for tall weeds only or to kill weeds between crop rows.
- **Basal applications** are used to control woody plants. Herbicide designed for this use is applied to the lower portion of individual stems. The base and any exposed roots are thoroughly wetted to the point of runoff. There may be chemical damage to stem tissues, causing a girdling effect, or the herbicide may be taken up by roots. This method works best for stems less than 15 cm in diameter.
- **Cut surface treatments** (hack and squirt) can be made for very selective control of woody plants. Herbicide is placed in a cut in the bark for better penetration into plant tissues.
  - **Frill treatments** are made in a ring of overlapping cuts around the base of a tree. Herbicide is then sprayed or squirted into the cut evenly around the tree.
  - **Notching** is done like frill treatments, but with a specified number of notches per centimeter of trunk diameter.
- **Injection** is where the herbicide is injected into the tree trunk with a specific injection tool.
- **Stump treatment** is sometimes done to prevent regrowth of trees which sprout from their bases. Stems are cut as close to the ground as possible and herbicide is applied to the entire cut surface of the stump, particularly the perimeter. All sprouts must be cut and treated. Stump treatment is most effective if herbicide is applied immediately after the tree is cut.

Weather

Conditions of temperature, humidity and rainfall may influence the uptake and translocation of herbicide by a plant. High temperatures and dry air (low humidity) reduce herbicide uptake. Warm temperatures and high humidity usually result in the greatest penetration of leaf surfaces. However, some contact herbicides (e.g. bromoxynil) work better in cool temperatures. Rainfall during or immediately after foliar herbicide applications can wash off or dilute herbicide deposits on leaves and reduce herbicide effectiveness. Some soil-applied herbicides may be watered in with rainfall, some may be leached out or diluted by too much rainfall. Most translocated herbicides do not function well if weather conditions are unfavourable for plant growth. Thus, if weather is too dry or too cold, the growth slows and the herbicide is not moved around the plant as required.

CHEMICAL CLASSIFICATION OF HERBICIDES

Herbicides can be divided into groups according to their chemical characteristics. Herbicides within a group have a similar chemical structure and often have a characteristic mode of action, fate in soil or toxicity. Table 13 lists the major groups of herbicides and summarizes their characteristics.

Table 13. Characteristics of major chemical classes of herbicides.

A. **Inorganic Compounds**

Many common inorganic salts, such as table salt, are toxic to plants if applied at sufficiently high rates. Some inorganic salts are commonly used as soil sterilants, including sodium chlorate and boron mixtures.

B. **Organic Compounds**

Aliphatics — absorbed by roots or leaves, translocated, interfere with growth processes of grasses in particular, soil persistence is approximately 1 to 3 months, low acute mammalian toxicity, e.g., dalapon, TCA.

Bipyridyliums — directed at foliage, contact herbicides, destroy cell membranes, deactivated immediately in soil, moderate to high mammalian toxicity, e.g., diquat, paraquat.

Benzoic acids — absorbed by leaves or roots, translocated, disrupt growth by upsetting plant hormone balance, soil persistence is approximately 2 to 3 months, low acute mammalian toxicity, e.g., dicamba, chloramben.

Carbamates — absorbed by roots or leaves, translocated, inhibit cell division or photosynthesis, soil persistence generally less than one month, low mammalian toxicity, e.g., asulam, barban, chlorpropham.

Phenoxys — absorbed by roots or foliage, translocated, disrupt growth by upsetting plant hormone balance, soil persistence generally less than one month, acute mammalian toxicity varies from low to high, e.g., 2,4-D, dichlorprop, mecoprop, MCPA.

Thiocarbamates — absorbed by germinating shoots of grass seedlings, translocated, alter distribution of plant hormones and inhibit cell division, soil persistence is approximately one to eight weeks, low mammalian toxicity, e.g., butylate, EPTC, triallate, vernolate.

Triazines — absorbed by roots or leaves, translocated to leaves, interfere with photosynthesis, variable soil persistence from a few weeks to one year, low to moderate mammalian toxicity, e.g., atrazine, metribuzin, prometryne, simazine, terbutryn.

Uracils — absorbed by roots, translocated, inhibit photosynthesis, soil persistence can be six months to several years for sensitive plants, low mammalian toxicity, e.g., bromacil, terbacil.

Ureas — absorbed by roots, translocated, inhibit photosynthesis, soil persistence varies from a few months to over a year, low mammalian toxicity, e.g., diuron, linuron, chloroxuron, tebuthiuron, chlorbromuron.

HERBICIDE SPRAY AND VAPOUR DRIFT

Herbicide drift is the movement of herbicide spray or vapour through the air to areas away from the target. Herbicide drift presents a hazard to sensitive vegetation, wildlife, people, livestock and aquatic organisms adjacent to treated areas.

Drift of herbicide spray depends on several conditions:

- size of spray droplets,
- height of spray release,
- type of spray (e.g., oil or water), and
- atmospheric conditions (air movement).

When a spray fluid leaves a spray nozzle, the size of the droplets will be governed by the size of the nozzle opening, the spray pressure and surface tension of the fluid. Fine nozzle openings and high pressures produce fine sprays. In a fine spray, most droplets are between 100 to 250 microns (0.1 to 0.25 mm) in size. Droplets smaller than 150 microns present a relatively high drift hazard even under low wind conditions. Most droplets in coarse sprays are 400 to 1,000 microns in size. Coarse sprays require considerable wind before there is significant drift.

Spray drift may increase under atmospheric conditions known as a **temperature inversion**. In these conditions, cool air is trapped under a layer of warm air and smoke or dust and other particles are trapped in the lower air mass. Gentle breezes come from variable directions. Fine spray droplets can remain suspended in the cool air mass for long periods and can drift with slight air movement for a considerable distance. This condition is more likely to occur in the early morning or late afternoon. Pesticides should be applied with extreme caution under such conditions.

Drift of herbicide vapours results when a herbicide vapourizes to produce fumes which may be carried long distances downwind. The tendency of a liquid to vapourize (volatility) is dependent on the nature of the chemical and the temperature. Higher temperatures increase herbicide volatility. Volatile herbicides include some phenoxy, dinitro and thiocarbamate compounds. Although only a small amount of herbicide drift may occur as a vapour, sensitive plants can be damaged near a treated area.

Many problems from herbicide drift have resulted from the phenoxy herbicides. Some commonly used formulations of 2,4-D are volatile. The amine and acid formulations of 2,4-D have the lowest volatility and the 2,4-D esters have higher volatility. Products with very high volatility can no longer be sold in Canada. Crops or ornamentals susceptible to damage from 2,4-D vapours include the following:

grapes	red clover
tomatoes	alfalfa (young)
cucumbers	crimson clover
beans	tree fruits
lentils	roses
peppers	hydrangeas
peas and vetches	deodar cedar

In order to minimize the drift of herbicide from spray or vapours, the following conditions should be observed:

- the wind velocity should not be in excess of 8 km/h,
- temperatures should be as cool as possible,
- avoid spraying during temperature inversions,
- always use the lowest application rate that will do the job,
- use low pressures: 300 kPa or less,
- use larger orifices which apply a minimum of 225 L/ha,
- use a slow spraying speed for motorized applicator units,
- release spray as close to the target area or plants as possible,
- select low-volatile formulations, and
- use nozzle spray shields where possible.

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PUBLICATIONS ON HERBICIDES AND WEED CONTROL RECOMMENDATIONS

Anon. 1982. Weed Control Manual — An introduction. Ministry of Agriculture and Food. Kamloops, B.C. 22 pp. (Much of the information in this manual was incorporated in the Ministry of Environment Handbook).

Anon. 1985. Field Crop Facts — Weed Control Series. Agdex 640. Ministry of Agriculture and Food. Victoria, B.C. (Each pamphlet covers a different problem weed including the following: Canada thistle, cleavers, common burdock, diffuse knapweed, field bindweed, leafy spurge, lens-podded hoary cress, narrow-leaved hawk's beard, night-flowering catchfly, nodding thistle, ox-eye daisy, perennial sow thistle, scentless chamomile, toadflax, western water hemlock, wild oats.)

Cranston, R. 1980. *Knapweed — Its Cause and Effect in British Columbia*. Ministry of Agriculture and Food. Victoria, B.C. 10 pp.

Ministry of Agriculture and Fisheries. Crop Production Guides for Field Crops, Berries, Grapes, Nursery, Tree Fruit and Vegetables (updated yearly).

Pasic, B. *et al.* 1984. *Weed Control Study Manual*. Washington State University Cooperative Extension. Pullman, Washington. 43pp.

Weed Science Society of America. 1983. *Herbicide Handbook*. Fifth Edition. Weed Science Society of America. Champaign, Illinois. 515 pp.

REFERENCE LIST OF HERBICIDES AND THEIR PROPERTIES

The following reference list includes a description of most herbicides used in British Columbia when this text was published. Herbicides are listed alphabetically by active ingredient with some examples of trade names. No endorsement of products is implied. Information contained in these lists could become out-of-date and may not represent current recommendations. **The current registered label is the authority on a pesticide's registered uses, application methods and safety precautions.**

The relative acute mammalian toxicity is given for each active ingredient listed. LD_{50} values (mg/kg body weight) are listed where available and are derived from tests with rats unless indicated otherwise (Rb = rabbit). The lowest LD_{50} is listed for each herbicide where several are given in the literature reviewed.

allidochlor *(Randox, CDAA)* — is an acetamide compound used as a selective herbicide for weed control in onions. It is absorbed through plant roots. Persistence in soil ranges from three to six weeks. Heavy rains may cause leaching. Allidochlor has a low acute mammalian toxicity (LD_{50}: oral = 700) but vapours should be avoided because of strong irritation to skin and eyes. Allidochlor is no longer registered for use because the manufacturer has ceased production. Existing stocks can be used up.

amitrole *(Allizol, Amizol, Amitrol-T)* — a non-selective, triazole compound particularly useful for controlling many perennial weeds such as quackgrass, horsetail, poison-ivy, milkweed, Canada thistle and cattails on non-crop land. It is a systemic herbicide readily absorbed by roots and foliage and translocates to growing tips during active growth. It affects plants by upsetting the formation of chlorophyll, causing them to turn yellow or yellow-white within two weeks. Amitrole can be used for spot treatment of some weed problems in pasture and non-crop land. Persistence in the soil is generally 2 to 4 weeks. Treated areas must not be grazed for 6 months following treatment. It has a low acute mammalian toxicity (LD_{50}: oral = 1,100).

asulam *(Asulox F)* — is a carbamate compound used as a selective, translocated, postemergence-applied herbicide. It is taken up by roots or leaves and interferes with cell division in areas of active growth. Asulam may be tank-mixed with other herbicides such as 2,4-DB. Asulam controls many weeds in flax and alfalfa. Drift to other crops must be avoided. Asulam also controls horsetail and bracken fern in non-crop and forested areas. Persistence in soil is generally less than 2 weeks. It has a low acute mammalian toxicity (LD_{50}: oral = 2,000; dermal > 1,200).

atrazine *(Aatrex, Atra-Mix, Atrazine, Eramox 80W, Primatol A, Vectal Atrazine)* — a translocated triazine compound used at low rates as a selective, preplant, soil-incorporated, preemergence or postemergence herbicide. At higher rates, atrazine is a non-selective soil sterilant on drier soils if applied preemergence or when weeds are small (< 4 cm). Available in flowable, granular and wettable powder formulations. Absorption is through root uptake, although some foliar absorption does occur. It inhibits photosynthesis. Foliar activity is enhanced by the addition of Korn oil or recommended surfactants. Persistence of toxic effects in soil may be for up to a year. Cucumbers, beans, peas, grass and legume seeds, and sugar beets are very sensitive; grains are moderately sensitive; flax, peas and fababeans are more tolerant. Corn is very tolerant to atrazine. Atrazine has a low acute toxicity to mammals (LD_{50}: oral = 1,780; dermal = 7,500 Rb).

barban *(Carbyne, Wypout)* — is a selective, postemergence-applied carbamate compound mainly used for control of wild oats in wheat, barley, rapeseed, flax, and several other crops. Some suppression of wild buckwheat can be obtained when higher rates of application are used. Best results are obtained under good growing conditions where the wild oats are in the two-leaf stage. The chemical inhibits growth and reduces tillering. It persists for less than 3 weeks in most soils. Barban may not be mixed with any other pesticides. Barban has a low acute mammalian toxicity (LD_{50}: oral = 600; dermal > 1,600), but is a skin irritant and is toxic to fish.

benazolin — is a benzoic acid compound applied as a selective, translocated, postemergence herbicide. Root uptake is very slight. It is registered for control of wild mustard in canola. Rapidly leached from soils. It has a low acute mammalian toxicity (LD_{50}: oral > 3,000) but is irritating to eyes and skin and is toxic to fish.

bensulide *(Betasan)* — is a sulfonamide compound used as a selective, preemergence herbicide. It is used for control of many broadleaved weeds and grasses in numerous crops and in turf. It is taken up by roots and inhibits root growth. Bensulide persists in soil for about 4 to 6 months. It has a low acute toxicity to mammals (LD_{50}: oral = 770; dermal = 3,950Rb), but is toxic to fish and aquatic organisms.

bentazon *(Basagran)* — is a benzothiadozole compound used as a selective, translocated, postemergence-applied herbicide. Bentazon is translocated after absorption through the leaves and has no effect on germinating seeds. Bentazon is more active in warm weather and a specific wetting agent is usually recommended. Bentazon controls many broadleaved weeds in corn, fababeans, flax and peas. It usually persists for less than six weeks in soil. It has a low acute toxicity to mammals (LD_{50}: oral = 1,100; dermal = 2,500), but it may cause skin and eye irritation.

borate, borax (sodium metaborate tetrahydrate, sodium tetraborate decahydrate) — are inorganic polyborate compounds which are incorporated with bromacil *(Hybor-D)* and sodium chlorate *(monobor-chlorate)* in mixtures used as soil sterilants. Borate is taken up through plant roots and causes tissue dessication. It is also highly toxic to plant seedlings. In soils, borate can persist for up to one season, except when leached in high rainfall areas. It is not readily degraded by microorganisms. When used in a mixture, borate slows the degradation of other pesticides because of its toxicity to soil microorganisms. Borate has a low acute toxicity to mammals (LD_{50}: oral > 2,000) and a low toxicity to fish and wildlife.

bromacil *(Hyvar X, Hyvar XL)* — is a substituted uracil. It may be combined with diuron *(Krovar I)* or 2,4-D *(Calmix, Calcide)*. It is an effective broad-spectrum soil sterilant. The chemical works primarily through the roots and must be activated by moisture. Relatively low rates are required. It is generally used on noncrop land, railways, and rights-of-way. Bromacil usually persists in soil for less than six months. It has a low acute mammalian toxicity (LD_{50}: oral = 5,200) but may irritate skin. It has a low toxicity to fish and wildlife.

bromoxynil *(Brominal, Pardner, Torch)* — a benzonitrile compound used in grain crops, seedling grasses and turf for hardkill weeds such as buckwheats, lady's-thumb, and smartweeds. Bromoxynil is a contact type herbicide, therefore good spray coverage is essential. It inhibits photosynthesis and plant respiration, thereby killing the weed. It may be tank-mixed with Avenge, 2,4-D, Hoe-Grass, MCPA, or Roundup. Bromoxynil is mainly formulated as an emulsifiable concentrate. It has a moderate acute toxicity to mammals (LD_{50}: oral = 190) and may irritate skin. It may be toxic to fish and other wildlife.

butylate *(Sutan)* — a carbamate similar in use and application to EPTC, requiring the same immediate preplant incorporation method. It provides good seedling grass control and moderate broadleaved weed control in the lighter mineral soils, low in organic matter. It generally persists for less than three weeks in soils. It has a low acute toxicity to mammals (LD_{50}: oral = 4,000); dermal > 2,000 Rb) and is toxic to fish.

2,4-D Butyric — see phenoxybutyric acids: 2,4-DB

chloramben *(Amiben, Vegiben)* — a benzoic acid herbicide which provides preplant, preemergence and postemergence control of seedling grass and broadleaved weeds. It inhibits root development in seedlings. Chloramben can be used for weed control in soybeans, dry common beans (white and kidney), lima beans, asparagus, pumpkin, snapbean, squash, sunflowers and ornamentals. Available in liquid or granular formulations, chloramben requires good soil moisture for best results, but it will leach in heavy rains. Chloramben generally persists for less than 6 to 8 weeks in soil. It has a low acute mammalian toxicity (LD_{50}: oral = 3,500; dermal = 3,200) and low toxicity to fish.

chloroxuron *(Tenoran)* — is a substituted urea used as a selective, preemergence and postemergence herbicide to control many seedling grasses and broadleaved weeds. It is used mainly in strawberries and ornamentals (nurseries, shelter belts). Chloroxuron is absorbed primarily through the seedling roots and, therefore, requires good soil moisture. It is translocated and inhibits respiration. It resists leaching but persists in the soil for less than *six months*. Chloroxuron is non-corrosive and nonflammable. It has a low acute toxicity to mammals (LD_{50}: oral = 3,000; dermal > 10,000).

chlorpropham *(CIPC, Chloro IPC)* — is a carbamate material formulated as an emulsifiable concentrate, wettable powder, or granule. It is used in many crops, including onions, gladioli, and ornamentals for broadleaf and grass weed control. Also see growth regulators. It is very effective on seedling grasses and chickweed, but requires good soil moisture, otherwise it is rapidly lost from the soil surface. It is most effective when applied preemergence or early postemergence to weeds. It is absorbed through seedling shoots, or leaves or roots of older plants. It inhibits cell division. It generally persists in soil for less than 2 to 3 months. Chlorpropham has a low acute mammalian toxicity (LD_{50}: oral = 3,800).

chlorsulfuron *(Glean)* — is a selective, postemergence-applied herbicide for control of many annual broadleaved weeds in spring and duram wheat, oats, and barley. Successful control of Canada thistle can be achieved with chlorsulfuron in these crops. Very low rates of application are used with this product. Chlorsulfuron is a contact herbicide with residual activity. It is a rapid inhibitor of cell growth in the growing tips of roots and shoots of sensitive plants. Differences in plant metabolism is the basis of selectivity for chlorsulfuron. It adsorbs poorly to clay and a little to organic matter in the soil. Rate of leaching is related to the movement of soil moisture and to pH. Less leaching occurs if the pH is lower than 6. Chlorsulfuron should not be used on sandy soils, soils with less than 0.5% organic matter or soils with pH over 7.0. Small quantities of chlorsulfuron can remain in soil and injure crops other than wheat and barley for up to three years or more after an application. Soil from fields treated with chlorsulfuron should not be moved to other areas. It has a low acute toxicity to mammals (LD_{50}: oral = 5,500).

chlorthal *(Dacthal)* — is a phthalic acid used as a selective, preemergence herbicide. Formulated as a wettable powder, it provides control of certain annual grasses and broadleaved weeds on mineral soils, and kills by acting on germinating seeds. A stable compound, it requires warmth and good soil moisture. It is not effective on rich organic or muck soils. Tolerant crops include vegetable crops, strawberries, agronomic crops, some nursery stock, flowers, and turf. Generally less than one half the herbicide applied remains in the soil 100 days after treatment. It has a low acute mammalian toxicity (LD_{50}: oral 3,000; dermal > 10,000), but may be irritating to the eyes.

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clopyralid *(Lontrel)* — is a translocated, selective, postemergence herbicide for control of Canada thistle, scentless chamomile, wild buckwheat and top growth of perennial saw thistle in Polish and Argentine varieties of rapeseed (including canola). For fields treated with clopyralid the previous year, wheat, oats, barley, rye, flax, or rapeseed can be seeded or the field summer fallowed. Do not seed to crops other than those listed above, the year following treatment. Phytotoxic levels of clopyralid may remain in soils for over one year. Clopyralid has a low acute mammalian toxicity (LD_{50}: oral 5,000; dermal > 2,000 Rb).

cyanazine *(Bladex)* — is a triazine compound used as a selective preemergence herbicide for control of annual grasses and broadleaved weeds in corn. Cyanazine is absorbed by leaves and roots and translocated. It inhibits photosynthesis. Cyanazine has a short persistence; less than half the herbicide applied remains in the soil two weeks after treatment. Do not use on peat or muck soils, or on sandy soils which contain less than 1% organic matter. It has a moderate acute toxicity to mammals (LD_{50}: oral = 150; dermal > 2,000 Rb).

cycloate *(Ro-Neet)* — is a thiocarbamate compound effective as a selective soil incorporated herbicide for control of seedling grasses and some broadleaved weeds in spinach, sugar beets and table beets. It should be applied to moist, but not wet, soil. Irrigation is required in dry soils. Cycloate is taken up by the roots and inhibits growth. Use on mineral soils only and incorporate immediately after application as it is volatile. Not compatible with other pesticides. Generally less than one-half the herbicide applied remains in the soil 4 to 6 weeks after treatment. Cycloate has a low acute mammalian toxicity (LD_{50}: oral = 3,200; dermal > 4,600 Rb).

2,4-D — see phenoxyacetic compounds

dalapon *(Basfapon, Dowpon)* — is an aliphatic acid similar to TCA. Dalapon is formulated as a sodium salt, which is readily soluble in water. It is primarily a grass killer, absorbed through foliage and also through roots. At high rates it is non-selective, at low rates it removes grassy weeds from tolerant crops. Repeated low doses are more effective than a single heavy dose. It is used for quack grass control in British Columbia coastal regions. The land is then planted to a partially tolerant crop such as potatoes. Heavy treatments of dalapon will make the soil toxic to many crops, including grain, peas and corn, for five weeks or more. Cultivation after application increases the uptake and hence the effectiveness. Conditions such as drought and cold, which slow growth, decrease its effectiveness. Dalapon upsets the enzyme balance of plants and affects protein movement. Since it corrodes iron, aluminum and brass, it should be thoroughly rinsed from equipment after use. It is nonvolatile and nonflammable. Dalapon has a low acute mammalian toxicity (LD_{50}: oral = 3,900) but is irritating to eyes.

dazomet *(Basamid, Mylone)* — is an organic compound used as a fumigant for killing seeds in soil. In contact with moisture, it is converted to a mixture of formaldehyde, hydrogen sulphide, and methyl isocyanate. It is immediately toxic and lasts two to three weeks in soil. It has a moderate acute mammalian toxicity (LD_{50}: oral = 320).

2,4-DB — see phenoxybutyric acids

desmedipham *(Betanex)* — is a carbamate compound used as a selective, postemergence herbicide for control of many broadleaved weed-seedlings in sugar beets. It is absorbed by leaves and inhibits photosynthesis. Generally less than one-half the herbicide applied remains in the soil after one month. It has a low acute mammalian toxicity (LD_{50}: oral 8,000; dermal > 4,000).

dicamba *(Banvel, Dyvel)* — is one of the benzoic acids. This chemical is available as the dimethylamine salt formulation alone or as a mixture with 2,4-D, MCPA or mecoprop *(Killex, Kil-Mor, Target)*. It is effective on a wide range of weeds in grain and turf, particularly smartweed, buckwheats and other *Polygonum* species. Underseeded grain crops cannot be treated because legumes are sensitive. Dicamba is also effective on perennials such as Canada thistle and on many species of brush. It translocates in the plant in a manner similar to 2,4-D. Root absorption occurs, but the primary action is through the leaves. At normal rates it breaks down rapidly in soil and persists for less than one to three months. It is volatile and, as with 2,4-D, care should be taken to avoid drift to sensitive plants. Spray equipment being used for other purposes must be thoroughly cleaned. It has a low acute mammalian toxicity (LD_{50}: oral = 1,000; dermal > 2,000 Rb).

dichlobenil *(Casoron)* — is a benzonitrile compound. Available in granular form and used as a selective, preemergence herbicide for control of many grassy and broadleaf weeds in woody ornamentals, fruit trees, grapes, raspberries, loganberries, blackberries, cranberries and high bush blueberries. Dichlobenil is effective on annual and perennial seedlings. Moisture is needed to move dichlobenil into the soil to prevent loss by volatilization under warm weather conditions. Temperatures should not exceed 18°C at the time of application. It is taken up by plant roots and affects their growing tips. The herbicide may remain effective in soil for two months to a year. It has a low acute mammalian toxicity (LD_{50}: oral = 2,700; dermal > 1,350).

diclofop methyl *(Hoe Grass)* — is a selective, postemergence-applied herbicide used for control of wild oats, green and yellow foxtail, barnyard grass, persian darnel, and volunteer corn in many broadleaved and grass crops. Diclofop methyl works by both contact and systemic action. Uptake is primarily through the leaves. Penetration and uptake via the roots is also possible, provided the soil is sufficiently moist and the rate of application is relatively high. The site of action of diclofop methyl is the growing tips. Depending on environmental conditions, it usually takes 10 to 14 days after application before plants are dead. Grassy weed control is most rapid under optimal growing conditions. The younger the weed, the more sensitive it will be to diclofop methyl activity. Generally less than one-half the applied herbicide remains in the soil after 10 to 30 days. Hoe Grass II is a mixture of diclofop methyl and bromoxynil which can be used for control of certain grassy and broadleaved weeds in wheat, barley and flax. Diclofop methyl has a low acute toxicity to mammals (LD_{50}: oral = 563; dermal > 2,000), but is highly toxic to fish. Do not apply diclofop methyl within 60 days of harvest.

dichlorprop (2,4-DP) — see phenoxypropionic acids

difenzoquat *(Avenge)* — is a pyrazolium herbicide used for selective, postemergent wild oat control in barley, wheat, rye and triticale. It is readily absorbed by leaves. It generally persists for less than one year. Difenzoquat has a moderate acute mammalian toxicity (LD_{50}: oral = 270; dermal = 3,500 Rb).

dinoseb amine *(Premerge, Sinox PE)* — is a dinitrophenol compound which is no longer registered for use in Canada due to potential chronic effects in applicators. Existing stocks of products can be sold and used. Dinoseb amine is applied preemergence or postemergence for selective control of seedling, grassy and broadleaved weeds. It is a contact herbicide which disrupts cell membranes. It does not control established perennials. Dinoseb amine is used for weed control in some food and flower crops such as peas, beans, oats, seedling alfalfa, clovers, daffodils, tulips, gladiolas, strawberries and potatoes. It is also a non-selective contact herbicide when used with a surfactant. With preemergence applications, control is best on firm, moist soils. With postemergence applications, weed control is best when foliage is dry and temperatures are between 21 and 29°C. Higher rates must be used on organic soils. Dinoseb remains phytotoxic in the soil for about two to four weeks. This product has a high acute mammalian toxicity (LD_{50}: oral = 37; dermal = 200). It is very toxic to fish and wildlife. It is flammable.

dinoseb general *(Dow General, Sinox General)* — is a dinitrophenol compound used for control of annual grassy and broadleaved weeds, and for topgrowth control of perennial grass and broadleaved weeds. Control is by contact action only. Dinoseb general can be used for preharvest spraying of potatoes and for seed crops of flax, legumes and soybeans to facilitate harvest. It can also be used as a directed spray for weed control in grapes and bush fruit. Dinoseb remains phytotoxic in the soil for about two to four weeks. Do not store below −10°C. This product has a high acute mammalian toxicity (LD_{50}: oral = 58; dermal = 200). It is very toxic to fish and wildlife. It is flammable.

NOTE: DINITROPHENOLS ARE SOME OF THE MOST POISONOUS HERBICIDES IF TAKEN INTERNALLY! VERY HARMFUL TO THE EYES.

diphenamid *(Enide)* — is an acetamide compound used as a selective, preemergence herbicide. This chemical is useful in peppers, tomatoes, strawberries, ornamentals and a few other crops. Many seedling grasses and several annual broadleaved weeds appear to be susceptible. It is absorbed by seedling roots and inhibits root development. Diphenamid is formulated as a wettable powder. It has low solubility in water, hence it needs rain, shallow soil incorporation, or irrigation. It is effective only when applied before the weed seeds germinate. It leaches readily from sandy soil but slowly in silt or clay soils, and is strongly adsorbed by organic matter. Under warm, moist conditions it may remain phytotoxic in the soil for 3 to 6 months. It may persist longer under dry conditions. Being somewhat persistent, it may injure small grains or sensitive crops planted the following season. Apply no more than once per season. Diphenamid has a low acute mammalian toxicity (LD_{50}: oral = 700).

diquat *(Reglone)* — this chemical, like paraquat, is a pyridine compound and is readily adsorbed by plant tissues. Diquat is effective for crop desiccation, killing potato tops, and as an aquatic herbicide. It is a non-selective contact herbicide. Diquat is not effective for control of perennial weeds as they grow back after their tops are burned off. It is very rapidly and completely deactivated by soil. It should only be used with clean water since muddy water adsorbs diquat and reduces its effectiveness. It has a moderate acute mammalian toxicity (LD_{50}: oral = 215; dermal > 3,000) but it may be irritating to the skin.

diuron *(Karmex)* — is a substituted urea not as soluble (42 ppm) as monuron. Diuron is used at high rates as a soil sterilant. At lower rates it is used as a selective, preemergence herbicide to control seedling broadleaved weeds and grasses in grapes and asparagus. Dandelions are resistant. Diuron is absorbed primarily by roots and is translocated. It disrupts photosynthesis. Diruon requires moisture to move the chemical into the root zone. Phytotoxic levels disappear within one season at the lowest application rates but may persist for longer than one season at higher rates. Diuron has a low acute mammalian toxicity (LD_{50}: oral = 3,400) but may cause irritation to the skin and eyes.

2,4-DP — see phenoxypropionic acids

endothall *(Herbicide 273 Liquid, Des-i-cate)* — is a phthalic acid used as a selective, preemergence and postemergence herbicide. Its main use is for control of wild buckwheat and lady's thumb in sugar beets, although it does give control of some other broadleaved and grassy weeds. It is a contact herbicide. Endothall can be mixed with desmedipham or phenmedipham for improved control of broadleaved weeds. Endothall can also be used as a potato top killer. Endothall has a high acute toxicity to mammals (LD_{50}: oral = 38), and is irritating to eyes and skin.

EPTC *(Eptam, Eradicane*)* — is a thiocarbamate compound applied as a preplant, soil-incorporated herbicide for con-

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trol of certain broadleaved weeds and many annual grasses. High rates of EPTC will control quackgrass and yellow nutsedge. Crops in which EPTC can be used include corn, alfalfa, birdsfoot trefoil, flax, potatoes, drybeans and some ornamentals. EPTC is formulated as granules and emulsifiable concentrate and is very effective on germinating weed seeds and very young seedlings, especially grasses. Best results are obtained in warm, moist soils. EPTC vaporizes readily and much of the chemical is lost unless it is quickly worked into the soil. The chemical is taken up by the roots and shoots of germinating weeds where it disrupts cell division. EPTC is not persistent in the soil, however, it will give effective weed control for approximately 6 to 8 weeks. EPTC is not corrosive. It has a low acute mammalian toxicity (LD_{50}: oral = 1,400; dermal = 2,600 Rb).

Eradicane is a special formulation which has a crop protectant added for grassy and broadleaved weed control in corn.

ethofumesate *(Nortron)* — is a methanesulphonate compound used as a selective, preplant, preemergence, or postemergence herbicide for control of some annual grasses and a number of broadleaved weeds in sugar beets. Ethofumesate is absorbed by emerging seedling shoots and acts as a growth inhibitor. Susceptible crops must not be planted for one year. Do not use on muck or peat soils. Dry soils reduce activity. It may be mixed with other herbicides. It has a moderate persistence; generally less than one-half the herbicide applied remains in the soil after 1 to 4 months. Ethofumesate has a low acute mammalian toxicity (LD_{50}: oral = 5,650).

fenoprop *(Silvex)* — see phenoxypropionic acids

ferrous sulphate (moss killers) — ferrous sulphate and mixtures with ammonium sulphate are inorganic herbicides used for control of mosses in lawns, and mosses and lichens on roofs. Some roof moss killers also incorporate zinc sulphate. All are water soluble and may be applied as a spray or dry. Moss killers are usually marketed as proprietary mixtures of varying concentrations. Apply according to manufacturer's recommendations.

flamprop-methyl *(Mataven)* — is an organic compound used as a selective, translocated, postemergence-applied herbicide for control of wild oats in spring, winter and duram wheat (except Selkirk & Garnet), triticale, sunflowers and several forage crops. Flamprop-methyl is absorbed through leaves and is readily transported to the growing point in the stem of wild oats. Here cell elongation and division is impaired. Mataven should not be mixed with other herbicides, and for optimum control, an interval of four days should be allowed between the application of Mataven and the use of bromoxynil, MCPA or bromoxynil-MCPA, and an interval of seven days should be allowed between the application of Mataven and products containing 2,4-D or dicamba. Toxicity is low. Generally less than one-half the herbicide applied remains in the soil after 1 to 4 weeks. Flamprop-methyl has a low acute mammalian toxicity (LD_{50}: oral = 1,210). Use goggles to protect eyes.

fosamine ammonium *(Krenite)* — is a carbamate compound used as a postemergence, growth-regulating herbicide. It is absorbed by foliage and translocated to all parts of the plant. Good spray coverage is required, however. It will control many woody species on non-cropland areas. Fosamine ammonium is applied to brush from mid-June to late September. Response may not be observed until the following spring, particularly if minimum recommended rates are used or if cool temperatures prevail when spray is applied. Susceptible treated plants fail to refoliate and subsequently die. The addition of a surfactant is required to control most conifers and root suckering of certain deciduous species. Do not use on food or forage crops, and avoid drift. Generally less than one-half the herbicide applied remains in soil after 1 to 2 weeks. It has a low acute mammalian toxicity (LD_{50}: oral = 10,200; dermal > 1,680 Rb). Safe for fish and wildlife.

glyphosate *(Roundup, Vision)* — is an amino acid compound which is a broad-spectrum, postemergence, translocated herbicide. It is used for control of many annual and deep-rooted perennial weeds including brush species in noncrop areas. It is also used on cropland before emergence of barley, wheat, oats, soybeans and corn, for preplow cleanup or spot control of perennial weeds in legumes and grasses, and for pasture renovation. Avoid drift onto foliage of any crops or desirable plants. Rain within six hours of application reduces effectiveness. Glyphosate is quickly deactivated in soil. No residue remains in the soil to affect subsequent crops. It has a low acute toxicity to mammals (LD_{50}: oral = 4,300; dermal > 7,900 Rb), but may cause eye irritaion. it has a low toxicity to fish.

hexazinone *(Velpar)* — is a triazine compound used as a non-selective, postemergence herbicide on noncrop land. Registered uses in Canada include highways, industrial sites, pipelines, railroads, utility rights-of-way and forestry land. It is absorbed by foliage and roots. It has some contact activity but is translocated, mostly upward. It inhibits photosynthesis. Hexazinone leaches readily through some soils and caution must be used near domestic water sources or waters inhabited by fish. Field tests found that less than one-half the herbicide applied remained in soils after 1 to 6 months. Do not use adjacent to desirable vegetation. Avoid drift. It has a low acute toxicity to mammals (LD_{50}: oral = 1,700; dermal = 5,300) but is an eye, nose, throat and skin irritant. It has a low toxicity to fish and wildlife.

ioxynil *(Totril)* — is a benzonitrile compound used as a selective, postemergence herbicide for control of several annual broadleaved weeds in onions. Grasses are resistant to ioxynil. Ioxynil works best on seedling weeds and works by contact action. Ioxynil is absorbed by the leaves, but only translocated slightly. It inhibits respiration and photosynthesis. Ioxynil has no phytotoxic effects in the soil. It has a moderate acute mammalian toxicity (LD_{50}: oral = 110; dermal = 210) and is toxic to fish.

iron sulphate — see ferrous sulphate

linuron *(Afolan, Lorox)* — a substituted urea herbicide for selective, preemergence and postemergence broadleaved weed control. Gives suppression of some grassy weeds. Linuron can be used in soybeans, field corn, tree fruits, carrots, potatoes, asparagus, wheat, oats, barley, flax and shelter belts. It may injure potatoes and corn in light, sandy soil and must be used only as a directed spray on emerged corn. It is mainly absorbed through the root system and translocated to leaves and terminal buds. Some linuron is absorbed through foliage. Foliar activity is significantly increased through the use of surfactants. Two major properties influence the behavior of linuron in soil: very strong adsorption by soil colloids (clay and organic matter) and low solubility in water. Conditions such as coarse textured soils that are low in organic matter and have little

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capacity to bind linuron, heavy rainfall, cool weather and shallow planting depth in soybeans can result in injury to crop plants. Persistence in soil is two to four months. It is nonflammable and noncorrosive. Linuron has a low acute mammalian toxicity (LD_{50}: oral = 1,500) but may irritate the eyes.

MCPA — see phenoxyacetic compounds

MCPB — see phenoxybutyric acids

mecoprop, MCPP — see phenoxypropionic acids

metobromuron *(Patoran)* — a substituted urea compound formulated as a wettable powder. It is used selectively for preemergence control of seedling broadleaved weeds and grasses in potatoes and beans. It works primarily through the roots, but does have some foliar activity. Moist soil is essential. It gives approximately 8 weeks of control. Some sensitive crops may be injured if planted within one year following application of this material. Metobromuron has a low acute mammalian toxicity (LD_{50}: oral = 2,000; dermal > 10,200 Rb).

metolachlor *(Dual, Primextra)* — is an acetanilide compound used as a selective, preplant incorporated or preemergence herbicide for control of annual grasses in corn. It is absorbed by shoots and roots of germinating seedlings. Metolachlor may be mixed with atrazine (Primextra), which gives broader spectrum weed control. Do not use metolachlor on muck soils or apply metolachlor once crop emergence has begun. Generally less than one-half of the herbicide applied remains in the soil after 1 to 2 months. There could be some injury to subsequent rotation crops if planted in the same year. Metolachlor has a low acute mammalian toxicity (LD_{50}: oral = 2,800; dermal > 10,000 Rb), and is relatively safe to fish.

metribuzin *(Lexone, Sencor)* — is a triazine compound used as a selective, preplant incorporated, preemergence or postemergence herbicide for control of many broadleaved weeds in spring wheat, barley (except Klondike), potatoes, fababeans, lentils, field peas and tomatoes. Sensitive crops are crucifers, cucurbits, flax, strawberries and sunflowers. Most plant absorption occurs through roots but some occurs through leaves. Metribuzin inhibits photosynthesis. Moisture is needed to activate preemergence control. Do not apply on light soils containing less than 3% organic matter. Do not harvest or graze treated crops until 70 days after application. Generally less than one-half the herbicide applied remains in the soil 1 to 2 months after treatment. Metribuzin has a low acute mammalian toxicity (LD_{50}: oral = 1,100; dermal > 20,000).

mineral oils *(Agricultural Weed Killer No. 1,* petroleum oils, petroleum solvents, stoddard solvents, herbicide oils) — are used as selective and nonselective, postemergence and preemergence (to crop) herbicides on some crops and noncrop areas. They kill the top growth of weeds on contact. The lower the grade of oil (less refined) and the greater the amount of unsaturated aromatic hydrocarbons present, the greater will be the oil's phytotoxicity. Light oil fractions such as kerosene and stoddard solvent are used for selective control in tolerant crops such as carrots, parsnips, parsley, dill and celery. Heavy oils such as crude oil, diesel oil and crankcase oil are nonselective. They injure the growing point of weeds producing slow-acting chronic toxicity. Mineral oils are considered non-toxic to mammals but may cause some eye and skin irritation.

monolinuron *(Afesin, Monolinuron)* — is a substituted-urea compound used for selective, preemergence control of several broadleaved and grassy weeds. It is absorbed by both roots and leaves and inhibits photosynthesis. Sufficient soil moisture must be available after application to obtain good preemergence weed control. Monolinuron can be used in potatoes, field beans (kidney, white and yellow eye), lima beans, snapbeans and soybeans. Perennial weeds are not controlled. Sandy soils and soils with less than 1% organic matter may show crop injury. Do not spray when heavy rains are expected. Do not plant other crops within four months of application. Monolinuron has a low acute mammalian toxicity (LD_{50}: oral = 2,200). Toxicity to fish is low; nontoxic to bees.

MSMA *(Glowon,* monosodium methane arsonate) — is an organic arsenic compound used for thinning conifer stands in forest management. It is used on trees with a 2 to 15 cm diameter. It is injected to axe frills and translocated upward. MSMA has a low acute toxicity to mammals (LD_{50}: oral = 700).

naptalam *(Alanap 3)* — is a phthalic acid compound. It is used for selective preemergence weed control in cucumbers, melons, squash and pumpkin. Naptalam acts on seeds prior to and during germination. Emerged weeds are not controlled. Do not use on low organic soils, light sandy soils, or alkaline soils. Beets, tomatoes, spinach and lettuce are very sensitive. Naptalam is noncorrosive, nonvolatile, activated by moisture, leaches quickly and decomposes in six to eight weeks. Warm soils speed up breakdown, cool wet soils increase the potential for crop injury and decrease weed control. Naptalam has a low mammalian toxicity (LD_{50}: oral = 1,700; dermal > 8,500) but may cause eye irritation. It has a low acute toxicity to wildlife and fish.

oils — see mineral oils

paraquat *(Gramoxone, Sweep, Terraklene, Weedrite – with diquat)* — is a pyridine compound used as a nonselective, postemergence, contact herbicide for control of herbaceous plants. Paraquat is a water-soluble herbicide which gives rapid foliar kill. It translocates slightly in perennial grasses such as quack grass and bluegrasses. Like diquat, paraquat is absorbed and inactivated in the soil. Because it kills green tissue very rapidly, it is useful for weed and grass control around trees and shrubs. It may be combined with other chemicals for residual control. It is an effective crop desiccant. Paraquat is somewhat more corrosive than diquat, especially at high concentrations. Equipment should be thoroughly cleaned after use. Paraquat has a high acute toxicity to mammals (LD_{50}: oral = 150; dermal = 236). All solutions should be handled with caution. The lung is the primary organ affected. Avoid any intake by mouth or breathing of fine mists of the spray solution. This herbicide has no known antidote.

pebulate *(Tillam)* — a selective, preplant incorporated, thiocarbamate herbicide. Pebulate will control several annual grassy and broadleaved weeds in tomatoes. Pebulate is adsorbed onto dry soil but can be removed by leaching. Pebulate leaches slower than EPTC and faster than cycloate. Degradation in soils occurs mainly by microorganisms. Generally less than one-half the herbicide applied remains in the soil after two or three weeks. Pebulate has a low acute mammalian toxicity (LD_{50}: oral = 920; dermal > 2,900 Rb).

petroleum oils — see mineral oils

petroleum solvents — see mineral oils

phenmedipham *(Betanal)* — is a carbamate compound primarily used as a postemergence herbicide for control of certain annual grasses and broadleaved weeds in sugar beets. It is absorbed by leaves and inhibits photosynthesis. It remains in the top 5 cm of soil. Generally one-half the herbicide applied remains after 25 days. Phenmedipham has a low acute mammalian toxicity (LD_{50}: oral > 8,000; dermal > 4,000), but is toxic to fish.

PHENOXYACETIC COMPOUNDS — this group includes 2,4-D and MCPA which are incorporated into a large number of products which interfere with growth regulation in plants. They are translocated and are most effective when plants are growing rapidly. Phenoxy herbicides are more toxic to herbaceous broadleafed plants than to grasses and more toxic to deciduous trees than to conifers. Phenoxy herbicides are more actively taken up by foliage than roots. The herbicides are formulated as an acid, sodium salt or amine salt which are soluble in water or as an ester which is soluble in oil. Ester formulations are generally considered the most toxic to plants and are often used on more resistant species, especially woody plants. Esters also tend to resist washing off the plant. Esters are more volatile than sodium salt or amine formulations, although the most volatile esters are no longer registered for use in Canada. Application equipment must be thoroughly cleaned with special materials before applying other pesticides to desirable crops.

2,4-D *(Amkil, Dacamine 4-D, Estakil, Estasol, Estemine 500, Forestamine, For-ester, Formula 40-F, Sure-Shot Forest Amine, Weedar 80, Weedaway, Weedex, Weedone, Weed-Rhap LV60)* is used postemergence in grain crops, turf, and other grasses for annual and perennial broadleaved weeds, or in brush control on easier-to-kill species. Combination with other chemicals such as dicamba, mecoprop or picloram extends the control spectrum. The average persistence of phytotoxic concentrations of 2,4-D in soil is one to four weeks. Persistence is longer in cold, dry soils. Persistence in the soil may prove injurious to subsequent crops of sensitive plants. 2,4-D has a moderate acute toxicity to mammals. The amine and acid formulations are more toxic (LD_{50}: oral = 300 to 375) than the salt and ester formulations (LD_{50}: oral = 620 to 666).

MCPA *(Estakil MCPA, Estemine MCPA, Methoxone Amine 500, No-weed, Weedar MCPA, Weedaway MCPA, Weedone MCPA)* is similar to 2,4-D. It is more effective on some weed species such as buttercup and hemp nettle. It is not as toxic to oats and clovers, hence, has special uses such as where oats are seeded down. MCPA persists in the soil for about one month under wet conditions and six months under dry conditions. It has a low acute toxicity to mammals (LD_{50}: oral = 700) but is irritating to eyes and skin.

2,4,5-T is no longer registered for use in Canada.

PHENOXYBUTYRIC ACIDS — include **2,4-DB** *(Cobutox 400, Embutox E)* and **MCPB** *(Tropotox)*. Their main value is that 2,4-DB can be safely used in alfalfa and MCPB in clovers and peas. Annuals are most effectively controlled when the chemicals are applied to weeds less than 2.5 cm high. Formulations and applications are generally the same as for the previous groups, except that the rate of application is greater and the water rates are more specific. Small quantities of MCPA are added to MCPB formulations to extend their effectiveness on mustard, wild radish, and other resistant annuals. 2,4-DB and MCPB have low to moderate acute mammalian toxicities (LD_{50}: oral = 500 to 680).

PHENOXYPROPIONIC ACIDS — include **dichlorprop** (2,4-DP) and **mecoprop** *(MCPP, Compitox, Mecoturf)*. These materials have properties like those of 2,4-D but with different selective action. They must be used with the same precautions. They are formulated as esters. Dichlorprop is formulated in mixtures with 2,4-D (e.g. *Desormone, Isoprop 600, Propaturf, Silvaprop LV700)* for control of a greater range of broadleaf weeds, including woody plants. Mecoprop is used in turf on clover and for many persistent weeds. It appears to be safer on bent grasses than 2,4-D, provided cool weather and drought periods are avoided. In some products, mecoprop is formulated with 2,4-D and dicamba (e.g. *Botanix, Killex, Kil-Mor, Norkem 400)* for control of a larger number of weed species. Dichlorprop and mecoprop have a low to moderate acute mammalian toxicity (LD_{50}: oral = 375 to 800). Fenoprop *(Silvex)* which is the propionic acid formulation of 2,4,5-T is no longer registered for use.

picloram *(Tordon)* — is a picolinic acid compound used for control of many broadleaved weeds, woody species, and conifers in established grasses. Picloram is effective on hard-to-eradicate woody species such as conifers and vine maple, and on difficult perennial weeds such as field bindweed and Canada thistle. Grasses are quite tolerant. A granular picloram formulation is available for spot control. A special formulation of picloram plus 2,4-D containing low levels of picloram is available for broadleaved weed control in wheat and barley. Picloram is absorbed by foliage and roots and translocated. It appears to be a growth regulator, somewhat more active than, but similar to 2,4-D. Picloram is not to be used on cropland (except for spot control on permanent pasture, range land and some crops), because of soil persistence and the extreme sensitivity of some crops such as beans, potatoes and peas. It will be broken down in clear water by sunlight and is degraded in warm, moist soil having a good organic matter content. It can persist for a number of years in dry, cold soils and in soils low in organic matter. Some leaching may occur in sandy soils. It must be used with caution around desirable trees and shrubs. Picloram has a low acute mammalian toxicity (LD_{50}: oral = 8,200) and a low toxicity to fish and wildlife. Avoid direct contact, since some skin and eye irritation may occur.

prometryne *(Gesagard)* — is a triazine compound used as a selective, preemergence or postemergence herbicide for control of certain annual broadleaved and grassy weeds. Prometryne can be used in carrots, celery, peas and potatoes. Prometryne works by both contact and root action and has residual effect for six to eight weeks. Best results are obtained when applied to moist soil. Lowest rates should be applied on sandy soils. Only tolerant crops listed on the product label can be planted on treated land in the same season prometryne is used. It is noncorrosive and nonflammable. Prometryne has a low acute toxicity to mammals (LD_{50}: oral = 2,500; dermal > 3,100 Rb).

propanil *(Stampede)* — is an anilide compound used as a selective postemergence, contact herbicide for control of some annual broadleaved and grass seedlings, especially foxtail and barnyard grass, in wheat, barley, oats and flax.

It has a very short soil persistence of one to three days. It is noncorrosive and nonflammable. Propanil has a low acute mammalian toxicity (LD_{50}: oral = 1,380; dermal > 1,000).

propyzamide *(Kerb)* — is a benzamide compound used as a selective herbicide to control quack grass, certain other perennial grasses such as orchard grass, timothy and most annual grasses, including wild oats. Propyzamide also controls chickweed and, in established pastures, foxtail barley. It is used in alfalfa, trefoil, established pastures, established ornamentals, strawberries, apples, pears and lowbush blueberries. Certain grazing restrictions apply, and to avoid injury, it is necessary to wait 3 to 12 months before planting certain other crops in propyzamide-treated soil. Propyzamide is more effective in cool weather. It is absorbed primarily by roots, with some foliar activity. Rain or irrigation is beneficial. It has a low acute mammalian toxicity (LD_{50}: oral = 5,600) but is a mild eye and skin irritant.

pyrazon *(Pyramin)* — is a pyridazone compound used as a selective preplant, preemergence and postemergence herbicide for control of many broadleaved weed seedlings in sugar beets and table beets. Moisture is needed to activate this material. Shallow soil incorporation is recommended as pyrazon is absorbed by the roots. It inhibits photosynthesis. Crop foliage is susceptible when wet. Do not apply when temperature and humidity are high. Beets are susceptible in the cotyledon stage. On soils classified as sands or loamy sands, crop injury can occur if the organic matter content is less than 2%. Cabbages, carrots, cucumbers, lima beans, and tomatoes are very susceptible. Established perennial weeds are not controlled, grasses are controlled poorly. It is noncorrosive and nonflammable. Pyrazon lasts four to eight weeks in soil and is tightly absorbed by organic matter. Pyrazon can be used with dalapon, TCA, and triallate. It has a low acute mammalian toxicity (LD_{50}: oral = 2,500).

sethoxydim *(Poast)* — is a selective, postemergence herbicide for control of most annual grasses in rapeseed (including canola) flax, soybeans and sugar beets. Sethoxydim also suppresses some perennial grasses, especially quack grass, but does not control broadleaved weeds. Sethoxydim is both a contact and systemtic herbicide. Uptake into the plant occurs rapidly, primarily through the leaves. Sethoxydim affects plants at their growing point such as nodes, roots and bulbs. Complete control is obtained in one to three weeks following treatment, depending on growing conditions. Do not make applications to grasses stressed longer than 20 days due to lack of moisture, as unsatifactory control can result. Do not graze treated fields or harvest for feed prior to crop maturity. Sethyoxydim has a low acute toxicity to mammals (LD_{50}: oral = 2,700; dermal > 5,000).

siduron *(Tupersan)* — is a substituted-urea compound used as a selective, preemergence herbicide on turf for control of crabgrasses, foxtail, and barnyard grass. Siduron is most readily absorbed through roots and inhibits root growth. Apply at seeding time or on established turf prior to weed emergence. Annual bluegrass is resistant, as are red fescues, redtop, perennial ryegrass and orchard grass. Bent grasses may be injured, do not use on golf greens. Use lower rates on sandy soils, higher rates on high organic soils. Agitate while spraying and water in. Do not use treated grass for livestock. There has been no evidence of herbicide residue in soil one year after treatment. Siduron has a low acute toxicity to mammals (LD_{50}: oral = 7,500; dermal = 5,500 Rb).

simazine plus related active triazines *(Princep, Simadex, Primatol S)* — is a triazine compound similar to atrazine. Simazine is applied as a preemergence or postemergence (preemergence to the weeds) herbicide. Crops in which simazine can be used include certain fruit crops, alfalfa, birdsfoot trefoil, asparagus, ornamentals, shelter belts, forest and Christmas trees and corn. Simazine controls several annual broadleaved and grassy weeds. Simazine is absorbed mostly through plant roots with little or no leaf penetration. It does not adhere well and is readily washed off leaves by rain. After simazine is absorbed by roots, it moves up the plant to growing tips and leaves. Simazine is tightly held in the soil. It has a solubility of 5 ppm and hence is useful under humid conditions where long residual action is desired. It will not leach readily and breaks down slowly in soil. At high rates, simazine is a good soil sterilant. Like atrazine, it has low acute mammalian toxicity (LD_{50}: oral > 5,000; dermal > 3,100 Rb).

sodium chlorate *(Atlacide)* — is an inorganic compound and is a white salt, very soluble in water. Its chief value is that of a relatively cheap soil sterilant, but it will kill foliage on contact. In solution, it acts strongly with organic materials and, because it is highly oxidative, it becomes a serious fire hazard upon drying. Usually it is mixed with other salts, which act as fire retardants, such as borate *(Monobor-Chlorate)* or borate and bromacil *(Ureabor)*. It leaches rapidly from soils and its effectiveness is short-lived in rich organic or muck soils. Sodium chlorate is highly corrosive, therefore, equipment should be cleaned properly after use. It has a distinctly salty taste and is attractive to livestock. It is essential that livestock be kept away from treated areas, for large amounts will poison them. Crystals formed on drying catch fire readily. Rubber boots should be worn when applying sodium chlorate, and clothing should be kept clean to reduce the danger of fire. It has a low acute mammalian toxicity (LD_{50}: oral = 1,200; dermal > 20,000).

2,4,5-T — see phenoxyacetic compounds

TCA (NaTA, TCA) — trichloroacetic acid is an aliphatic acid compound used for selective postemergent annual grass control in flax, canola, oats, barley, field peas, sugar beets and red beets. Mixtures of MCPA with TCA increase the spectrum of weed control in barley, oats, peas and flax. TCA can be mixed with 2,4-D for broad spectrum weed control on barley. TCA is highly soluble in water and leaches readily. TCA disappears from the soil in about three months under moist, warm conditions. It may last longer in soils with high organic matter under dry, cool conditions. TCA is absorbed more readily through the roots than plant foliage. It precipitates proteins within the plant which are essential for growth. TCA has a low acute toxicity to mammals (LD_{50}: oral = 3,200) but can cause irritation to both skin and eyes, and may cause burning on prolonged contact.

tebuthiuron *(Herbec 20P, Spike)* — is a substituted urea compound used as a total vegetation control herbicide on rights-of-way, railroads, industrial sites, highways and other noncrop areas. It is applied shortly before or during periods of active weed growth. Rainfall is needed after application to carry tebuthiuron into the root zone where it is readily absorbed and translocated. Photosynthesis is inhibited. It does not leach readily. Its half life in soil varies from 12 to 15 months even when annual rainfall is in excess of 100 cm. Do not use on food crops or near desirable plants, except as indicated on the label. Tebuthiuron has a low acute mammalian toxicity (LD_{50}: oral = 640).

terbacil *(Sinbar)* — is a uracil compound similar to bromacil and useful at low rates for selective weed control of many annual and some perennial grasses and broadleaved weeds in established apple and peach orchards, blueberries, and strawberries. At higher rates it is a soil sterilant, so must be used with caution. Soil persistence at lower rates is 5 to 6 months. Do not plant nontolerant crops for two years in areas treated with the higher rates. It is sprayed just prior or during periods of active weed growth, absorbed by the roots, and translocated. Photosynthesis is inhibited. It requires moisture to be activated. Terbacil has a low acute mammalian toxicity (LD_{50}: oral > 5,000; dermal > 5,000).

terbutryn plus related active triazines *(Igran)* — is a triazine compound used as a selective, preemergence and early postemergence herbicide for control of many annual grasses and annual broadleaved weeds in potatoes and on noncrop areas. Terbutryn is absorbed through roots and leaves, and translocated. Photosynthesis is inhibited. Water is needed in preemergence applications to carry terbutryn into the root zone. It is readily adsorbed in soils with high clay and organic content, which reduces leaching. Terbutryn has a residual effect for 3 to 10 weeks. It has a low acute toxicity to mammals (LD_{50}: oral = 2,500, dermal > 2,000) but is toxic to fish.

triallate *(Avadex BW)* — is a carbamate compound used as a selective, soil-incorporated, preplant or preemergence herbicide for control of wild oats in spring and duram wheat, barley, flax, canola-rapeseed, peas, mustard and forage legumes. Mixtures with trifluralin also suppress green and yellow foxtail. Applied prior to germination, triallate is absorbed by wild oat shoots usually resulting in death before emerging through the soil surface. Triallate is adsorbed on soil particles. It is decomposed in the soil by microorganisms and can persist for 6 to 8 weeks. Triallate has a low acute mammalian toxicity (LD_{50}: oral = 675).

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triclopyr *(Garlon)* — is a picolinic acid compound which will give selective control of many woody plants and broadleaf weeds. It is absorbed by leaves and translocated throughout the plant. Triclopyr is not strongly bound to soils and some leaching may occur in sandy soils under high rainfall. Average half life in soil is 46 days, although this varies with soil and climate. Triclopyr has a low acute toxicity to mammals (LD_{50}: oral = 713). The active ingredient has a relatively low toxicity to fish but the butoxyethyl ester formulation has a much higher fish toxicity.

trifluralin *(Rival, Treflan, Weed Preventor)* — is a dinitroaniline compound used as a selective, preplant incorporated herbicide for control of several annual broadleaved and grassy weeds. Trifluralin can be used in soybeans, dry beans, snapbeans, carrots, fababeans, direct-seeded cabbage, cauliflower, alfalfa, turnips, mustard, transplanted tomatoes, peppers, broccoli, cabbage, brussel sprouts, lima beans, peas and ornamentals. Weeds are killed as they germinate. To work effectively, trifluralin must be uniformly mixed throughout the soil in the zone of weed seed germination since it acts on the growing points of the root and shoot as they emerge from the seed. Trifluralin inhibits cell division and the actively growing points in the root and shoot. Do not apply to peat or muck soils. Do not apply to wet soils, soils in poor working condition or soils which contain more than 15% organic matter. It has a low acute toxicity to mammals (LD_{50}: oral = 3,700; dermal > 2,000). It is toxic to fish.

2,4-D — see phenoxyacetic compounds

vernolate *(Surpass)* — is a carbamate compound used as a selective, soil-incorporated, preplant and preemergence herbicide for control of annual grasses and broadleaved weeds in soybeans and potatoes. Some crops show greater tolerance to vernolate than the closely related EPTC. Established weeds are not controlled. Swift soil incorporation is essential. Wet soils at application time cause rapid volatilization. Persistence of soil residues is very short. Vernolate has a low acute toxicity to mammals (LD_{50}: oral = 1,400; dermal = 4,600Rb) but it is toxic to fish.

weed oils — see mineral oils

zinc sulphate — see ferrous ammonium sulphate

GROWTH REGULATORS

Plant growth regulators are used to regulate or modify the growth of plants. These chemicals are used to thin apples, control the height of turfgrass, control the height of some floral potted plants, promote dense growth of ornamentals and to stimulate rooting. They are used in minute amounts to change, speed up, stop, retard or in some way influence vegetative or reproductive growth of a plant.

Particular attention must be given to the precise rate, concentration, timing and method of application of these chemicals. Even slight variations in their use may have a significant effect on their performance. Equally important is the plant itself. Differences in age, stage of development, rate of growth and vigour can be expected to influence the response of whatever chemical is applied.

Plant growth regulators are not herbicides *per se*, but they are used to control plant growth and act on plants in much the same way as some herbicides. They range in toxicity to humans and wildlife as do many herbicides. Plant growth regulators must be registered for use in Canada and are assigned a Pest Control Product Act Registration number.Most of the plant growth regulators fall into one of the following general categories:

- blossom and fruit thinning of fruit trees (e.g. carbaryl, DNOC, naphthaleneacetic acid, naphthaleneacetamide);
- increasing blossom and fruit set on fruit trees (e.g. daminozide, ethephon, gibberellic acid);
- controlling preharvest fruit drop in fruit trees (e.g. naphthaleneacetic acid);
- control of suckering and sprouting in various plants (e.g. chlorpropham, maleic hydrazide, naphthaleneacetic acid);
- regulation of stem growth in various plants (e.g. ancymidol, chloroflurecol-methyl, chlormequat, daminozide); and
- promotion of root growth in various plants (e.g. maleic hydrazide, naphthaleneacetamide).

REFERENCE LIST OF GROWTH REGULATORS AND THEIR PROPERTIES

The following reference list includes a description of most growth regulators used in British Columbia when this text was published. Growth regulators are listed alphabetically by active ingredient with some examples of trade names. No endorsement of products is implied. Information contained in these lists could become out-of-date and may not represent current recommendations. **The current registered label is the authority on a growth regulator's registered uses, application methods and safety precautions.**

The relative acute mammalian toxicity is given for each active ingredient listed. LD_{50} values (mg/kg body weight) are listed where available and are derived from tests with rats unless indicated otherwise (Rb = rabbit). The lowest LD_{50} is listed for each growth regulator where several are given in the literature reviewed.

ancymidol *(A-Rest)* — is a pyrimidine compound used for height control by reducing internode elongation. It is applied as a soil drench on moist soil to container grown chrysanthemums, lillies and poinsettias in greenhouses. Avoid eye and skin contact. Do not contaminate food, feed or any water. Ancymidol has a low acute mammalian toxicity (LD_{50}: oral > 2,000; dermal > 2,000 Rb).

carbaryl *(Sevin)* — is a carbamate insecticide used in the wettable powder form for apple thinning and to reduce vegetative growth and heights on nursery azaleas, greenhouse geraniums, and greenhouse poinsettias. On poinsettias richer green foliage and red bracts are evident. Do not apply to apple trees within seven days of harvest. Carbaryl has a moderate acute mammalian toxicity (LD_{50}: oral = 400; dermal > 2,000). Avoid inhalation of the dust or spray mixture. Avoid skin contact and wear long sleeved clothing. Launder clothing before reuse. Do not contaminate food, feed or any water. Carbaryl is highly toxic to bees.

chlorflurecol-methyl (chlorflurenol)—is a morphactin compound used to retard growth of certain trees, bush, and turf grasses. It is only available in formulations with dichlorflurecol-methyl and flurecol-methyl *(Maintain CF125)*. Formulations for turf use also contain maleic hydrazide. Some turf weeds are also controlled. Do not use on food plants or crop land. Do not contaminate food, feed, or water. Avoid inhalation. Chlorflurecol-methyl has a low acute toxicity to mammals (LD_{50}: oral = 3,100) but is an eye, nose and skin irritant. Launder clothing before reuse. Seek immediate medical attention in case of accident. Chlorflurecol-methyl is toxic to fish.

chlormequat *(Cycocel)* — is a chlorinated hydrocarbon used to produce early budded, compact symmetrical azaleas. Use on early blooming, label recommended varieties only and strictly adhere to recommended application time. Chlormequat must not be used in combination with other pesticides or fertilizers. Frost free storage is essential. Chlormequat has a moderate acute toxicity to mammals (LD_{50}: oral = 670; dermal = 440). Avoid eye and skin contact.

4-chlorophenoxyacetic acid *(4-CPA, Seedless Set)* — is a phenoxy compound to aid fruit set of tomatoes and promote an early harvest. Launder clothing before reuse. Do not contaminate any other plants, food, feed, seeds, fertilizers, insecticides or fungicides. It has a low acute toxicity to mammals but is a skin and eye irritant.

chlorpropham *(Sprout-Nip)* — is a carbamate compound used as a sprout inhibitor on potatoes after harvesting, prior to storage, or while in storage. Do not contaminate seed potatoes. Chlorpropham is flammable. Operators of fogging equipment should be fully aware of equipment limitations and safety procedures. Do not contaminate food, feed, fertilizers, plants, seeds or insecticides. Chlorpropham has a low acute toxicity to mammals (LD_{50}: oral = 3,800). Avoid inhalation, wear protective clothing and safety gear when fogging.

4-CPA — see 4-chlorophenoxyacetic acid

daminozide *(Alar, B-Nine)* — is used as a growth inhibitor on apple trees, cherry trees, peach trees and grapes. Increased fruit set and early fruit maturity are also promoted. In greenhouses, daminozide is used to retard new growth on azaleas, hydrangeas, chrysanthemums, and poinsettias. Stem elongation on bedding plants such as aster, cosmos, marigold, petunia, salvia and zinnia is reduced. Do not add wetting agents. Store cool and dry. Daminozide has a low acute toxicity to mammals (LD_{50}: oral = 8,400; dermal = 1,600 Rb).

ethephon *(Ethrel)* — is an organophosphorous compound to promote ripening of apples, cherries and tomatoes. When applied on young apple trees, vegetative growth is reduced and flower bud development is promoted. Do not contaminate other plants or any water. Ethephon is corrosive. Ethephon has a low acute toxicity to mammals (LD_{50}: oral = 4,229; dermal = 5,730), but is harmful to eyes and skin and is a mucous membrane irritant.

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flurecol-methyl — see chlorflurecol-methyl

gibberellic acid *(Activol)* — is an organic plant hormone used to promote fruit spur development on sour cherry trees and to break dormancy of rhubarb roots. Do not contaminate any water. Keep containers sealed and store cool and dry. It has a low acute toxicity to mammals (LD_{50}: oral = 6,300).

maleic hydrazide *(De-Sprout V, Gro-tard, MH 30, Retard, Slo-Gro, Sprout-Stop, Malazide)* — the diethanolamine salt of maleic hydrazide is applied as a preharvest sprout inhibitor on beets, carrots, onions, potatoes and rutabagas intended for storage. Growth of many ornamental trees and shrubs is inhibited when applied in their vigorous growing stage. Mowing of turf is reduced or eliminated when maleic hydrazide is applied to lawns. Check also under chlorflurecol-methyl. Maleic hydrazide has a low acute toxicity to mammals (LD_{50}: oral = 1,400; dermal = 400 Rb).

naphthaleneacetamide *(Amid Thin)* — is used for chemical thinning of apples and pears. Do not apply on early varieties later than petal fall. Formulations containing indolebutyric acid; 2-methyl-1-naphthalaneacetic acid, and 2-methyl-l-naphthalene acetamide are used to promote rapid rooting of many woody ornamentals and cuttings. Formulations which also contain thiram are used on some herbaceous and woody ornamentals to stimulate root formation while controlling damping-off and other soilborne diseases. Do not contaminate food, feed or any water. Store separate from seeds, fertilizers, and other pesticides. Naphthaleneacetamide has a low acute toxicity to mammals (LD_{50}: oral = 1,000).

naphthaleneacetic acid (NAA, *Tre-Hold*) — is used for chemical thinning of apples and to prevent premature apple drop. Do not use on early apple varieties. Resprouts from pruning may be prevented by spraying or painting the cuts on American elm, Chinese elm, red maple, silver maple, sugar maple, sycamore, and water oak with the ethyl ester formulations. Naphthaleneacetic acid is marketed in aerosols, as a paste, and as a wettable powder. Do not mix with insecticides or fungicides. Naphthaleneacetic acid has a low acute toxicity to mammals (LD_{50}: oral = 5,900), but is irritating to eyes.

CHAPTER QUIZ

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Questions	Answers
1. What is a weed?	1. A plant growing where it is not wanted.
2. What are "noxious weeds" under the provincial Weed Control Act?	2. Noxious weeds are those weeds which are a particular problem in some locations and must be controlled to reduce their nuisance and prevent spread.
3. Why may annuals be difficult to control?	3.. Annuals produce many seeds and grow rapidly.
4. When is it best to control biennials?	4. In their first year of growth.
5. What is the most difficult type of perennial to control? Why?	5. Creeping perennials — because new plants can regrow from fragments of creeping roots or stems.
6. Name the two major groups of flowering plants.	6. Narrowleaved plants and broadleaved plants.
7. Who could you obtain help from in identifying weeds?	7. Weed specialists in the Ministry of Agriculture and Fisheries.
8. Name five categories of weed control.	8.. Prevention, physical, cultural, biological and chemical controls.
9. What is the main disadvantage of contact herbicides?	9. They only remove top growth, most perennials regrow from surviving roots.
10. Why is it important to use the correct application rate for translocated herbicides?	10. An overdose of translocated herbicides may kill plant parts first contacted and prevent further absorption and translocation.
11. What are three categories of soil-applied herbicides?	11. Non-residual, temporary residual, long-term residual.
12. Why are the following factors important for herbicide selectivity (a) leaf shape, (b) leaf surface, (c) plant physiology, (d) growing sites, (e) growth stages, (f) application rate, (g) formulations, (h) application timing, (i) soil properties.	12. (a) some leaf shapes retain more herbicide than others. (b) surface hairs and wax layers affect herbicide penetration into the leaf. (c) some plants break down herbicides into non-toxic chemicals. (d) some plants have protected growing sites. (e) some plants are more susceptible to herbicides during some growth stages. (f) some herbicides are selective at low application rates, non-selective at high rates. (g) some formulations are more toxic than others. (h) some herbicides are selective if applied before crops or weeds have germinated or when they reach a certain size. (i) soil types influence herbicide toxicity and the time that a herbicide remains active at certain soil depths.
13. Indicate the conditions when herbicide spray or vapour drift is reduced: (a) high or low wind velocity, (b) high or low temperature, (c) large or small application rate, (d) high or low pressure, (e) large or small orifice size, (f) fast or slow spraying speed, (g) nozzle close or far from target area, (h) high or low volatility of herbicide.	13. (a) low, (b) low, (c) small, (d) low, (e) large, (f) slow, (g) close, (h) low.

Chapter 13

STRUCTURAL AND STORED PRODUCT FUMIGATION

CONTENTS

INTRODUCTION

Fumigation is one of the oldest methods of pest control used by man. Originally, substances were burned to give off acrid or aromatic smoke or fumes. Modern fumigants may be either gases, or solid or liquid chemicals which release toxic vapours, to control pests in enclosed spaces.

Fumigants are hazardous to apply because they are extremely poisonous and because the toxic gas can be easily inhaled. Therefore, applicators must know the properties of fumigant chemicals and how to use them safely.

A fumigant gas must spread quickly and uniformly throughout an enclosed space. The gas spreads as independent molecules which will penetrate into the cracks and crevices of infested structures, into spaces between products packed in bags or storage bins, or into the voids between soil particles. After the fumigation period is completed (several hours to several days), the gas diffuses away when the space or commodity is aerated. Fumigants have no residual action following aeration.

Pesticides dispersed as aerosols, fogs, smokes or mists do not fall within the definition of true fumigants. This is because these pesticides are applied as particles or liquid droplets suspended in air. They do not penetrate into materials or diffuse away as readily as fumigants. Smoke generators leave a residue of fine particles, primarily on horizontal surfaces.

There are a limited number of chemicals which possess the requirements of a useful fumigant. Only four fumigant active ingredients are presently registered for control of structural pests. Desirable characteristics and qualities of a fumigant include the following:

- high toxicity to insects,
- excellent penetrability,
- poor absorption and no residues after aeration,
- no reaction with treated commodities,
- rapid rate of diffusion and dispersion, and
- no chronic effects to workers exposed to low concentrations.

The following are the most common situations where fumigants are employed:

Soil Fumigation. Soils, either in a greenhouse or a field, may be fumigated for the control of insects, diseases and nematodes. Soil fumigants are discussed in the chapter on Nematodes, Nematicides and Soil Fumigation.

Fumigation Under Sheets. Fumigants are *sometimes* released under gas-proof sheets to control insects or plant disease organisms in food commodities or plant materials. Sheets are made of polyethylene or more durable materials such as nylon coated with neoprene or polyvinyl chloride. The edge of the cover must be carefully sealed (e.g. by sand-filled tubes), and where sheets are joined, they must be carefully sealed (e.g. rolled and clamped). In large operations, a check should be made for leaks using a leak detector around the edge and at joints. Any serious leaks should be corrected. During aeration, respirators must be worn. To begin aeration, one corner of a sheet is lifted, then after a period of time, another corner is lifted. When high concentrations of fumigant have dispersed, the sheets are carefully removed.

When large objects (e.g. buildings) are fumigated under sheets, loss of fumigant through leakage cannot be predicted. It may be necessary to set up equipment to record gas concentrations at a number of locations within the area being fumigated.

Space Fumigation. Fumigants may be applied to enclosed spaces such as aircraft, warehouses, railcars, trucks, offices, greenhouses, grain bins or special fumigation chambers. Fumigation can only be carried out where the enclosed structure can be made sufficiently gas-tight. Generally, fumigants are used in cases where no other pesticide will be effective.

Fumigation of Grain in Bulk. Fumigation is sometimes required to control various beetles, moths and mites infesting stored grain. Fumigant gas (methyl bromide) can be released in the space above the stored grain, or aluminum phosphide tablets or pellets are inserted into the grain where they release phosphine gas. Insects are often located in pockets in the grain which can be detected by the use of probes. Fumigant tablets are applied to such pockets through a metal pipe (Sinha and Muir, 1973; Watters, 1976).

Certain species of insects inhabit the surface layer of stored grain. It may not be desirable to use a fumigant because it would be necessary to fumigate the entire container in order to control the near-surface insects. Such infestations may be controlled with a non-fumigant insecticide (e.g. malathion) sprayed as a mist in the space over the grain. Label directions must be strictly *followed.*

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Fumigation of Honey Bee Hives. Calcium cyanide dust is registered for use in the beekeeping industry to kill bee colonies. The dust reacts with moisture in the air to produce the highly toxic hydrogen cyanide gas. A small amount of calcium cyanide dust is placed on a piece of cardboard and slipped into the entrance of the hive.

Vacuum Fumigation. In vacuum fumigation, goods requiring treatment are placed in a chamber capable of withstanding reduced internal pressures. The air in the chamber is partially removed before the fumigant is *introduced. The use* of vacuum fumigation increases the penetration of the fumigant into the material undergoing treatment. Vacuum fumigation can also be completed in a shorter time (e.g. 2 to 4 hours) than atmospheric fumigation which generally takes 12 to 24 hours.

FUMIGANT APPLICATION

SEALING OF STRUCTURES BEFORE FUMIGATION

Buildings of all sizes and shapes can be fumigated if properly sealed. The sealing materials to be used may consist of masking tape, heavy kraft paper, polyethylene sheets, etc., depending on their availability and practicality. Proper sealing must be done carefully, because a leak can make the difference between the success and failure of a treatment. In particular, methyl bromide and phosphine are highly-penetrating and will quickly leak through unsealed cracks and crevices. In general, buildings made of brick or concrete and in good state of repair are best suited for fumigation. It is necessary to seal the windows, doors and all external openings. Roof ventilators, chimneys and heat ducts should also be sealed using polyethylene or other gas-proof sheets.

If only one room in a building or only part of a structure is to be fumigated, with people living or working within the building, special attention should be given to the partitions between fumigated and unfumigated areas. A gas detector must be used to check for leaks and immediate corrective action must be taken if necessary. People may have to be ordered out of the building for their own safety.

DOSAGE OF FUMIGANT

The amount of fumigant recommended for most fumigation treatments is given as the weight or volume of chemical required for a certain volume of structure or weight of stored material (see Appendix IV for volume calculations). This dosage requirement is followed by the recommended duration of the exposure period. Usually the dosage can be varied in relation to the time of exposure. Thus longer exposure periods require a lower dosage.

Fumigants act on insects and rodent pests mainly through their respiratory systems. The poisoning of insects by fumigation is largely influenced by their rate of respiration which drops as temperatures decrease. More fumigant is usually required to kill an insect at low temperatures than at high temperatures.

Another consideration in fumigation is the phenomenon known as 'sorption'. Sorption includes adsorption of the gas onto surfaces of material in the space being fumigated. It also includes absorption of the gas into the material where it may become chemically bound. In both cases, the gas is retained by some materials during fumigation, resulting in less gas available to circulate throughout the system. Generally, the more material to be fumigated within a chamber, the greater the amount of fumigant that will be required to leave enough circulating gas to kill the pest organisms. Adsorption is greater at lower temperatures, thus dosages have to be increased at low temperatures.

FINAL CHECKS BEFORE FUMIGATING

Before fumigants are applied, it is necessary to ensure that all precautions have been taken to avoid accidents. The following points should be carefully checked:

- In any fumigation, large or small, no person should ever work alone. Because poisonous gases are being used, serious consequences may result if a fumigator becomes sick, loses consciousness, or is unable to finish and control the fumigation. No matter how small the dose or the scale of the work, at least one other person must be present who can take action in case of an emergency.
- To eliminate all possible sources of fire, all pilot lights and gas burners must be extinguished, and all electrical systems or equipment switched off.
- Place warning signs (Figure 25) at strategic points. If necessary, a watchman should be used to prevent admittance during fumigation.
- It is advisable to notify police, fire and health departments before fumigation. In some jurisdictions it is required by law. Pesticide applicators should be aware of local regulations concerning fumigation.
- Be sure that people, domestic animals and desirable plants are well removed from the space to be fumigated. Also remove materials that may be adversely affected by the gas, i.e. methyl bromide reacts with such materials as rubber, leather, furs and articles containing sulphur.
- Ensure that the correct protective gear is used, and that it is in good working order.
- Carry a first aid kit.

INTRODUCING AND DISPERSING THE FUMIGANT

Generally, fumigants must be circulated to mix with air, when first applied. This is particularly true with the heavier fumigants like methyl bromide and chloropicrin. If a gas is heavier than air, it will sink to the bottom of a chamber, if not circulated. It is also desirable to increase the speed of circulation or diffusion of a fumigant in order to attain uniform concentrations as soon as possible after it is released. Circulation can be achieved by

Figure 25. Entry warning sign for area where fumigation has been carried out (from Workers' Compensation Board).

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means of fans, blowers or multiple gas inlets. Fans or other circulation devices should be set up so they can be controlled from outside the fumigated space. Once a fumigant gas is mixed with air, it settles out very slowly and circulation need not continue.

After a structure is properly sealed and ready for fumigating, it is important that applicators start to release the gas from the area furthest away from the planned exit, such as the top floor of a building. They should continue working away from the released gas towards the exit. Applicators should not enter the same room more than once during the process of gas release. Full-face gas masks or supplied-air respirators and protective clothing should be worn by applicators until they have reached fresh air and there is no further possibility of exposure to the fumigant. Fans should be left running until uniform distribution of the fumigant is reached. Usually 30 to 60 minutes is sufficient.

AERATION OF STRUCTURES

Once the fumigation is completed, ventilation may be started by opening doors and windows from the outside of the building. The fans used for circulating the fumigant may be turned on again until the process of aeration is completed. If an applicator has to enter the building to open windows or doors for aeration, a supplied-air breathing apparatus should be used. Time spent in the building should be kept to a minimum.

After aeration, the building must be checked for residual gas with a suitable gas detector. No one must be allowed into the building until it is gas-free. This may take several hours. Finally, the fire department and the residents must be informed when the fumigation has ended and entry into the building is allowed.

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PERSONAL SAFETY

Appropriate combinations of chemically-resistant gloves, boots, pants, jacket and eye protection should be used to prevent exposure to fumigants in their solid or liquid forms. The dust from calcium cyanide or aluminum phosphide should not contact the skin. Generally, gloves are not worn when applying methyl bromide as they trap the gas against the skin, causing blisters or irritation. Rings and watches should also be removed.

In any fumigation work, a gas mask must be worn where there is a possibility of exposure to the gas. The gas mask is usually the most important piece of equipment for the safety of the fumigator. For most fumigation, the canister-type of respirator with full-face mask (gas mask) is used. The canister on this type of respirator gives protection for a specified period from gases that do not exceed a concentration of 2% by volume in air. It is most important to check before each fumigation that the canister on the respirator is the right one for use with the specific gas or mixture of gases being used (Table 14). Cartridge-type respirators give protection against gases up to only 0.1% by volume. They should not be used in any phase of fumigation work.

Table 14. Type of canister used with respirators for various fumigants.

Fumigant	Designation of Canister Type
methyl bromide	organic vapours
chloropicrin	organic vapours and gases
hydrogen cyanide (HCN)	acid gases
phosphine	all service

Directions on canister respirators warn that they are not to be used in situations immediately dangerous to life and health (IDLH). These respirators are not recommended for use where a person is exposed to continuing dangerous conditions during a fumigation operation. When such conditions occur, canister respirators should be used for emergency escape only. A self-contained breathing apparatus or a supplied-air respirator should be used for working where there are dangerous levels of fumigants. Such respirators are also required for entering a fumigation chamber where high levels of fumigant are present. Table 15 shows concentrations immediately dangerous to life and health (IDLH) for several fumigants.

DETECTING FUMIGANT GASES

The ability to detect the presence of a fumigant by its smell varies considerably with the fumigant in use (Table 15). Most fumigants have characteristic odours, but only phosphine has a good initial warning property that permits a worker to smell the chemical before it reaches 10% of the maximum exposure level permitted for an 8-hour period by W.C.B. Methyl bromide and chloropicrin are considered to have poor warning properties because their odour threshold is more than six times higher than the maximum permitted level. Chloropicrin may be added to methyl bromide to improve the ability of workers to detect methyl bromide. However, the use of chloropicrin does not assure that the applicator will smell the mixture before permissible levels of methyl bromide are exceeded.

There are three types of equipment for detecting levels of fumigants in the air: gas detector tubes, thermal conductivity meters and the halide meter. Gas detector tubes have the widest use and are best suited to evaluating fumigant levels in the region of permissible levels for human exposure. Different detector tubes are required for each fumigant.

Table 15. Some characteristics of structural and stored product fumigants (from W.C.B., 1985).

Fumigant	Maximum level permitted in air[1]	Odour	IDLH level[2]	Flammability
chloropicrin	0.1 ppm	acid, irritating		not flammable
hydrogen cyanide	10.0 ppm	bitter, almond	50 ppm	flammable
methyl bromide	5.0 ppm	none	2,000 ppm	not flammable
phosphine	0.3 ppm	onion, mustard	200 ppm	very flammable

[1] levels permitted for up to eight hours.

[2] Immediately Dangerous to Life or Health: a concentration which would cause a person without respiratory protection to be fatally injured or would cause irreversible and incapacitating effects on a person's health. Only self-contained or supplied-air respirators should be used for protection at or above the IDLH level (W.C.B. 1991, Standard Practices for Pesticide Applicators).

USEFUL PUBLICATIONS ON FUMIGATION

Monro, H.A.U. 1961. *Manual of Fumigation for Insect Control.* FAO Agriculture Studies No. 56. 289 pp.

Monro, H.A.U. 1969. *Insect Pests in Cargo Ships.* Canada Dept. Agric. Publ. 855, Ottawa. 39 pp.

Sinha, R.N. and W.E. Muir. 1973. *Grain Storage: Part of a system.* The AVI Publishing Co., Westport Conn. 481 pp.

Watters, F.L. 1976. *Insects and Mites in Farm-stored Grain in the Prairie Provinces.* Agriculture Canada Publication 1595. Department of Supply and Services, Ottawa. 25 pp.

REFERENCE LIST OF FUMIGANTS AND THEIR PROPERTIES

The following reference list includes a description of the pesticides registered for use as fumigants of structures and stored products in Canada when this text was published. The fumigants are listed alphabetically by active ingredient with some examples of trade names. No endorsement of products is implied. Information contained in this list could become out-of-date and not represent current use recommendations. **The current registered label is the authority on a pesticide's registered uses, application methods and safety precautions.**

aluminum phosphide *(Phostoxin, Phosphine, Detia Gas, Detia Tablets)* — formulated as pellets or tablets. Each formulation contains aluminum phosphide, ammonium carbamate and paraffin. The toxic gas, phosphine, and ammonia and carbon dioxide are released upon contact with water or moisture in air. Although phosphine is highly flammable, ammonia and carbon dioxide provide an inert atmosphere around the phosphine to suppress any fire hazard. The residue which remains after fumigation is non-poisonous. Aluminum phosphide is effective against all stages of insect pests and also against burrowing rodents. Phosphine is highly toxic to humans. An 'all-service' type canister must be used with a respirator during use of this fumigant. A concentration of 200 ppm of phosphine in air can be fatal to humans if exposed for less than one hour. Human exposure to 7 ppm can cause poisoning symptoms.

calcium cyanide — see hydrogen cyanide

chloropicrin *(Picfume)* — is a nonflammable tear gas, used to fumigate stored grain, soil and cereal products. When used to fumigate grain, no aeration is required. Chloropicrin should not be used to fumigate processed food or feeds. It is highly toxic to some plants. Chloropicrin is not used as a structural fumigant since the fumes do not dissipate quickly enough. Chloropicrin is nonflammable and is sometimes mixed with other fumigants to reduce their fire hazard. It is also mixed with other fumigants for its tear gas property so that no one can accidently remain in treated areas which contain fumigant in concentrations dangerous to human health. It is highly toxic to humans.

HCN — see hydrogen cyanide

hydrogen cyanide (calcium cyanide, HCN) — is a highly dangerous colourless gas, generated from the reaction of calcium cyanide with moisture. It is toxic to all forms of life but usually not phytotoxic at concentrations toxic to insects. HCN was once used as a fumigant for grain and other commodities. It is now used in British Columbia only for killing honeybee colonies. Its use requires a Restricted Use Permit. Hydrogen cyanide is highly toxic to humans (LD_{50}: oral = 4 mg/kg). It is readily absorbed through the skin.

methyl bromide *(Brom-O-Gas, Meth-O-Gas, Sanex MB-C-2)* — is one of the most versatile fumigants commonly used. It is a very penetrative fumigant, yet diffuses away quickly during the aeration process, leaving a minimum of residual vapour. Methyl bromide is effective as an insecticide, nematicide, herbicide, miticide and rodenticide. Methyl bromide is used to fumigate grain in bulk as well as all types of structures and transport vehicles, soil and commodities under tarps. Although nonflammable, it should not be stored in cylinders containing aluminum, as a highly flammable compound is then formed. In heavy infestations considerable time must be allowed for this rather slow-acting gas to take effect. As methyl bromide is odourless and colourless, chloropicrin is often added as a warning agent for applicators. This fumigant is highly toxic to man. Exposure to a concentration of 1,000 ppm methyl bromide in air for 30 to 60 minutes is dangerous to life. Repeated exposure to 100 ppm can cause serious poisoning.

phosphine – see aluminum phosphide

CHAPTER QUIZ

Questions

1. What is the difference between a true fumigant and a pesticide applied as an aerosol or mist?
2. Are fumigants more or less toxic to insects as temperatures increase?
3. How does sorption affect the concentration of fumigant in a fumigation chamber?
4. Why is it necessary to use fans to circulate methyl bromide?
5. When would an applicator use a canister-type respirator and when would an applicator require an air-supplied respirator?
6. Name the most widely-used device for measuring fumigant levels in air.

Answers

1. Fumigants are gases which disperse as individual molecules; aerosols and mists are liquid droplets suspended in air which do not readily penetrate cracks and stored products.
2. Fumigant toxicity increases as temperatures increase.
3. Sorption increases as the amount of material in a chamber increases, resulting in less fumigant available to kill the pest organisms.
4. Methyl bromide is heavier than air and will not mix readily unless the air is circulated.
5. Canister-type respirators should be used in situations where there is potential exposure to a fumigant gas, but not where the gas could be immediately dangerous to life or health. An air-supplied respirator may be required for entering a fumigated area, before aeration.
6. Gas detector tubes.

Chapter 14

WOOD DESTROYING INSECTS, FUNGI, AND THEIR CONTROL

CONTENTS

THE INSECTS AND FUNGI RESPONSIBLE FOR WOOD DETERIORATION

INTRODUCTION

The need to prevent wood from deteriorating is necessary in a wide variety of commercial and domestic situations in British Columbia. Fungi are the most frequent cause of wood deterioration. Insects such as termites, carpenter ants and powderpost beetles may also cause significant structural losses. Insects may cause direct structural damage or increase the susceptibility of wood to fungal decay.

INSECTS WHICH ATTACK WOOD

There are three groups of insects which cause significant damage to wood structures in British Columbia. A few other groups of insects cause relatively minor damage.

Termites. Two species of termites cause damage to wood structures in British Columbia: the Pacific dampwood termite and the western subterranean termite. The life-cycle stages of these termites consist of eggs which hatch into nymphs which become workers, soldiers or winged adults (gradual metamorphosis).

Pacific dampwood termites are found mainly in coastal areas. They prefer damp, rotting wood in contact with the ground or with a continual source of dampness. They feed on wood, usually following the grain. Their excavations may extend indefinitely as long as the wood is uninterrupted. They generally do not tunnel through soil or move across concrete surfaces. Flights of reproductive adults take place in late July through September. Pairs search out a suitable nest site, and lay eggs — usually in moist, rotting wood. It may take over four years for a large colony to develop.

Western subterranean termites establish colonies in dead wood in the soil. They may extend colonies into wood structures, above ground, by means of shelter tubes. These tubes may extend over concrete foundations or through cracks in foundations. They use these tubes to move between their soil nests and wood which provides them with a source of food. The nymphs are about 6 mm long — about half as large as the Pacific dampwood termite nymphs. Flights of reproductive adults generally occur in late summer after a rainfall.

Carpenter Ants. Carpenter ants excavate galleries in dead wood to provide room for their nest. They prefer partially decayed wood, but can bore into sound wood. They may also nest in debris or within walls (e.g. in insulation). Particles of wood are removed from galleries and generally discarded outside the nest area. Carpenter ants do not eat wood as termites do and often forage for food some distance away from the nest. Foraging ants or excavated wood particles, seen as 'sawdust' at the base of posts or along sills, may be indications of an infestation.

There are three species of carpenter ants in British Columbia. Only one species is known to bore into wooden structures. Ant specimens should be identified to be certain they are the species which causes structural damage.

Carpenter ants have four stages in their life-cycle (complete metamorphosis), consisting of the egg, larva, pupa and adult. In May through June, large winged adults (about 10 mm long) emerge and fly from nests which have been established for several years. During these swarms, mating takes place and a reproductive queen selects a site to lay eggs to start a new nest. This is usually in partially decayed, rotting wood. Several sizes and forms of adults develop to perform various tasks as a colony grows.

Powderpost beetles. There are several different species and some have a high degree of preference for certain types or species of wood. The beetles which attack softwoods (most structural lumber), often fly into crawl spaces beneath buildings or other sheltered spaces. They lay their eggs on exposed wood if the atmosphere is sufficiently humid. The larvae (less than 5 mm long) burrow into the wood where they tunnel for 1 to 2 years before pupating and emerging as an adult. Entrance holes are so small they are rarely observed, but exit holes are usually large enough to be seen and are associated with a fine sawdust. The appearance of the sawdust can be used to determine whether infestations are old or active. The adults may lay more eggs on nearby wood if the air remains sufficiently humid. As populations increase, they may reduce much of the interior of infested wood to a powder.

There are other wood-boring insects such as the golden buprestid, longhorned beetles and ambrosia beetles which enter wood shortly after trees are cut. These insects may live for several years in lumber used in construction and emerge into finished structures. They do not usually cause structural damage as their number will be few in any building and they do not usually reinfest after exiting from the wood.

Assistance with identification of these and other wood-boring insects can be obtained from experts at the Pacific Forestry Centre in Victoria.

THE WOOD-ATTACKING FUNGI

The fungi which attack wood can be divided into four groups:

Decay fungi. Decay-causing fungi are the most serious of the wood invaders as they attack the cell walls, reducing the strength of the wood (Figure 26). These wood-destroying fungi are in a class which is characterized by the production of conspicuous conks, brackets, or mushrooms which release millions of tiny spores capable of starting new infections if they land on damp, unprotected wood. Wood-destroying fungi develop most rapidly when temperatures are between 24 and 32°C, the moisture content of the wood is greater than 30 percent and the oxygen supply is adequate.

Attack by true wood-destroying fungi can be rapid

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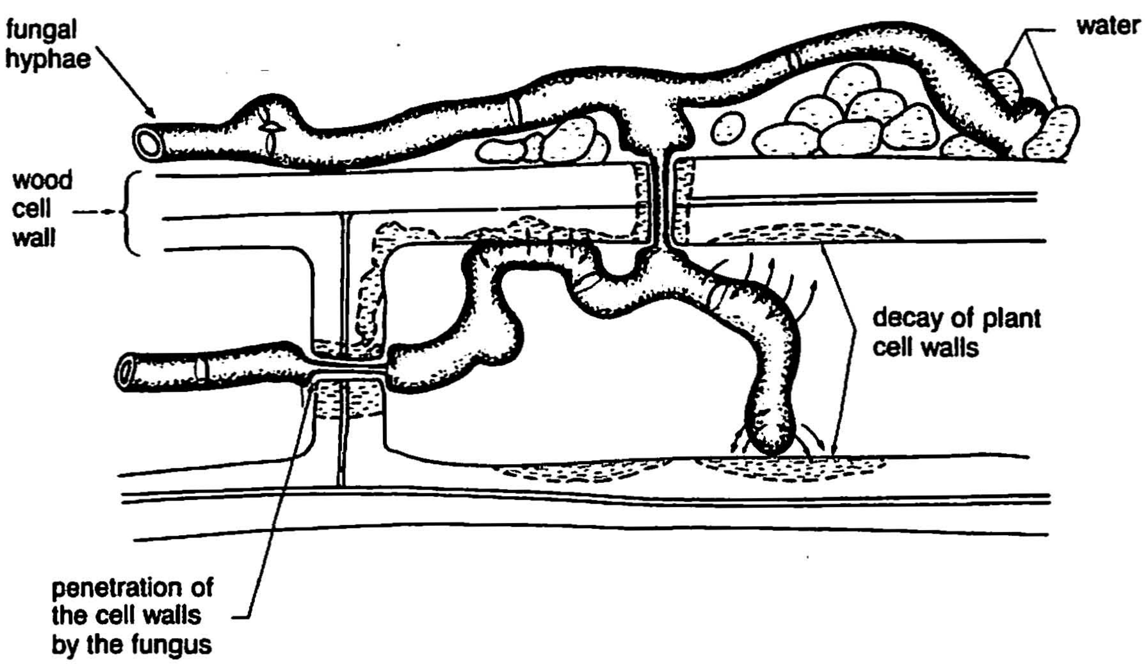

Figure 26. Diagram illustrating the microscopic hyphae (filaments) of a wood-destroying fungus (from Smith, 1977). Note the fungus requires damp conditions.

and can result in dramatic losses of wood weight and strength. When wood is outdoors, its rate of decay is limited by the natural variation in temperature and moisture content of the wood. But, under warm, moist conditions normally prevalent in houses, and where there is water seepage, structural lumber could be decayed to the point of collapse within one year.

Often such decay is incorrectly described as "dry rot". In fact, all wood-destroying fungi require moisture for decay or rot to occur. Dry rot is caused only by two fungi which possess water-conducting strands, so they can attack wood at some distance from a water source. The rots caused by other wood-destroying fungi are often referred to as wet rots. They may look dry and crumbly following remedial measures to correct the problem.

Moulds. Moulds develop on wood under warm, moist conditions. They are superficial and can be removed by brushing or planing. Moulds alone do not weaken wood, but they may aid the activities of more serious decay fungi. Moulds can be various colours and can be a problem in the production of clean, bright wood-pulp.

Sapstain fungi. These fungi penetrate sapwood resulting in a blue or black discolouration which cannot be removed. They feed on sugars and starches and do not attack the cell walls. Thus they have very little effect on wood strength. The sapstain fungi can quickly develop on freshly-cut lumber piled in lumber yards. Sapstaining may be especially severe during overseas transit under the warm, moist conditions in a ship's hold. The discoloration of lumber from sapstain fungi reduces the economic value of the lumber for domestic and foreign markets.

Soft-rot fungi. Under some conditions, such as extreme wetness, the decay fungi may be unable to develop, but soft-rot fungi may cause damage. They tend to be more tolerant of most chemical preservatives than the decay fungi and can be a problem in wooden water-tanks, pipes and pilings.

PREVENTING WOOD DETERIORATION

PHYSICAL ALTERATIONS

Wood destruction from fungi can be avoided or reduced in buildings and dwellings by good building practices, use of moisture barriers and maintenance of proper atmospheric humidity. Once wood has dried below 20 percent moisture content, it will not be subject to fungal decay. Even under exterior uses, very little decay occurs if the wood dries reasonably quickly after being wet. However, fungal decay will occur when wood is in contact with the ground or contains cracks, grooves or trimmings that hold water for prolonged periods.

Generally, insects will attack damp, rotting wood or wood in contact with the ground. Rotting wood is more susceptible to carpenter ants although they can also attack dry wood. Carpenter ants are discouraged by eliminating decayed wood such as in woodpiles alongside homes. Dampwood termites can be prevented if wood is kept dry. Control of existing colonies of these termites usually requires removal of the infested wood. Subterranean termites can be prevented if no wood is left in or on the soil to start a colony. Existing subterranean termite colonies are controlled by preventing the termites from moving between their soil nests and wood structures. There should be no cracks in foundations which provide termites with concealed access from the soil to wood. Powderpost beetles are discouraged if enclosed spaces are heated or well ventilated.

Wherever possible, the following precautions should be observed:

- always remove waste wood, such as concrete forms, from construction sites, crawl spaces and under dirt-filled porches;
- avoid contact of wood with the soil whenever possible;
- use good wood, i.e. not infested wood;
- avoid the use of excessively green wood from freshly cut trees;
- always join wood properly;
- install moisture barriers, e.g. polyethylene sheeting behind the drywall finish inside the stud walls and polyethylene over dirt floors in crawl spaces;
- provide sufficient roof overhang and install adequate gutters, flashings and down-pipes;
- ventilate crawl spaces and attics;
- maintain painted wood surfaces;
- repair leaking plumbing and roofs promptly; and
- heat dwellings sufficiently to avoid dampness.

WHERE PESTICIDES ARE USED

Pesticides are used to prevent, stop or retard the action of insects and fungi which cause wood to deteriorate. **Wood preservatives** protect wood against both fungi and insects. Some **insecticides** protect against specific wood-destroying insects. A small number of **anti-sapstain chemicals** are used to protect lumber from sapstain fungi. These pesticides are used to prevent wood deterioration in a wide variety of commercial enterprises:

- lumber companies use wood preservatives to pressure treat some structural lumber to be used on exteriors or in damp locations;
- some exterior lumber, particularly 'field cuts' of pressure-treated wood, may be treated with a wood preservative by brushing or dipping during construction;
- wood used for railroad trestles, railway ties and bridges is usually pressure treated with a wood preservative before installation;
- hydro poles, telephone poles, wooden pilings and fence posts are treated with a wood preservative before installation;

- standing poles (e.g. Hydro) already installed in the ground are sometimes treated with a wood preservative by injection or bandage application to retard their deterioration;
- a wood preservative may be applied to retard or stop *localized decay* in existing buildings;
- a wood preservative may be applied to greenhouse flats or to fruit and vegetable containers to prevent growth of moulds;
- insecticides are applied to eradicate insect infestations in buildings; and
- anti-sapstain chemicals may be applied to lumber after being rough cut and again after final cutting to protect against sapstain fungi.

Insecticides, wood preservatives and anti-sapstain chemicals are pesticides and must be registered under the Pest Control Products Act (Canada). Paints with very low concentrations of preservatives to prevent fungal growth in the paint are not considered pesticides. However, paints and stains which are sold as wood preservatives must be registered as pest control products.

Structural pest control operators often treat insect infestations and occasionally deal with fungal decay problems. Certified applicators must be in attendance during such treatments.

Some anti-sapstain pesticides and wood preservatives are applied at sawmills, lumberyards or wood preservation plants to supply treated wood for new construction. Applicator certification may not be required on such industrial sites, although workers should be well-trained to handle these chemicals safely. A waste disposal permit must be obtained from the Waste Management Branch of the Ministry of Environment and Parks to dispose of wood wastes containing anti-sapstain chemicals and wood preservatives.

TYPES OF PESTICIDES

Insecticides. A wide variety of insecticides are available to control carpenter ants (any product registered for ants). A number of carbamate and organophosphorous insecticides (e.g. carbaryl, propoxur, chlorpyrifos, diazinon and fenthion) have a moderate residual activity when applied as a barrier for foraging ants. Dusts are usually better than sprays for forcing pesticides into cracks and crevices.

Few insecticides are currently registered for treatment of termites and powderpost beetles. Chlorpyrifos has recently been registered for control of termites.

Wood Preservatives. There are a number of wood preservatives with different properties and uses. Care should be taken to select the right preservative for the intended use of the wood. Both creosote and pentachlorophenol are widely used preservatives because of their high toxicity to fungi and insects. However, both can cause acute toxic effects in humans. As well, both contain contaminants which are suspected to cause chronic health effects after long-term exposure. Care must be taken to use these preservatives only on exterior surfaces where they will not be in contact with humans or animals. Treated wood may produce vapours for several years. Therefore, these preservatives should not be applied where their vapours will drift into houses or work areas. Treated wood should not be used in farm buildings, in areas contacted by farm animals, feed or agricultural products.

There are three wood preservatives with interior and exterior uses. Copper naphthenate is less effective, but also less hazardous than pentachlorophenol or creosote. Copper naphthenate is used on boat hulls, exterior planking, greenhouse benches, flats, posts and poles. Where the green colour of copper naphthenate cannot be tolerated, zinc naphthenate may be substituted. However, it is otherwise inferior. Copper-8-quinolinolate is the only preservative registered for treatment of picking-baskets, vegetable boxes, refrigerator shelving, etc., where contact with food is a possibility.

There are a number of preservatives used in pressure treatment plants and commercial soaking or steeping operations. Some of the more important of these pesticides are the oil-based formulations of creosote and pentachlorophenol or water-based products containing mixtures of metallic salts. These salts are mainly chromated copper arsenate (CCA) and ammoniacal copper arsenate (ACA).

Sapstain Protection Chemicals. Several commercial anti-sapstain products are used in British Columbia. The most widely used products contain the water-soluble active ingredients sodium tetrachlorophenate and sodium pentachlorophenate. These chemicals have a relatively high toxicity and are very hazardous if used without adequate safeguards to reduce exposure to workers or the environment. Two additional chemicals registered for anti-sapstain use are copper-8-quinolinolate and TCMTB. These are less toxic than the sodium chlorophenates.

PESTICIDE APPLICATION METHODS

Pressure treatment. Pressure treatment involves the use of high pressure to force chemical preservative into the subsurface layers of wood. Pressure treatment is the best method for treating wood where there is a potential for severe decay. It can only be done at commercial pressure-treatment plants. Wood to be treated must first be kiln-dried or well seasoned to remove water. Dry wood allows good penetration of the preservative.

Soaking. Wood may be left to soak for several hours to several days in solutions of wood preservative such as creosote, pentachlorophenol or copper naphthenate. In the hot and cold bath method, well-seasoned wood is placed in heated preservatives for one to three hours, then transferred to a cool tank for a further hour. If wood is soaked in cool preservative only, it should be left for a minimum of 24 to 48 hours to a maximum of a week.

The wood should have no bark and must be dry. The treatment is most effective when done during warm weather in summer. Soaking is a practical method of treatment that may extend the life of fence posts to 20 years or more. Penetration depends on the type of wood treated and the oil or solvent used. Heat improves penetration.

Dipping. Wood, such as window sashes, that will be used where the decay potential is low, may be dipped for a few seconds to 15 minutes in one of the oil-type preservatives. The wood must be well seasoned before dipping. This is a very fast, low-cost operation, but is of little value for preservation of wood used in severe decay situations.

Surface application. Applying two coats of a preservative oil by spraying, brushing or flooding may be useful for certain exterior woodwork. This is almost useless for preservation of fence-posts or other wood in severe decay situations. Surface treatments with preservatives or insecticides may not be effective against termite infestations as the pesticides will not penetrate far into the wood. However, control of localized infestations of termites in buildings may be obtained by applying pesticide to voids and channels in damaged wood, to spaces between members of a structure and between wood and foundations. Applications may be made to inaccessible areas by drilling and then injecting the pesticide into voids and galleries. Surface treatments of wood may be effective in control of powderpost beetles to prevent adults from laying eggs on wood surfaces *after* they emerge. It is unlikely that the powderpost beetle larvae tunnelling inside the wood will be affected by surface applications.

Perimeter treatments. A barrier of pesticide can be applied as a perimeter spray or dust around building foundations to control carpenter ants. The pesticide is contacted as the ants leave the nest to forage. The ants should have no way to leave the building except to cross the pesticide treated area (e.g. remove wood piles and tree branches against buildings).

Foundation treatments. Subterranean termites are controlled by applying a residual pesticide around a building's foundations — in the soil on the outside of foundation walls, under cement slabs, in foundation wall voids and inside the foundation wall, if there is a dirt crawl space.

Treatment of standing poles, posts and beams. Poles for telephone and hydro lines, and posts and beams of bridges, may be treated some years after installation to retard decay and extend their life. The area of most concern is at the ground-line where decay is most rapid. One treatment method is to install ground-line 'bandages', which usually contain a formulation of pentachlorophenol in grease. The following procedure may be used:

(a) the soil is excavated to a depth of 45 to 60 cm,
(b) all decayed wood is scraped off,
(c) a 5 to 10 mm thick coating of approximately 10 percent pentachlorophenol in grease is applied in a band from about 45 to 55 cm wide — usually from just above the soil-line to at least 10 cm below the area of decay,
(d) the treated area is wrapped in a waterproof bandage, and
(e) the excavation is backfilled.

Note that precautions with such ground-line bandages include preventing contamination of drinking water, lakes, streams or rivers. In situations where livestock or wildlife may contact the treatment area, it is recommended that an additional barrier of cloth is placed over the bandage, particularly above the soil (see labels for detailed directions and precautions).

There are several other on-site decay treatment methods. Two fumigants, chloropicrin and metam-sodium, are registered for this purpose. These fumigants are poured or injected as a liquid into drilled holes which are then plugged with dowels. The liquid converts to a gas which permeates the pole and kills decay causing organisms. Pentachlorophenol solutions also may be injected or pumped into drill holes which are then plugged. Wood preservation gels (consisting of mixtures of active ingredients such as sodium fluoride, creosote, potassium dichromate, 2,4-dinitrophenol and pentachlorophenol) may be brushed onto prepared surfaces. These mixtures are highly toxic and must be handled with caution. When such on-site treatments are required on public land, or on private land used for forestry, transportation or public utility purposes, a pesticide use permit must be obtained.

Sapstain prevention. Anti-sapstain chemicals are used to prevent growth of the fungi which attack freshly-cut, unseasoned lumber. The fungus stains the wood to cause unsightly blemishes. Several commercial anti-sapstain products are widely used by the lumber industry. These chemicals are dissolved in water and are directly applied to lumber, either by spray applications or submerging the lumber for a few seconds in a diptank containing the treatment solution. While such treatments usually occur on privately-owned land, special care is required in locating and operating sapstain protection facilities to prevent worker and environmental contamination.

SAFETY PRECAUTIONS

All wood preservatives are poisonous to animals, therefore precautions must be taken during applications. The least hazardous preservatives, such as copper naphthenate, zinc sulphate and borax, are dangerous primarily if taken internally or if skin or eyes are severely contaminated. The more hazardous preservatives include creosote, the chlorophenols, the heavy metal salts (CCA and ACA) and patented mixtures containing sodium fluoride, potassium dichromate or dinitrophenol and other ingredients. Care must be taken with these chemicals to avoid oral intake. As well, skin and eye contact and inhalation of vapours should be avoided.

The two most commonly used hazardous pesticides are creosote and pentachlorophenol. Creosote is less of a problem because it is so objectionable in appearance and odour that workers usually take extra care to avoid contact. About two tablespoons of creosote would be lethal to an adult if taken orally. Recent studies have suggested that long-term exposure to creosote could lead to chronic health effects.

One of the greatest dangers of poisoning is during the use of pentachlorophenol. Because it is readily available and 'safe-looking', many people assume it is safe and either don't read or ignore the label warnings. Pentachlorophenol is easily absorbed through the skin and by inhalation. In North America, there have been numerous cases of poisoning due to excessive skin exposure to this chemical; some incidents have been fatal. Symptoms of poisoning are characterized by weakness, marked loss of appetite, a feeling of constriction in the chest, laboured breathing when doing moderate exercise and almost always excessive sweating. Headache, dizziness, nausea and vomiting may be present. Illness may be produced by the cumulative effect of several exposures. The onset of severe illness tends to be very sudden.

Protective clothing is strongly recommended when using all preservatives. Follow label directions and observe basic precautions appropriate for all pesticides.

- use liquid-proof gloves and boots which protect against the pesticide applied;
- protect the eyes with goggles or face shields and use a liquid-proof apron if there is any possibility of splashing;
- change and launder clothing daily when handling preservatives; and
- never allow food or drink near operations involving these preservatives.

Wood treated with creosote and pentachlorophenol must not be used indoors or on children's playground equipment or picnic tables. Treated wood should be handled with gloves. Wood treated with most other preservatives is unlikely to cause more than a minor skin irritation to humans, but should be dry before use.

All wood preservatives are toxic to plants to some degree. Creosote and pentachlorophenol will kill all foliage they contact. Creosote and pentachlorophenol are not approved for use on greenhouse benches and flats. Copper naphthenate is safe for use in greenhouses provided the treated wood or clay pots are dry before planting. CCA is registered for the pressure treatment of wood to be used in greenhouses and landscape timbers.

The large-scale use of sapstain control chemicals and their high toxicity has resulted in concern for worker and environmental safety in the forest industry. A publication titled *Chlorophenate Wood Protection — Recommendations for Design and Operation,* contains information on the use of sapstain prevention chemicals. This publication is available from the B.C. Ministry of Environment and Parks. Workers employed in sapstain protection operations should be familiar with the personal protection discussed in this publication.

USEFUL PUBLICATIONS IN DECAY PREVENTION AND CONTROL OF WOOD-ATTACKING INSECTS

Canadian Standards Association. 1983. *Wood Preservation.* CSA 080. Rexdale, Ontario.

Ebeling, W. 1975. *Urban Entomology*. University of California, Division of Agricultural Sciences. 694 pp.

Henning, F.A. and D.E. Konasewich. 1984. *Recommendations for the Design and Operaion of Creosote Wood Preservation Facilities*. Environment Canada, Environmental Protection Service. Vancouver, B.C. 113 pp.

____________. 1984. *Recommendations for the Design and Operation of Pentachlorophenol Pressure Treating Wood Preservation Facilities*. Environment Canada, Environmental Protection Service. Vancouver, B.C. 121 pp.

____________. 1984. *Recommendations for the Design and Operation of ACA Wood Preservation Facilities.* Environment Canada, Environmental Protection Service. Vancouver, B.C. 121 pp.

____________. 1984. *Recommendations for the Design and Operation of Pentachlorophenol Thermal Treating Wood Preservation Facilities*. Environment Canada, Environmental Protection Service. Vancouver, B.C. 118 pp.

____________. 1984. *Technical recommendations For the Design and Operation of CCA Wood Preservation Facilities.* Environment Canada, Environmental Protection Service. Vancouver, B.C. 109 pp.

Konasewich, D.E. *et al.*, 1983. *Chlorophenate Wood Protection: Recommendations For Design and Operation*. B.C. Ministry of Environment, Victoria. 90 pp.

Krzyzewski, J. and H.P. Sedziak. 1974. *Preservation and Performance of Fence Posts*. Eastern Forests Products Laboratory Report OPX82E. Forestry Service, Environment Canada. 29 pp.

Ormrod, D.J. 1978. *Wood Preservation on the Farm*. B.C. Ministry of Agriculture. Publication No. 78-19. Victoria. 10 pp.

Ruppel, D.H. 1978. *Carpenter Ants*. Forest pest leaflet No. 58. Pacific Forest Research Centre. Forestry Service, Environment Canada. 6 pp.

Ruppel, D.H. 1978. *Termites in British Columbia*. Forest Pest Leaflet No. 57. Pacific Forest Research Centre. Forestry Service, Environment Canada. 6 pp.

Smith, R.S. 1977. *Protection and Preservation of Wood Against Attack by Fungi.* Western Forest Products Laboratory Information Report JP-X-170. Forestry Directorate, Fisheries and Environment Canada. Vancouver. 14 pp.

Truman, L.C. *et al.* 1976. *Scientific Guide to Pest Control Operations*. Harvest Publishing Co. Cleveland, Ohio. 276 pp.

Note: The former Western Forest Products Laboratory of the Canadian Forestry Service evaluated wood preservatives and application methods for many years. The laboratory has now been transferred to the private sector and is known as Forintek Canada Corporation. The company continues to conduct research for the wood products section of the forest industry. Enquiries can be directed to: Forintek Canada Corp. Western Laboratory, 6620 N.W. Marine Drive, Vancouver, B.C. V6T 1X2.

REFERENCE LIST OF WOOD PRESERVATIVES AND ANTI-SAPSTAIN CHEMICALS[1]

The following reference list includes a description of most wood preservatives and anti-sapstain chemicals used in British Columbia when this text was published. The pesticides are listed alphabetically by active ingredient with some examples of trade names. No endorsement of products is implied. Information contained in these lists could become out-of-date and not represent current recommendations. **The current registered label is the authority on a pesticide's registered uses, application methods and safety precautions.**

The relative acute mammalian toxicity is given for each active ingredient listed. LD_{50} values (mg/kg body weight) are listed where available and are derived from tests with rats unless indicated otherwise (Rb = rabbit). The lowest LD_{50} is listed for each pesticide where several are given in the literature reviewed.

ammoniacal copper arsenate (ACA) — is an arsenic compound formulated with arsenic pentoxide, copper oxide and ammonia. This product is used in the pressure treatment of telephone poles and landscape timbers. It has a high mammalian acute toxicity (arsenic pentoxide LD_{50}: oral = 8) and may cause chronic effects in workers exposed over long periods. Exposure to ammonia gas is a potential cause of acute toxic effects for unprotected workers in wood preservation plants. ACA is toxic to aquatic life; copper is the most toxic constituent.

arsenic pentoxide — see ammoniacal copper arsenate and chromated copper arsenate.

bis (tri-n-butyltin) oxide — is formulated with copper naphthenate to be used on field cuts (i.e. cut ends) of pressure treated lumber. It has a moderate mammalian acute toxicity (LD_{50}: oral = 87; dermal = 1,170).

borax (sodium tetraborate decahydrate) — is an inorganic compound formulated with sodium pentachlorophenate, sodium tetrachlorophenate, and related chlorophenates to resist blue stain, sapstain and mould on freshly-cut lumber. It may be applied as a dip or spray, depending on the formulation. Do not expose freshly-treated lumber to rain. Keep away from desirable plant species and do not contaminate root zones. Borax alone has a relatively low mammalian toxicity (LD_{50}: oral = 2,660).

[1] See reference List in Chapter 8 for insecticides discussed in this Chapter.

borax, anhydrous (sodium tetraborate anhydrous) — is an inorganic compound formulated with creosote, pentachlorophenol, tetrachlorophenol, and related chlorophenols to resist termites and stop wood decay on standing poles and posts. It is applied as a grease in a bandage treatment. Care must be taken to keep livestock and wildlife from treated surfaces. Keep away from desirable plant species and do not contaminate root zones.

chloropicrin *(Timberfume)* — is a nonflammable tear-gas used to stop decay in standing posts and poles. It is injected as a liquid into drilled holes. The holes are plugged and the gas produced by the liquid permeates the wood. The vapours of chloropicrin are extremely irritating. It should be handled outdoors when measuring out or transferring to other containers. Do not allow chloropicrin liquid or vapours to contact any desirable plants. Its vapours can be fatal if inhaled.

chromated copper arsenic (CCA) — is an arsenic compound formulated with arsenic pentoxide, chromic acid and copper oxide. It is used mainly for pressure treatment of wood used for patio construction, playground equipment, landscape and foundation lumber and fence posts. It can be used as a brush-on treatment only for field-cuts of lumber (i.e. cut ends of pressure treated lumber). It has a high mammalian acute toxicity (arsenic pentoxide LD_{50}: oral = 8) and may cause chronic effects in workers exposed over long periods. CCA is toxic to aquatic life; copper is the most toxic constituent.

chromic acid — see chromated copper arsenic.

coal tar creosote — see creosote

copper naphthenate *(Green Cuprinol, Nuodex Copper)* — is an organic copper compound used to resist wood decay, termites and wood borers in exterior and interior structural lumber. Formulations with bis (tri-n-butyltin) oxide are used for the same purposes and also are used for application to field cuts. Copper naphthenate may be applied by brush, spray or dip. It is not to be used on surfaces contacted by food. It is phytotoxic. Copper naphthenate has a moderate acute mammalian toxicity (LD_{50}: oral = 450).

copper oxide — see chromated copper arsenic. It has a moderate acute mammalian toxicity (LD_{50}: oral = 470).

copper-8-quinolinolate *(Oxine-Copper, Quindex)* — is an organic copper compound applied by brush or spray or by dipping to resist mould and sapstain on logs and lumber. It is also used as a dip to resist mould, rot and stain on horticultural lumber (e.g. fruit and vegetable containers, field crates, pallets, greenhouse flats). It is applied by soaking or pressure treatment to resist decay in poles, posts and structural lumber. It is also formulated with tetrachlorophenol or pentachlorophenol to be used as a dip or spray to prevent mould and sapstain on timbers and freshly-cut lumber. Copper-8-quinolinolate is harmful if swallowed and is an eye and skin irritant mainly because it is acidic. Formulations with petroleum distillates are highly flammable. It has a low acute mammalian toxicity (LD_{50}: oral > 10,000).

creosote (coal tar creosote) — is a distillation product collected during the preparation of coke from bituminous coal. Wood is pressure treated with creosote for preservation of railway ties, pilings and bridge timbers. It is applied by brush or as a dip or steep process to resist decay in poles, posts and structural lumber. Creosote is formulated with dinitrophenol, potassium dichromate, pentachlorophenol and sodium fluoride to be used for treating the groundline area of posts and poles — applied with a brush, spatula or as a bandage. Creosote is highly toxic to fungi and insects. It is long-lasting in both fresh and salt water. Disadvantages of creosote include the strong odour, it is sticky and black on freshly treated wood, and it is inflammable for a time after treatment until the lighter oils have evaporated. Creosote has a low acute mammalian toxicity (LD_{50}: oral = 725), however it is irritating to the skin and easily absorbed through the skin. Components of creosote have been found to act as accelerators or promoters of carcinogenesis in test animals. Creosote is phytotoxic and is toxic to fish.

cupric oxide — see copper oxide

dichlofluonid — is a sulfamide compound with fungicide activity. It is incorporated in paints and stains to resist wood decay. Dichlofluanid has a moderate mammalian acute toxicity (LD_{50}: oral = 500).

dinitrophenol — see creosote

metam-sodium *(Pole-Fume, Wood-Fume)* — is a liquid fumigant used to stop insects and decay in standing poles and posts. Metam-sodium is applied by drilling and injection. The liquid breaks down into methyl isothiocyanate which permeates the wood as a gas. The liquid metam-sodium has a low acute mammalian toxicity (LD_{50}: oral = 820), but is hazardous because of the gas it produces. Metam-sodium is irritating to the eyes, nose, throat and skin. A respirator should be worn if applying metam-sodium in an enclosed space. The oral LD_{50} for methyl isothiocyanate is 97.

pentachlorophenol plus related chlorophenols — is used extensively for wood preservation. The active ingredients usually consist of 85% pentachlorophenol and 15% other chlorophenols. It is available in three forms: dry flakes used in commercial preparation of preservative solutions, concentrated solutions (usually 40 percent PCP), and ready-to-use solutions (usually five percent PCP). The type of petroleum oil used as a solvent depends on the intended use of the treated wood. Wood which is not subject to severe decay conditions may be dipped in light oil solutions of PCP. The oil evaporates quickly, leaving a paintable surface. Wood which requires greater decay resistance and yet must be painted after treatment is frequently pressure-treated with pentachlorophenol in light oil or liquefied gas. PCP is also formulated with borax anhydrous, creosote, copper-8-quinolinolate, dichlorfluanid, sodium fluoride, TCMTB or tetrachlorophenol. Pentachlorophenol is not to be used on interiors of buildings or on horticultural lumber or on surfaces that contact food or farm animals. Pentachlorophenol has a moderate acute mammalian toxicity (LD_{50}: oral = 125; dermal = 320). Illness may be produced by the cumulative action of several doses and the onset of critical illness can be sudden. Atropine should not be used as an antidote for poisoning. Pentachlorophenol contains contaminants which may cause chronic health effects following long-term exposure. It is highly toxic to fish and is phytotoxic.

sodium fluoride — see creosote. Sodium fluoride has a high mammalian toxicity (75 — 150 mg/kg is lethal to man).

sodium pentachlorophenate — is formulated with sodium tetrachlorophenate and related chlorophenols to resist stains, mould and decay on freshly cut lumber and timber. It is applied as a spray or by dipping. It has a moderate mammalian acute toxicity (LD_{50}: oral = 210, dermal = 250). It contains contaminants which may cause chronic health effects with long-term exposure. It is highly toxic to fish and is phytotoxic.

sodium tetraborate-anhydrous — see borax, anhydrous

sodium tetraborate decahydrate — see borax

sodium tetrachlorophenate — see sodium pentachlorophenate

TCMTB *(Busan)* — is a thiocyanate compound (2-(thiocyanomethylthio) benzothiazole) used as an anti-sapstain treatment. It is applied by spray or by dipping freshly cut lumber. TCMTB has a low mammalian toxicity (LD_{50}: oral = 1,590; dermal > 10,000 Rb), but is toxic to fish.

zinc naphthenate *(Clear Cuprinol, Nuodex Zinc)* — is an organic zinc compound which is applied by brushing or spraying or by dipping or soaking wood to resist decay, termites and wood-borers. Some formulations incorporate pentachlorophenol. Zinc naphthenate is phytotoxic. It has a low acute mammalian toxicity (LD_{50}: oral = 4,920).

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CHAPTER QUIZ

Questions

1. Name the three main groups of insects causing structural damage and the type of wood they are likely to attack.

2. What damage is caused by the four types of fungi which attack wood?

3. What is the main physical method to prevent wood decay?

4. What wood preservatives can be used on interior surfaces of buildings?

5. List the order of the following wood preservative application methods from most to least effective:
a) dipping, b) brushing, c) pressure, d) soaking.

6. Should wood be dry when using a preservative? Why?

7. Why is pentachlorophenol considered a hazardous wood preservative?

8. Could chlorophenates on the skin cause health problems? What are symptoms of poisoning?

Answers

1. **carpenter ants** — prefer rotting wood but can excavate sound wood.
termites — western subterranean termites require rotting wood in soil to start a colony, then can enter structural wood if in contact with soil or through shelter tubes; dampwood termites require damp wood to become established.
powderpost beetles — require a humid enclosed space.

2. **decay fungi** — destroy wood strength
moulds — may encourage decay fungi and can stain wood
sapstain fungi — stain wood
soft-rot fungi — can cause wood decay in very wet conditions.

3. reduce moisture content of the wood; once wood is dried to less than 20% moisture content, it will not decay.

4. Three wood preservatives can be used on interior surfaces: copper napthenate, zinc napthenate and copper-8-quinolinolate.

5. pressure, soaking, dipping, brushing.

6. yes — wet wood will not absorb preservatives.

7. Pentachlorophenol does not smell strongly and is easily splashed on skin when used carelessly. Severe illness can occur rapidly with little warning.

8. yes — weakness, loss of appetite, feeling of constriction in chest, laboured breathing, excess sweating.

Chapter 15

BIRD CONTROL, AVICIDES AND BIRD REPELLENTS

CONTENTS

BIRD CONTROL AND ITS REGULATION

Although more than 400 bird species occur in British Columbia, only a few of them become pests. Birds may be pests by damaging crops or injuring livestock, or by nesting and roosting in buildings. Large numbers of roosting birds may result in unacceptable noise levels and may deface buildings and automobiles with their excrement. Birds and bird droppings may pose a health hazard by carrying disease organisms which can cause serious illness in people or in domestic animals. For example, rock doves (also called feral pigeons or domestic pigeons) can carry several disease organisms which can infect humans. Around airports, birds may pose a safety hazard to air traffic.

Bird control may be accomplished either by lethal methods such as use of avicides, shooting or trapping, or non-lethal methods such as chemical repellents, mechanical scaring devices or protective netting. Non-lethal methods are generally preferred for several reasons:

- many crop-damaging bird species (e.g. European starling and American robin) are beneficial to agriculture when not damaging crops,
- non-lethal methods are often more effective in reducing damage than lethal methods,
- lethal methods may be hazardous to non-target species of birds or mammals, and
- many people are opposed to killing birds under any circumstances.

Bird control in urban areas is likely to be controversial, especially if poisoning is involved. Such control programs should include public information meetings or advertisements.

A list of major bird pest species in British Columbia, and permit requirements for their control, is given in Table 16. Proper identification of the bird species is necessary both for obtaining the correct permit and selecting the most appropriate control method. Assistance in bird identification can be obtained from a District Conservation Officer (Ministry of Environment) or a District Horticulturist (Ministry of Agriculture and Fisheries).

The federal Migratory Bird Regulations, administered by the Canadian Wildlife Service of Environment Canada, protect most species of migratory birds, including their eggs and nestlings. A federal permit is required to kill or frighten federally-protected species. Most other bird species (e.g. upland game birds, hawks and owls, the crow family, and blackbirds) are protected by the provincial Wildlife Act, and a permit from the Wildlife Branch, Ministry of Environment, is needed to kill or frighten them. Six bird species (rock dove, black-billed magpie, American crow, northwestern crow, European starling, and house sparrow) are not protected by either federal or provincial laws and can be killed by approved methods without a permit.

The B.C. Ministry of Environment can occasionally issue federal permits as well as provincial ones. Initial inquiries about permits should be directed to a District Conservation Officer of the B.C. Ministry of Environment.

Persons planning to shoot pest birds must have a valid firearms or hunting licence. They should check with local authorities (municipal or Regional District governments, or RCMP offices) about areas closed to shooting. Persons planning to scare birds should enquire about local noise bylaws which may prohibit operation of bird-scaring noisemakers in some areas.

Table 16. Structural, airport and agricultural bird pests[1] of British Columbia and permit requirements for their control (type of pest in parenthesis: A = airport, C = crop, L = livestock and poultry, S = structural).

No Permit Required	Federal Permit Required[2]
American Crow (C,L)	American Robin (C)
Black-billed Magpie (C,L)	American Wigeon (C,A)
European Starling (C,S,A)	Barn Swallow (S)
House Sparrow (S)	Canada Goose (C,A)
Northwestern Crow (C,L)	Cedar Waxwing (C)
Rock Dove (S,C)	Cliff Swallow (S)
	Dunlin (A)
Provincial Permit Required[2]	Glaucous-winged Gull (A,S)
Brewer's Blackbird (C)	Mallard (C,A)
Common Raven (L)[3]	Mew Gull (A)
Red-winged Blackbird (C)	Northern Pintail (C,A)
Ring-necked Pheasant (C)	Sandhill Crane (C)
Steller's Jay (C)	Snow Goose (C,A)
	Thayer's Gull (A)
	Trumpeter Swan (C)

[1]Bird names follow the American Ornithologists' Union Checklist (1983).

[2]For some of these pest birds (e.g. trumpeter swan, swallows), kill permits are not normally issued; for others, kill permits, as opposed to scare permits, may be issued only if damage is serious.

[3]Can be shot without a permit but with a valid hunting licence in certain regions.

METHODS OF CONTROL

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Control of pest birds may require a combination of several methods to be effective. Identification of the birds and careful observation of their habits will help in selecting the most appropriate control method(s). Control methods may be grouped into the following categories: bird-proofing, repellents, chemosterilants and lethal techniques.

BIRD-PROOFING

Bird-proofing of buildings is the best and most permanent means of dealing with structural bird pests. Starlings can be prevented from nesting in buildings by covering all openings with chicken wire or netting with a small mesh size (no more than 2 cm). Birds can be prevented from sitting or nesting on ledges by the use of netting, rows of metal spikes or pieces of slanting wood or metal to eliminate flat surfaces preferred by birds. Strips of heavy plastic such as polyvinyl chloride (PVC), suspended from doorways, will exclude birds from warehouses or farm buildings. Overhead wires can discourage gulls from congregating on buildings, in parks or other places where they are a nuisance. Designers of buildings should be aware of potential bird problems and should avoid including features attractive to birds. Protected ledges and window-sills are an open invitation to pigeons and other bird species.

Netting can also be used to protect home gardens, as well as commercial vineyards or berry fields from birds, but it is a costly method suitable only for high-value crops.

BIRD REPELLENTS

Four main types of bird repellents are recognized.

Auditory repellents. A variety of noisemaking devices are used to frighten birds. The most common are: automatic exploders (usually propane-powered), electronic noisemakers such as Av-Alarm, bird alarm and distress calls broadcast at high volume, special "orchard pistols" equipped with noisemaking "cracker" or "whistler" shells, or ordinary shotguns used as a frightening device by a person patrolling fields or orchards. Electronic noisemakers generally disperse birds over several days while other noisemaking devices should cause an immediate fright response. Broadcast alarm and distress calls can be highly effective in dispersing roosting birds in urban areas (under permit), but other noisemakers generally cannot be used in urban areas because of noise bylaws.

Visual repellents. Visual devices can be used to frighten some birds. Yellow plastic streamers which twist in the wind are suspended from poles above a vineyard or berry field. They produce flashes of light that have a repellent effect. Models of hawks or other predators, suspended from a balloon or from a tall pole, offer some protection against fruit-eating birds, although results have been inconsistent. Stationary models of owls or hawks, mounted on buildings, are soon ignored.

Non-poisonous chemical repellents. Several products known as gluepaste repellents (polymerized butenes), are useful for repelling birds from exterior ledges, from windowsills or from beams inside buildings. These chemicals are non-poisonous, but are sticky and irritating to birds. They may be effective for up to a year, but will have to be reapplied more frequently in exterior locations exposed to the weather. They can be applied either directly to a ledge or beam or, if needed for a short time only, can be applied on top of adhesive tape, which can later be removed. Ledges must be clean before applying the paste. Care must be taken that the material is not applied where maintenance personnel are likely to pick it up on their shoes.

Gluepastes have some drawbacks. Pigeons will sometimes deposit straw and nesting material on top of the gluepaste. Depending on the location of the ledges or beams, application of gluepastes may be costly and impractical; also, they are not effective in dusty areas. Where feasible, bird-proofing by means of netting or metal spikes is preferable to gluepastes, since it is a permanent solution to the bird problem, rather than a temporary one.

Poisonous chemical repellents. There is only one poisonous product, *Avitrol* (4-aminopyridine) registered for repelling birds in Canada. Birds eating *Avitrol*-impregnated baits react with erratic behaviour and distress calls, causing the remainder of the flock to become alarmed and leave the area. Although some bird mortality can be expected with *Avitrol*, effective bird control can often be achieved with a mortality rate of less than 3% of the flock. Thus *Avitrol* is considered a repellent rather than an avicide.

Avitrol may be used as a repellent for blackbirds and starlings in corn; for rock doves, house sparrows, starlings and blackbirds around buildings and feed plants; and for gulls on airports. It is sold as a concentrate and as a premixed bait, in several formulations. The formulation used depends on the type of pest bird (e.g. whole corn is suitable for pigeons but not for smaller birds).

A careful study of bird feeding habits and locations prior to baiting is essential. The treated baits must be placed in locations where they will not be eaten by non-target bird species. Pre-baiting with untreated bait is required unless the pest birds are accustomed to feeding on bait-type foods in the proposed treatment area. *Avitrol* is highly soluble in water and must be reapplied after a heavy rain. If bird mortality occurs, bait must be withdrawn and replaced with bait having a lower concentration of active ingredient.

Purchase of *Avitrol* in British Columbia requires a Restricted Use Permit from the Pesticide Control Branch. For gull control, an additional federal permit from the Canadian Wildlife Service is required. If feasible, bird-proofing of buildings should be attempted before *Avitrol* is used.

CHEMOSTERILANTS

Ornitrol (azacosterol hydrochloride) is the only chemosterilant (reproductive inhibitor) for birds presently available in Canada, and may be used only for rock doves. It is a useful way of reducing populations without bird mortality, and hence without public controversy. *Ornitrol* is sold as a whole-kernel corn bait. This decreases the chance of consumption by non-target species. Like *Avitrol*, *Ornitrol* may be used only by qualified pest control operators. Reduction of a large pigeon population with *Ornitrol* may require baiting over an extensive area, and may take two to three years.

LETHAL CONTROL METHODS

Lethal control methods include shooting, trapping and the use of avicides. These methods should be considered only if all other control methods are ineffective or impractical.

Shooting. Killing bird pests by shooting is rarely an effective control method because they are usually so abundant that localized areas where birds are killed are quickly repopulated. Scaring birds by shooting at them or in their vicinity can be an effective control method, but must be done at frequent intervals and therefore is labour-intensive. Automatic exploders may be just as effective and require less labour.

Permits are needed to shoot any protected bird species, and also to operate firearms in most areas.

Trapping. Control of birds by trapping is rarely effective for the same reason as killing by shooting; usually localized areas where birds are removed are quickly repopulated. However, occasionally a trapping program is required to deal with small numbers of bird pests. Some traps are quite effective. One of the best known traps is the Modified Australian Crow Trap, which resembles a large chicken-wire cage (about 2.4 m by 1.8 m by 1.8 m), with openings in the roof panel for bird entry. Plans for this trap are available from the B.C. Ministry of Agriculture and Fisheries. Depending on the size of the entrance holes, it can be used for common ravens (under provincial permit), crows or starlings. Traps should contain bait appropriate for the target species, and they work best if a few pest birds are present in the trap as "decoys". Trapping starlings is most effective in early summer or in winter, when the birds are not migrating; it may be futile at other times of year. Several traps in a small area may be needed to affect the population measurably. Starlings and other small birds caught in these traps can be killed quickly by placing them in a plastic bag with a few small (0.5 cm) holes and then running automobile exhaust fumes into the bag.

Several smaller traps designed specifically for magpies, pigeons and sparrows are also available.

Avicides. There are only two avicides registered in Canada: fenthion and strychnine.

Fenthion is available as a liquid solution *(Rid-A-Bird 1100)* which is introduced into hollow artificial perches. It may be used to kill rock doves, European starlings, and house sparrows in and around buildings. It should not be used where other bird species may come into contact with the chemical. Secondary poisoning of predators and scavengers which eat poisoned birds is a significant hazard. In B.C., fenthion may only be used by government agencies and licensed pest control operators.

Strychnine is an avicide which is registered for control of only one bird species - rock doves. Strychnine is an inhumane method of poisoning and, as with fenthion, secondary poisoning of predatory animals is a potential problem. Its use as an avicide is not recommended in British Columbia.

USEFUL PUBLICATIONS ON BIRD CONTROL IN B.C.

Some general advice on bird control is contained in B.C. Ministry of Agriculture and Fisheries' Production Guides for commercial growers. For additional information on bird control and bird identification, the following books and publications are recommended:

Anonymous, 1980. *Birds Protected in Canada* (7th ed.). Canadian Wildlife Service, Occasional Paper No. I. 42 pp.

Anonymous, 1982. *Preventing Bird Damage to Prairie Crops.* Supply and Services Canada, Ottawa. 20 pp.

Blokpoel, H. 1976. *Bird Hazards to Aircraft.* Supply and Services Canada, Ottawa. 236 pp.

Boudreau, G.W. 1975. *How to Win the War With Pest Birds.* Wildlife Technology, Hollister, California. 174 pp.

Horstman, L.P. and J.R. Gunson. 1983. *Prevention and Control of Wildlife Damage in Alberta.* Alberta Energy and Natural Resouces Edmonton. 176 pp.

Robbins, C.S., H.S. Zim and B. Brunn. 1983. *Birds of North America: A Guide to Field Identification.* Golden Press, New York. 360 pp.

Smith, L.B. 1978. *Blackbirds and the Protection of Field Crops.* Agriculture Canada Publication 1652. Ottawa. 8 pp.

Vaudry, A.L. 1979. *Bird Control for Agricultural Lands in British Columbia.* British Columbia Ministry of Agriculture, Victoria. 19 pp.

Weber, W.J. 1979. *Health Hazards from Pigeons, Starlings, and English Sparrows.* Thomson Publications, Fresno, California. 138 pp.

REFERENCE LIST OF AVICIDES AND BIRD REPELLENTS AND THEIR PROPERTIES

The following reference list includes a description of avicides and bird repellents registered for use in Canada when this text was published. They are listed alphabetically by active ingredient, with some examples of trade names. No endorsement of products is implied. Information in these lists could become out of date and not represent current recommendations. **The current registered label is the authority on a pesticide's registered uses, application methods and safety precautions.**

The relative acute mammalian toxicity is given for each active ingredient. LD_{50} values (mg/kg body weight) are listed where available and are derived from tests with rats, unless indicated otherwise (Rb = rabbit). The lowest LD_{50} is listed where several are given in the literature reviewed.

4-aminopyridine *(Avitrol)* — is an organic bird repellant used to repel nuisance and crop-damaging birds in or near buildings, airports and corn and sunflower fields. It is also registered for the control of rock doves, European starlings, house sparrows and blackbirds. It is formulated as prepared concentrate baits of corn chops, whole corn, and mixed grains for further mixing with untreated bait. It is also available as a 25% concentrate powder to prepare poisoned bread for the control of gulls at airports. A Restricted Use Permit is required to use *Avitrol* in British Columbia. It has a high acute toxicity to mammals (LD_{50}:oral = 28.7; dermal = 327 Rb) and may cause skin irritation.

azacosterol hydrochloride *(Ornitrol)* — is an organic chemosterilant used to reduce flock size of the rock dove (domestic pigeon). *Ornitrol* is used as a treated whole corn bait and prevents formation of the embryo within the egg. Temporary sterilization does not harm the treated birds; fertility returns in about 6 months. Nontarget species may be affected, and it is therefore essential that only whole-kernel corn is used in prepared baits. Keep away from domestic animals and poultry. Prebaiting is mandatory if the pigeons are not used to feeding on whole corn. It has a moderate acute toxicity to mammals (LD_{50}:oral = 470; dermal = 7,800).

20,25 diazocholesterol hydrochloride — chemical name for azacosterol hydrochloride.

fenthion *(Rid-A-Bird 1100)* — is an organophosphorous compound available as a solution which is used to fill hollow metal perches (*"Rid-A-Bird* perches"). Fenthion may be used to control rock doves, European starlings and house sparrows. It is absorbed by birds through their feet, and will kill affected birds in a short time. Fenthion has a moderate acute mammalian toxicity (LD_{50}:oral = 190; dermal = 320). It may be fatal to humans if inhaled, swallowed or absorbed through the skin. Fenthion may be used as an avicide only by government agencies and licensed pest control operators.

gluepaste repellents —see polymerized butenes.

polymerized butenes *(Bird Tanglefoot, Hot Foot, Roost-no-more, Tacky-toes, Waco Bird Repellent)* — are used as bird repellents in non-poisonous "gluepastes" on perches and roosting areas. Gluepastes are registered in Canada for control of rock doves, European starlings and house sparrows. Beads of paste must be kept clean and reapplied as needed to achieve desired results. Phytotoxic; keep away from the bark of young trees. Paint thinner or turpentine may be used to clean hands and tools. Polymerized butenes have a very low acute toxicity to mammals.

strychnine — is a botanical compound used as an avicide and rodenticide that must be used with extreme caution. Bait stations must not be accessible to children, livestock, pets and wildlife. Before purchasing or applying strychnine, check with the Pesticide Control Branch regarding provincial restrictions. Rock doves are the only birds for which strychnine is registered. It has a high acute mammalian toxicity (LD_{50}:oral = 30).

CHAPTER QUIZ

Questions

1. Who would you contact to obtain assistance in the identification of a pest bird species?
2. Who would you contact to determine the kind of permit required to kill a bird pest?
3. Do you need a permit to repel (by non-lethal methods) federally or provincially protected species?
4. Name four categories of bird control methods.
5. Name three types of non-poisonous methods of repelling birds.
6. Name two requirements for use of *Avitrol* as a repellent.
7. What are some problems in using avicides to control bird pests?

Answers

1. District Conservation Officer of the B.C. Ministry of Enviroment and Parks or District Horticulturist of the B.C. Ministry of Agriculture and Fisheries.
2. Ministry of Environment and Parks District Conservation Officer.
3. Yes — permits are required for killing *or frightening* protected bird species.
4. Birdproofing, repellents, chemosterilants, lethal techniques.
5. Auditory, visual, gluepaste.
6. Obtain a Restricted Use Permit from Pesticide Control Branch and other bird control permits as required; study target bird feeding habits prior to baiting; pre-bait with untreated bait.
7. Direct poisoning of non-target birds and secondary poisoning of predators and scavangers which eat poisoned birds are hazards.

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Chapter 16

RODENTS AND RODENTICIDES

CONTENTS

RODENT PESTS

RODENT TYPES

Rodents are small to medium-sized mammals characterized by having single pairs of incisors in the upper and lower jaws. These teeth grow continuously during the animals' life and gnawing is necessary to keep them shortened. House mice, Norway rats, roof rats and nutria are rodent species which were introduced to Canada from other countries. Voles (meadow mice), wood (pack) rats, pocket gophers, chipmunks, squirrels, marmots, porcupines, muskrats and beavers are native rodents found in British Columbia. Moles, shrews and rabbits are not rodents.

RODENT DAMAGE

Rodents may consume or damage crops, stored food, packing materials and buildings. In agricultural areas, ground squirrels and marmots may damage forage crops and hay fields; voles and pocket gophers can damage orchard trees. In buildings, domestic rats and mice may gnaw on materials and consume or contaminate foodstuffs.

Many diseases can be transmitted by rodents and the external parasites they may carry (e.g. fleas). Contamination of food by rat droppings may cause food poisoning. To reduce the risk of catching diseases from rodents or their external parasites, never handle rodents with bare hands. Use gloves or tongs to remove dead animals.

RODENT IDENTIFICATION

Correct identification of a pest species is essential before a control program is initiated. Publications listed near the end of this chapter may help identify problem rodents.

The most common rodent pests in British Columbia are rats and mice. There are two species of rat, the Norway rat and the roof rat. Characteristics used to distinguish the rat species and house mice are shown in Figure 27. The Norway rat is also known as the brown, wharf or sewer rat. The adult body is 19 to 25 cm long and the tail is 15 to 22 cm long. The Norway rat typically builds its nest in burrows in the ground, or in refuse such as building debris or stored materials in basements.

The roof rat has several colour variants and may be referred to as the Alexandrine, black or ship rat. It is usually smaller than the Norway rat; the adult body is 15 to 22 cm long and the tail is 18 to 25 cm long. The roof rat is most likely to build its nest in walls, attics or trees.

Individual rats normally live 9 to 12 months and become sexually mature in 3 to 5 months. They may have 4 to 7 litters each, with 6 to 12 young per litter.

METHODS OF RODENT CONTROL

NON-CHEMICAL CONTROL

Rodent control should begin with preventative measures. Removing tall grasses and prunings from orchards and fields will help keep vole populations low.

Fruit trees may be protected from vole damage by placing plastic or metal guards around the trunks. Tilling the ground may reduce the numbers of ground squirrels.

In buildings, proper sanitation is essential for domestic rat and mouse control. Buildings can be rodent-proofed with materials such as concrete, sheet metal or wire screens. If only Norway rats are involved, rat-proofing of all ground-floor openings will usually suffice. If roof-rats are involved, holes in walls, eaves and roofs must be covered. Screens should have 3 to 6 mm mesh to exclude rats and mice. Broken window panes should be replaced promptly. Firewood should be stacked at least 20 cm off the ground and 15 cm from the side of buildings.

Domestic rats and mice must have food to survive and reproduce. Although rats and mice have a few preferences, they will eat almost any kind of food when hungry. Keep all feeds in covered cans, metal bins or hoppers. Food materials in compost piles should be covered with a layer of soil. Rats must drink water, whereas mice seldom need it. Eliminate water sources such as leaky taps, open water troughs, sweating pipes and open drains.

Traps are preferred when rodent populations are low. Traps should also be used where poisons may pose a special hazard or when cleanup of poisons after a control program is not feasible. In addition, trapping is often desirable for controlling rodents in homes because trapped animals can generally be found and will not die in inaccessible places, giving off putrifying odours. When using traps, proper placement and use of attractant baits is necessary to obtain effective control. Snap or spring traps and glue boards are lethal, whereas single or multiple-catch live traps are non-lethal.

Several ultrasonic devices are manufactured for repelling rats and mice. Such devices emit sounds at frequencies above 16 kHz which cannot be heard by humans but are detected by many species of mammals. Rats and mice tend to avoid high-frequency sounds, although the use of ultrasonics may be useful only to exclude these rodents from a confined area and not to repel established populations.

Shooting may be effective for larger rodents such as marmots, but it is time-consuming and can be dangerous.

Several electromagnetic devices have been represented as effective for rodent control, but none have proven successful.

CHEMICAL CONTROL

Chemical control products are either repellents or rodenticides. Chemical repellents, e.g. thiram, can be used to prevent rodent damage in orchards. Plant parts which are treated with repellent, e.g. the bark of fruit trees, taste unpleasant to the rodent pest. Repellents are used to protect crops, but they do not reduce the number of rodents in the infested area.

Rodenticides are poisons used to reduce rodent populations. There are four basic types of rodenticides:

Acute rodenticides (e.g. strychnine, zinc phosphide). These compounds are highly toxic to rodents. Only one feeding is required to obtain a lethal dose and effects of these pesticides occur quickly after ingestion. They can be used to rapidly reduce rodent numbers. They are hazardous to children, pets, domestic animals and wildlife because of their high toxicity. There is also a potential for 'secondary poisoning' with most of these

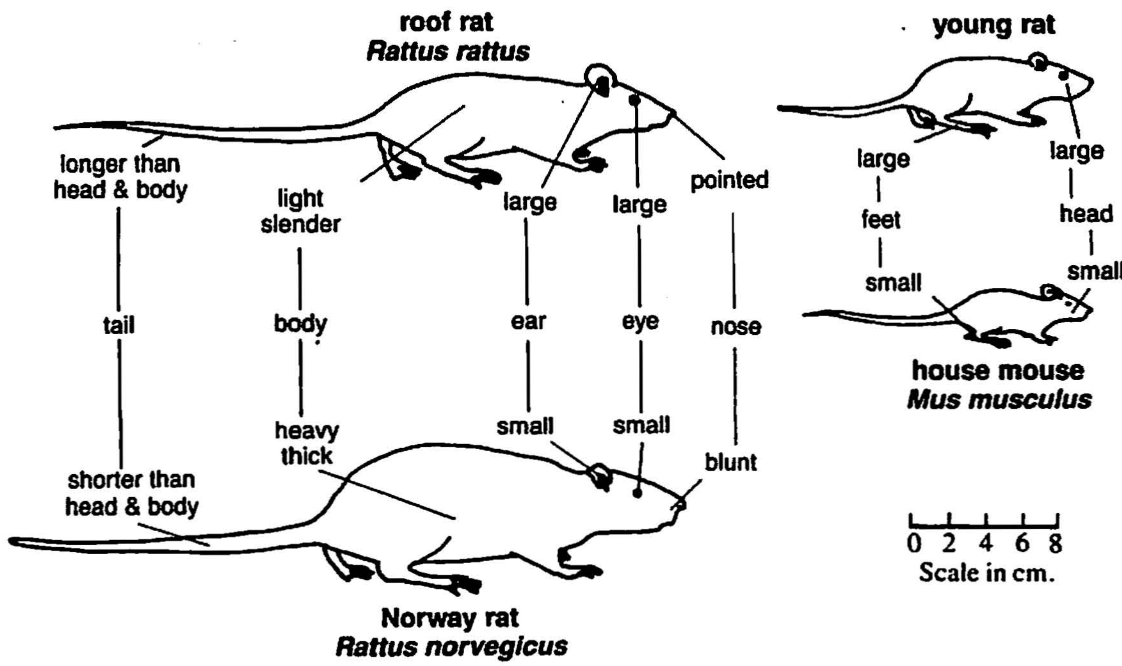

Figure 27. Characteristics of domestic rodents.

rodenticides, i.e. other animals may be affected by the chemical upon eating a poisoned rodent.

The use of acute rodenticides may lead to 'bait-shyness' among rodents. Because symptoms of poisoning occur quickly after feeding, rodents may associate poisoning symptoms with eating sublethal quantities of bait. These rodenticides therefore should not be used on a continuous basis. Laying unpoisoned food to encourage uninhibited feeding prior to poisoning (pre-baiting) is necessary to achieve good control with the acute rodenticides.

Multiple-dose anticoagulant rodenticides (e.g. chlorophacinone, diphacinone, warfarin). Rodents must feed on multiple-dose anticoagulants a number of times and death occurs after several days. Baits must be made available for 5 to 12 days and significant control may not occur for two weeks. Baits should be kept fresh by periodic replacement until feeding stops.

Anticoagulants inhibit the formation of prothrombin, a blood-clotting compound, and death occurs from internal or external bleeding. The antidote is a blood transfusion combined with intravenous and oral administration of Vitamin K_1.

Traps may be used effectively in combination with multiple-dose rodenticides. Poisoned rodents which have not received a fatal dose are often unwary of traps and are attracted to trap baits when unable to forage as usual.

Anticoagulants are generally safer than acute poisons for the control of domestic rats and mice around structures. However, cats and dogs are susceptible to anticoagulants and can succumb to a single dose. If signs of poisoning occur (e.g. bleeding from nose or mouth), pets may be saved with prompt attention from a veterinarian.

Resistance of rats and mice in urban areas to multiple-dose anticoagulant rodenticides has been reported in various parts of the world. Resistant populations of house mice have been confirmed in British Columbia. When anticoagulant baits fail to control rodent infestation, first ensure that baits have been used correctly. If resistance is suspected, rodents can be controlled with acute or single-dose anticoagulant rodenticides.

Single-dose anticoagulant rodenticides (e.g. brodifacoum, bromadiolone). Rodents require only one feeding of these recently developed rodenticides to obtain a lethal dose. They die a few days after eating the bait. Single-dose anticoagulant rodenticides are more toxic than the multiple-dose anticoagulants and are more hazardous to children, pets, domestic animals and wildlife. The mode of action and the antidote are the same as for multiple-dose anticoagulants.

Poisonous gases. Gas cartridges that produce toxic fumes (e.g. oxides of sulphur) are available for the control of burrowing rodents such as rats, pocket gophers, ground squirrels and marmots. These products should not be used near buildings or other combustible materials. Fumigants (e.g. chloropicrin and methyl bromide) may be used by qualified personnel to control rodents in granaries, warehouses and other structures. The hazards to humans and non-target animals often make this method undesirable.

Rodenticides are usually available as ready-to-use bait formulations. Baits consist of poison incorporated into food materials which should be readily accepted by rodents. Some rodenticides are available as concentrates so that pesticide applicators can prepare the bait. Extreme care must be used when handling these highly toxic rodenticide concentrates.

Grains, cereals, fruits, vegetables or mixtures of these are used in poison baits. Baits may be formulated as a loose meal or as pellets, tablets or cakes. They may be oiled, waxed, paraffinized or packaged in plastic pouches. Coloured dyes or pigments are often added as a safety precaution to permit identification of baits. Colour may also make poison baits less attractive to non-target species.

Poison baits should be placed in protected bait stations to prevent exposure to children or consumption by non-target animals, especially cats and dogs, and to reduce exposure to sun and moisture. Open bait trays are not recommended. Bait stations may be made of wood, plastic, metal or water-resistant cardboard. They should be marked to indicate they contain a poison. A thorough inspection of the premises or property is necessary to determine the feeding habits of the target species and to strategically place the bait stations.

When using baits, adequate rodent control may not be achieved for any of the following reasons:

- bait is not attractive,
- concentration of active ingredient in bait is too low,
- bait exposure period is too short,
- insufficient bait is used,
- not enough bait stations are used,
- bait stations are not located properly,
- other foods are readily available,
- alternate foods contain large quantities of Vitamin K, antidotal to anticoagulants,
- control area is too small and rodents are re-invading, or
- bait is being consumed by other animals.

Rodenticides may also be applied as tracking powders in rodent burrows and runways. The poison is picked up on the feet and fur and ingested during grooming.

Poisoned rats and mice should be removed from the control area and burned or buried. This practice will also prevent unsightliness, odours and secondary poisoning.

USEFUL PUBLICATIONS FOR RODENT CONTROL

Anderson, G.G. and H.A. Kluge. 1986. *Rodent Control on Agricultural Land in British Columbia*. B.C. Ministry of Agriculture and Food Publication No. 86-1. Victoria. 15 pp.

Agriculture Canada. 1986. *Control of Rats and Mice*. Publication No.1370/E. Communications Branch, Agriculture Canada. Ottawa. 10 pp.

Ebeling, W. 1975. *Urban Entomology*. University of California, Division of Agricultural Sciences, Los Angeles. 695 pp.

Guiguet, C.J. and I. McTaggart-Cowan. 1978. *The Mammals of British Columbia*. B.C. Provincial Museum Handbook No. 11. Victoria. 414pp.

Truman, L.C. 1976. *Scientific Guide to Pest Control Operations*. Harvest Publishing Co. Cleveland. 276 pp.

REFERENCE LIST OF RODENTICIDES, RODENT REPELLENTS AND THEIR PROPERTIES

The following reference list includes most rodenticides and rodent repellents used in British Columbia when this text was published. They are listed alphabetically by active ingredient, with some examples of trade names. No endorsement of products is implied. Information contained in these lists could become out-of-date and not represent current recommendations. **The current registered label is the authority on a pesticide's registered uses, application methods and safety precautions.**

The relative acute toxicity is given for each active ingredient. LD_{50} values (mg/kg body weight) are listed where available and are derived from tests with rats unless indicated otherwise (Rb = rabbit). The lowest LD_{50} is listed where several are given in the literature reviewed.

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alpha-chlorohydrin *(Epibloc)* — is an organic compound used as an acute rodenticide and sterilant for the control of rats. Male Norway rats and roof rats become sterile if they consume a sublethal dose. Use of this material may prevent a rapid increase in population numbers if rats consume only sublethal doses. It has a moderate acute toxicity to mammals (LD_{50}: oral = 127) and may irritate the eyes.

aluminum phosphide *(Phostoxin)* — is an organic compound used as an acute rodenticide for the control of groundhogs (woodchucks) and yellow-bellied marmots. It is formulated as tablets for placement in burrows. Phosphine gas is released on contact with soil moisture. It has a high acute toxicity to mammals (LD_{50}: oral = 8.7; dermal = 77).

brodifacoum *(Ratak, Talon)* — is a single-dose anticoagulant rodenticide. It is registered for the control of rats and mice in buildings and outdoor areas. Pellets should be placed in tamper-proof bait stations or in areas inaccessible to children, pets, domestic animals or wildlife. It has a very high acute toxicity to mammals (LD_{50}: oral = 0.27; dermal = 50). It is relatively non-toxic to birds.

bromadiolone *(Bromone, Maki)* — is a single-dose anticoagulant rodenticide. It is registered for the control of rats and mice in buildings and outdoor areas. It has a very high mammalian acute toxicity (LD_{50}: oral = 1.1; dermal > 400).

bromomethane — see methyl bromide

calciferol (ergocalciferol, *Sorexa)* — is a mixture of warfarin with Vitamin D_2 that calcifies the vital organs of rodents. It is intermediate in toxicity between the anticoagulants and acute rodenticides. It has a high acute mammalian toxicity (lowest dose reported to kill a dog = 4 mg/kg body wt.).

chlorophacinone *(KsC5, KsC7, KsGs, Rozol)* — is a multiple-dose anticoagulant rodenticide available as pellets, tracking powder or solution. It is used for mouse and rat control in buildings and outdoors as well as for ground squirrel control on farms. It does not require many feedings; in some cases death occurs after only one feeding. It has a high acute toxicity to mammals (LD_{50}: oral = 20; dermal = 200). It has a low toxicity to birds.

chloropicrin *(Brom-O-Gas, MB-C2)* — is a liquid which produces a highly poisonous but nonflammable gas (tear gas). Chloropicrin is registered for mouse and rat control in empty granary bins and non-food storage areas only. It may be added to methyl bromide as a warning agent. It has a high acute toxicity to mammals (LD_{50}: oral = 0.8) and is irritating to the eyes and skin.

3-chloro-1,2-propanediol — see alpha-chlorohydrin

coumafuryl — see fumarin

diphacinone *(Diphacin, Dipha-Tox, KsD5, Ratkil, Ramik Brown, Ramik Green, Rodent Cake)* — is a multiple-dose anticoagulant rodenticide available as blocks, cakes, pellets and dusts. It is effective for rodent control indoors, outdoors and in orchards. Control requires about two weeks of feeding on baits. Use protected bait stations, especially in food handling areas. It has a high acute toxicity to mammals (LD_{50}: oral = 2).

ergocalciferol — see calciferol

fumarin (coumafuryl, *Pes-San)* — is a multiple-dose anticoagulant rodenticide available as a sodium salt. Use protected bait stations in food-handling areas. It has a high acute toxicity to mammals (LD_{50}: oral = 25).

methyl bromide *(Brom-O-Gas,* bromomethane, *MB-C2, Meth-O-Gas)* — is a highly poisonous gas available in pressurized cans or cylinders. Methyl bromide is registered for mouse and rat control in dwellings, warehouses, food-handling plants and granaries. Follow label directions regarding removal of persons, pets and plants as well as all products that may absorb undesirable odours. In British Columbia, methyl bromide can be purchased and used only by certified applicators. It has a high acute toxicity to mammals (LD_{50}: oral = 21). (See chapter on Structural and Stored Product Fumigation.)

pindone *(Contrax-P, Pival, Pivalyn)* — is a multiple-dose anticoagulant rodenticide. It is used for rat and mouse control in structures and garbage dumps. Mortality to rats begins as early as the first week of continuous feeding. Use protected bait stations. It has a high acute toxicity to mammals (LD_{50}: oral = 50).

red squill — is a botanical compound used as an acute rodenticide for the control of Norway rats. It is no longer registered for use. It acts as a strong emetic and is not lethal to animals capable of vomiting. Rats cannot vomit baits, once eaten. Red squill may be very effective where a quick reduction of the rat population is desired prior to starting an anticoagulant baiting program. Rats receiving a sublethal dose quickly become bait-shy. It has a moderate acute toxicity to mammals. (LD_{50}: oral = 200) and is irritating to the skin.

strychnine *(Gopher-Cop, Gopher Getter, Gopher-Kill, Gopher Poison, Rodent Bait)* — is a botanical compound used as an acute rodenticide for the control of pocket gophers. It must be placed in burrows or applied with a burrow-builder machine. Strychnine is highly toxic to humans (LD_{50}: oral = 1), as well as to domestic animals and wildlife.

sulfaquinoxaline *(Eraze, Prolin, Sulfarin)* — is formulated in a mixture with the anticoagulant warfarin. This mixture is available as a ready-to-use bait. Sulfaquinoxaline is an antibacterial agent that retards the formation of vitamin K-producing bacteria in the intestines of rodents. Vitamin K is produced in a rodent's body to counteract anticoagulants. Therefore sulfaquinoxaline is used to increase the effectiveness of warfarin. It has a low acute toxicity to mammals (LD_{50}: oral = 1,000).

sulphur *(Giant Destroyer, Gopher Gasser, Woodchuck Bombs)* — gaseous oxides of sulphur are released from cartridges which are lighted and inserted into rodent burrows. Gases are toxic to pocket gophers, ground squirrels and marmots as well as domestic rats. Use outdoors only. Avoid inhalation of fumes.

thiram *(Rodent Repellent, Skoot)* — is formulated as a liquid concentrate to repel mice as well as rabbits and deer. It may be used to protect fruit trees and woody ornamentals. It is irritating to eyes, nose, throat and skin. Do not consume alcohol immediately prior to or within 24 hours after application. It has a moderate acute toxicity to mammals (LD_{50}: oral = 375; dermal > 2,000).

warfarin *(Eraze, Prolin, Rodentkil, Sorexa, Sulfarin)* — is a multiple-dose anticoagulant rodenticide. It is available in a variety of formulations for the control of domestic rats and mice. Mice are harder to control than rats. It has a moderate acute toxicity to mammals (LD_{50}: oral = 185). However, on a multiple-dose basis, most rats are killed if they ingest only 0.2 mg/kg/day for 5 days.

zinc phosphide *(Mouse Bait 2, ZIP, Z-Phos, ZP Rodent Bait)* — is an inorganic compound used as an acute rodenticide for the control of rats, mice, pocket gophers and ground squirrels. It is formulated as pellets or tracking powder. It can be used in orchards and tree farms. The pellets may be waxed or paraffinized to prevent deterioration under moist conditions. It has a high acute toxicity to mammals (LD_{50}: oral = 46).

CHAPTER QUIZ

Questions

1. Name three alternatives to chemical control of rodent pests.
2. What is secondary poisoning?
3. What is prebaiting; why is this done before acute rodenticide use?
4. Why should acute rodenticides not be used on a continuous basis?
5. Name three things you would consider if rodent control from an anticoagulant is not effective and you are sure your bait is suitable, in good locations and has been left out long enough?

Answers

1. Proper sanitation (removal of shelter and food), traps, ultrasonic devices, shooting.
2. Poisoning of a non-target animal from eating a rodent which has been poisoned by a rodenticide.
3. Prebaiting is the conditioning of rodents to eat a non-toxic food similar to the rodenticide bait to ensure they will eat a sufficient quantity of the poison bait to be killed.
4. Continued use of single-dose acute rodenticides can lead to bait shyness where the rodents associate poisoning symptoms with the bait and avoid it.
5. Are foods other than the bait too abundant? Is the area where bait is being set out too small and being invaded from rodents in an adjacent area? Do these rodents have a resistance to the rodenticide? Is the bait being consumed by other animals?

Chapter 17

OTHER PESTS : WILDLIFE AND DOMESTIC ANIMALS, SLUGS AND SNAILS, AQUATIC WEEDS, ALGAE AND FISH.

CONTENTS

WILDLIFE AND DOMESTIC ANIMAL PESTS

PROBLEM WILDLIFE AND THEIR CONTROL IN BRITISH COLUMBIA

In British Columbia, game animals, fur-bearing animals, raptors and game birds, as well as threatened and endangered species, are designated as "wildlife". They are managed and protected under the Wildlife Act and Regulations administered by the Ministry of Environment.

Occasionally, individuals of some wildlife species threaten human health or safety, or damage property of personal or commercial value. Such 'problem wildlife' may damage buildings or other structures as well as agricultural crops or products, or may injure domestic livestock or pets.

The Ministry of Environment is responsible for the management of problem wildlife which threatens or causes significant harm to man or damage to his property. The Ministry will use or recommend control practices which are directed at the individual problem animals or groups of animals actually causing harm or damage. Control methods for problem wildlife may include capturing and relocating problem animals, as well as shooting, trapping or poisoning.

Some agricultural and forestry crops can be protected from wildlife damage by the use of physical barriers such as fences or by chemical repellents.

REFERENCE LIST OF PREDACIDES, WILDLIFE REPELLENTS AND THEIR PROPERTIES

Predacides are poisons used to control predators. The following reference list includes most predacides and wildlife repellents registered for use in Canada when this text was published. They are listed alphabetically by active ingredient with some examples of trade names. No endorsement of products is implied. Information contained in this list could become out-of-date and not represent current use recommendations. **The current registered label is the authority on a pesticide's registered uses, application methods and safety precautions.**

The relative acute mammalian toxicity is given for each active ingredient listed. LD_{50} values (mg/kg body weight) are listed where available and are derived from tests with rats. The lowest LD_{50} is listed where several values are given in the literature reviewed.

ammonia *(Hinder)* — is formulated with salts of higher fatty acids (soap) as a liquid concentrate to repel deer and rabbits. It may be used to protect fruit trees and vines, vegetables and field crops, forage and grain crops, nursery stock and ornamentals, certain berry crops, as well as non-crop areas. Avoid inhalation or direct contact. Wash after application. Do not apply to food crops within 14 days of harvest.

naphthalene — is used to repel bats or squirrels in buildings. It has a low mammalian acute toxicity (LD_{50}: oral = 2,200; dermal > 2,500), but should not be placed where it can be picked up by children.

paradichlorobenzene — is used to repel bats in buildings. It has a moderate mammalian acute toxicity (LD_{50}: oral = 500), and should not be placed where it can be picked up by children.

putrescent whole egg solids *(Deer-Away, MGK-BGR)* — are formulated as a liquid concentrate to repel deer and elk. They may be used to protect conifer seedlings, ornamentals and fruit trees. Wash hands after application. Do not store near or contaminate feed or foodstuffs.

salts of higher fatty acids — are formulated with ammonia as a liquid concentrate to repel deer and rabbits. See ammonia.

soap — see ammonia.

sodium fluoroacetate — see sodium monofluoroacetate

sodium monofluoroacetate *(Compound 1080, sodium fluoroacetate)* — is an organic compound used as a predacide in wildlife management for the control of coyotes and wolves. In British Columbia, a Restricted Use Permit must be obtained before using sodium monofluoroacetate. It can only be handled or used by designated and certified staff of the Ministry of Environment and Parks. It has a very high acute toxicity to mammals (LD_{50}: oral = 0.22).

thiram *(Arborgard, Rabbit Repell, Rodent Repellent, Skoot)* — is formulated as a liquid concentrate to repel rabbits and deer as well as mice. It may be used to protect fruit trees and woody ornamentals. Do not contaminate food, feed or drinking water. It is irritating to eyes, nose, throat and skin. Wash contaminated clothing before re-use. Do not consume alcohol immediately prior to or within 24 hours after application. It has a moderate acute toxicity to mammals (LD_{50}: oral = 375; dermal > 2,000).

REFERENCE LIST OF DOG AND CAT REPELLENTS AND THEIR PROPERTIES

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A number of products have been developed for repelling nuisance cats and dogs. These products are registered for domestic use.

In the following reference list, domestic animal repellents are listed alphabetically by active ingredient with some examples of trade names. No endorsement of products is implied. Information contained in this list could become out-of-date and not represent current use recommendations. **The current registered label is the final authority on a pesticide's registered uses, application methods and safety precautions.**

bone oil *(Dawgone)* — is formulated with mustard oil and oil of lemongrass to repell domestic dogs. See mustard oil.

capsaicin *(Halt,* oleoresin of capsicum) — is formulated as a pressurized spray to repel attacking domestic dogs. It is irritating to eyes, nose and skin. Avoid inhalation or direct contact. In case of accident, wash thoroughly with clean water.

methyl nonyl ketone *(Detour, No, Repell)* — is formulated as a pressurized spray to repel domestic cats and dogs. It may be applied to furniture and rugs in residential areas. A granular formulation is available for outside areas. Do not apply to food, food-handling areas or foliage. Avoid eye and skin contact. Use gloves and wash hands after application. It has a low acute toxicity to mammals (LD_{50}: oral = 10,000).

mustard oil *(Dawgone, Scat's Off)* — is formulated with oil of lemongrass to repel domestic cats and dogs for use on evergreens, flowers, shrubs, trees, furniture and rugs. It is formulated with oil of lemongrass and bone oil to repel domestic dogs for use on outside building surfaces, garbage containers, posts, black tires, tire rims, evergreens, shrubs, trees and lawns. Do not spray on flowers, tender foliage or vegetables. Do not contaminate food, food utensils or drinking water. Avoid inhalation and contact with eyes, skin and clothing. Wash hands after application. Do not apply to humans, pets or birds.

oil of citronella *(Scent-Off)* — is formulated with oil of lemongrass and other active ingredients to repel domestic dogs and cats. It has a low mammalian toxicity (LD_{50}: oral = 900).

oil of lemongrass *(Dawgone, Scat's Off, Scent-Off)* — is formulated with bone oil and mustard oil or with oil of citronella and other active ingredients to repel domestic dogs and cats. See mustard oil.

MOLLUSCS (SLUGS AND SNAILS)

Slugs and snails belong to a large group of soft bodied animals called molluscs. Snails have a shell into which they can withdraw when disturbed or when conditions are unfavourable. Slugs do not have a shell and must find protection in damp places.

SLUG CONTROL

Slugs vary in size from about 1 to 20 cm in length and may be orange, grey, green, brown or black in colour. Slugs can attack many field and garden crops, preferring seedlings, tender shoots and leaves. Young slugs damage plants by rasping surface tissues; older ones feed on plant parts, eating irregular holes in the tissues. As slugs move, they leave a slime-like mucus trail which dries into silvery streaks. This is an important clue in determining their presence since they usually hide during the day and feed at night. These slime trails are undesirable on floral and ornamental crops and on produce sold for human consumption.

All slugs lay eggs, usually in clusters of 30 to 50, on the soil surface in concealed, moist locations. Typically, eggs are laid in autumn after the first rains and many species overwinter in this stage. The eggs hatch in spring and most slugs reach maturity and lay eggs by fall. Some species can be active all year, especially in warm places such as greenhouses.

Slugs can be controlled by a variety of cultural and chemical techniques. Slugs favour damp, shaded areas, so removing plant debris, old boards or other materials that could provide daytime hiding places will help to control them. Mow tall grass growing around fences and ditches.

Traps are effective in controlling slugs in small areas. Boards or bark at least 15 cm square can be left overnight on the ground close to valuable plants. The next day any slugs sheltering underneath can be destroyed.

Fly screen or sheet metal about 10 cm wide will provide an effective barrier against slugs. The material should be set into the soil on its edge to a depth of 5 cm and should completely surround the plant. For a flat or cold frame, tack screening across the top, leaving the cut edges of the screen sharp.

Baits, pellets, dusts and sprays are available for chemical control of slugs. Baits should be placed in areas where slime trails of slugs are seen or close to plants. **The baits should be inaccessible to dogs, cats and birds.** Place under boards or rocks or in cans with holes just big enough for slugs to enter. Slug bait can also be broadcast to make it less available to domestic animals.

AQUATIC SNAIL CONTROL

Aquatic snails become a nuisance when they are abundant and are carriers of the parasite which causes **swimmer's itch**, technically known as *schistosome dermatitis*. The adult parasite lives in the blood vessels of birds and small mammals. If the eggs of the adult parasite are passed into water, an early immature stage emerges and must enter certain species of snails to continue development. In about six weeks, the development within the snail has produced a generation of larvae that emerge from the snail host and swim into the water, awaiting the other host, usually a bird. Man is an abnormal host for these parasites. They penetrate human skin mistaken for the final host and cause a local, superficial infection.

Snails that carry the parasite live during the summer months in shallow water on the bottom of the lake. The parasite larvae which emerge from the snails may be carried for some distance on the water surface by wind-generated currents. Swimmer's itch may be controlled by removal of the carrier snails from the shallows used by swimmers and adjoining areas which contribute larvae to the swimming area. Snail numbers can sometimes be reduced by controlling aquatic weeds which provide a surface on which snails feed on microscopic algae. Aquatic weeds can be treated mechanically or chemically.

One molluscicide (niclosamide) is currently registered for aquatic snail control. Copper sulphate has been used in the past. It is best to treat snails in the early spring before the overwintering snail populations have time to build up their numbers through egg-laying which occurs in March through July. There may be concerns about chemical use in fish-bearing waters and domestic water supplies.

The infection in humans from swimmer's itch can be prevented to a large degree by showering or by drying with a towel after leaving the lake, i.e. by wiping off water containing the parasite. Thus, a public information program may suffice to alleviate the problem.

REFERENCE LIST OF MOLLUSCICIDES AND THEIR PROPERTIES

Only two molluscicide active ingredients for slug control and one for aquatic snail control were used in products registered in Canada when this text was published. General characteristics of these active ingredients are described below, but may not represent availability or current use recommendations. No endorsement of products is implied. **The current registered label is the authority on a pesticide's registered uses, application methods and safety precautions.**

copper sulphate (no registered product at the time of writing) — was used commonly in the past for snail control. Copper sulphate is effective in killing snails when concentrations of 2 mg/L for one hour or 4 mg/L for 30 minutes are obtained. See toxicity information on copper sulphate in reference list of aquatic herbicides and algicides.

metaldehyde — is considered both an attractant and toxicant to slugs and snails. It is non-phytotoxic at recommended rates except to certain species of orchids. Warm temperatures give best results. It has a low acute toxicity to mammals (LD_{50}: oral = 600), but baits must not be used in areas where they may be eaten by children or animals. Dogs are attracted to baits and may be poisoned; keep dogs away from treated areas. Metaldehyde must not contaminate plants grown for food.

methiocarb *(Mesurol)* — is a carbamate compound which is highly toxic to slugs. It kills slugs on contact. It has a high acute mammalian toxicity (LD_{50}: oral = 15; dermal > 2,000) and is highly toxic to fish and wildlife. Birds feeding on treated areas may be killed. Care should be taken not to contaminate water by cleaning application equipment or disposal of wastes of methiocarb.

niclosamide *(Bayluscide)* — is formulated into granules for control of certain species of freshwater snails that act as an intermediate host for the parasites that cause swimmer's itch. When applied as directed, it is reported not to harm game fish populations in treated waters. It is toxic to freshwater clams and mussels and may be toxic to fish. Niclosamide has a moderately toxicity to mammals (LD_{50}: oral = 500), and is toxic to fish at 0.5 ppm.

AQUATIC WEEDS AND ALGAE

AQUATIC WEEDS AND ALGAE CONTROL

Aquatic weeds and algae are sometimes a nuisance in lakes, reservoirs and ponds or in rivers, streams and ditches where they may restrict flow of water, clog pumps or otherwise interfere with water use.

Excessive weed growth may result from high nutrient input to a water body, e.g. runoff from agricultural lands or septic tanks. Long-term control of aquatic weed or algal growth in such cases should involve reducing nutrient levels. Nuisance growth may also develop when new weeds are introduced to a water system where there are no natural factors to control their growth.

There are a number of mechanical and chemical methods which have been developed for control of some aquatic weeds and algae growing in various habitat types. Note that the Pesticide Control Act Regulation prohibits use of a pesticide in a body of water that is not man-made, self-contained and on private land, unless a Pesticide Use Permit is obtained. Pesticide use in lakes and rivers or in waterbodies draining into fish-bearing waters may be hazardous to fish or fish habitat. Such use must be reviewed by the agencies responsible for these resources. Advice on aquatic weed and algae control can be obtained from the Water Management Branch, Ministry of Environment.

REFERENCE LIST OF AQUATIC HERBICIDES AND ALGICIDES

In the following reference list, herbicides registered for use in water are listed alphabetically by active ingredient, with some examples of trade names. No endorsement of products is implied. Information contained in this list could become out-of-date and not represent current use recommendations. **The registered product label is the final authority on a pesticide's registered uses, application methods and safety precautions.**

The relative acute mammalian toxicity is given for each active ingredient listed. LD_{50} values (mg/kg body weight) are listed where available and are derived from tests with rats. The lowest LD_{50} is listed where several values are given in the literature reviewed.

acrolein *(Magnacide)* — is used for the control of submerged and floating weeds and algae in irrigation canals. It has a high toxicity to mammals (LD_{50}: oral = 46; dermal = 562 Rb). It is absorbed by the skin and vapours are particularly irritating to any lesion and to the eyes. It is toxic to fish and wildlife and should not be applied to lakes, streams or ponds.

amitrole, aminotriazole *(Amitrol-T, Cytrole)* — is a triazole compound for non-selective control of emergent aquatic weeds such as cattails. It is not to be applied where water will be used for irrigation, drinking, fishing or other domestic purposes. It has a low toxicity to mammals (LD_{50}: oral = 1,100). It is not toxic to fish or wildlife when used as recommended. Spray drift can injure tomatoes, lawns, ornamentals and other desirable vegetation.

copper sulphate (no registered product at the time of writing) — is an inorganic algicide effective in controlling many forms of algae in water at rates between 0.1 and 1.5 mg/L. One mg/L is equal to 1 kg of copper sulphate per 1000 m^3 of water. It can be applied as a slug (i.e. dumping crystals directly into water), suspension dissolution (i.e. submerging a bag filled with crystals and towing behind a boat while the crystals dissolve) or by continuous application (dispensing low dosages over a long period). Copper sulphate will dissolve in water to 25% by weight. It is very corrosive to metals and equipment must be thoroughly cleaned immediately after use. Some species of fish are very sensitive so that it must be used with caution in fish-bearing waters. A concentration of 0.3 mg/L may be acutely toxic to trout. Toxicity to fish increases as alkalinity decreases. Copper sulphate has a low poison hazard to humans but gives water a bad taste at low concentrations. Guidelines for Canadian Drinking Water Quality (1978), list a maximum acceptable concentration of 1 mg/L of copper ion (= 3 mg/L of copper sulphate) in drinking water to avoid objectionable taste. It has a low toxicity to mammals (LD_{50}: oral = 600).

copper present as chelates of copper citrate and copper gluconate *(Algimycin Pill)* — is a preparation of inorganic copper for algae control which results in greater concentrations of copper in water than copper sulphate. Registered for use in farm, fish and fire ponds. May cause irritation of the skin. Not for use in public waters or waters draining into public waters or for use in potable waters. May be toxic to trout and other species of fish.

copper present as triethanolamine complex *(Cutrine-Plus)* — is a preparation of copper for algae control which prevents the precipitation of copper with carbonates or bicarbonates in water. Registered for use in farm, fish and fire ponds. It may cause irritation to skin and is harmful if swallowed. Not to be used in public waters or waters that drain into public waters or in domestic water supplies. Very toxic to fish in waters of low alkalinity (hardness). In hard water, it may be toxic to fish if the recommended maximum concentration for algal control of 0.4 ppm copper is exceeded.

dalapon *(Basfapon, Dowpon)* — is an aliphatic acid. It is selective, used primarily to control grass, cattails and bullrushes (monocots) in drainage ditches. It is translocated from leaves to roots and works slowly. May cause skin or eye irritation; contact with eyes or skin or clothing should be avoided. Do not graze or feed treated grain to livestock during the crop year of application. Do not allow spray drift to contact foliage or roots of desirable plants, especially lawns and other desirable turf. It has a low acute toxicity to mammals (LD_{50}: oral = 3,860) and has a relatively low toxicity to fish and other aquatic organisms.

2,4-D butoxyethanol ester *(Aqua Kleen)* — is a phenoxyacetic acid compound formulated into granules for control of many species of submerged and emergent aquatic weeds in lakes and ponds. Waters must have relatively slow exchange for effective weed control. The butoxyethanol ester (BEE) formulation of 2,4-D is relatively toxic

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to fish. 2,4-D BEE breaks down to 2,4-D acid which is less toxic to fish, in a few days at pH above 8, but takes longer at lower pH. A major limitation to use is potential contamination of water supplies for domestic use or irrigation. 2,4-D acid can persist for months at just above detectable levels in confined water bodies. Crops such as grapes, tomatoes, cucurbits, legumes and cole crops are sensitive to low levels of 2,4-D. The acute mammalian toxicity of 2,4-D is moderate (LD_{50}: oral = 375).

diquat *(Reglone)* — is a pyridine compound rapidly absorbed by plant tissues. It is used for control of submerged aquatic plants in ponds or Eurasian water milfoil in lakes. It is a contact herbicide and is not translocated. It only kills top growth and therefore provides only one season's control of aquatic weeds which regrow from perennial roots. Diquat may be fatal if swallowed, inhaled or absorbed through skin. Wear protective gear. Treated water is not to be used for consumption or swimming for 24 hours and is not to be used for irrigation for five days. It has a moderate acute toxicity to mammals (LD_{50}: oral = 231; dermal = 3,000).

paraquat *(Gramoxone)* — is a pyridine compound used as a nonselective herbicide for control of various emergent aquatic weeds. It is quite toxic to mammals and the lungs are the primary organ affected. Care must be taken to avoid breathing fine mists of the spray solution. Water must not be used for swimming, or human or animal consumption for seven days after treatment. Water must not be used for irrigation for five days after treatment. It has a moderate acute toxicity to mammals (LD_{50}: oral = 140; dermal = 236 Rb).

simazine *(Princep, Simadex)* — is a triazine compound similar to atrazine. It is registered for control of filamentous algae, pond scums and aquatic weeds in ponds. Water taken from treated ponds is not to be used for human consumption. Water flow is to be shut off for at least 10 days after treatment. It is also registered for application to exposed bottom sediments after lake or pond drawdown to control rooted emerged and submerged vegetation, as a soil sterilant. It has a low mammalian acute toxicity (LD_{50}: oral = 5,000; dermal = 8,160 Rb), but no tolerances have been set for fish. Fish taken from treated ponds are not to be used for human consumption.

FISH MANAGEMENT

Fish toxicants (piscicides) are used by fisheries managers for restoration and enhancement of sports fish populations in high-use lakes. Permits must be obtained for use of fish toxicants in water bodies that are not man-made, self-contained and on private land. Such treatments must be made under the direction of the Recreational Fisheries Branch of the Ministry of Environment.

Certified applicators should be familiar with the ecology of the lake to be treated, species of fish present, methods of monitoring piscicide dispersion, factors affecting application rates and methods of application.

The only active ingredient now registered for fish management in Canada is rotenone.

rotenone *(Noxfish Fish Toxicant, Rotenone Fish Poison)* — is a botanical made from the roots of *Derris* spp. and *Lonchocarpus* spp. and several other members of the pea family. It is formulated as a wettable powder and an emulsifiable liquid. Rotenone degrades relatively rapidly in water, more rapidly with high temperatures. It is generally detoxified within 1 to 4 weeks, but waters should be tested using fish bioassays before restocking. Detoxification can be increased by adding chlorine. Hogs are very sensitive and water from a freshly-treated lake could be injurious. Rotenone is non-phytotoxic, but very toxic to fish. The active ingredient has a moderately high mammalian acute toxicity (LD_{50}: oral = 132) however, it is usually formulated in low concentrations.

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SECTION IV

APPLICATION TECHNIQUES

Chapter 18

APPLICATION EQUIPMENT

CONTENTS

INTRODUCTION

A wide variety of equipment is available for applying pesticides. Application equipment can be simple, such as hand-held squirt bottles or complex, such as multiple-nozzle pressure sprayers. Factors to be considered in selecting equipment include the size and type of area to be treated, the type of pest, the pesticide formulation and the required application accuracy. It is important to select suitable equipment and to maintain the equipment to ensure effective pesticide application.

This chapter reviews the principal types of application equipment and describes basic sprayer parts and maintenance.

HAND-OPERATED SPRAYERS

Hand-operated sprayers are often used to apply small quantities of pesticides inside structures or for small treatments outdoors. Most are operated with compressed air which is supplied by a hand-pump. They are commonly used in the structural pest control industry and in home gardens. The disadvantages of hand-operated sprayers are that pressures and output rates usually fluctuate. They often do not provide sufficient agitation to keep wettable powders in suspension. Some examples of hand-operated sprayers include the following:

Pressurized cans (aerosols). Small non-reusable cans with a capacity of less than 1 L are available for home use.

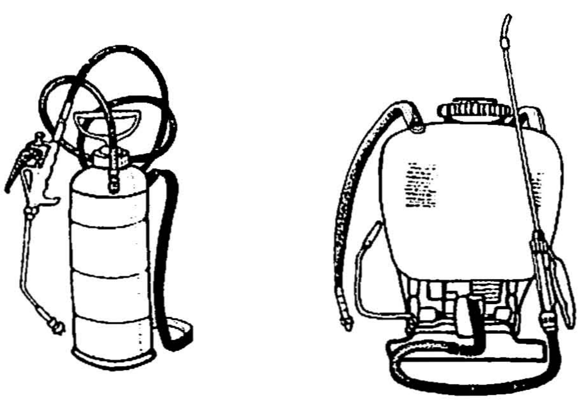
Pressurized cylinders. Large reusable cylinders for aerosol generation are available for structural, agricultural crop and greenhouse pest control.

Trigger pump sprayers ('squirt-gun' sprayer). The pesticide container is not pressurized. Instead, the pesticide and carrier are forced through the nozzle by pressure created when the trigger is squeezed.

Hose-end sprayers. A vacuum draws a fixed rate of pesticide from a small spray tank, to mix with water flowing through a hose. The spray-tank usually holds concentrated pesticide. Such sprayers may deliver 50 L or more of spray solution before they need refilling. The major disadvantage with these sprayers is that any dirt in the nozzle can change mixing ratios and make them unreliable.

Compressed-air sprayers (Figure 28). This type of sprayer operates under pressure, usually supplied by a manual pump which fits into the top of the spray tank. Compressed air above the spray mixture forces the liquid out of the tank through a hose and nozzle. Such sprayers may be hand-held (capacity 4 to 10 L) or backpack units (capacity up to 25 L). Some compressed-air sprayers are equipped with pressure gauges for accurate pressure control. Some nozzles are equipped with a shutoff at their tip to avoid dripping when spraying is stopped. This may be important for use indoors. Operating pressures for hand-operated sprayers are usually between 100 and 600 kPa[1].

Another type of compressed air sprayer uses a precharged cylinder of air or carbon dioxide to provide pressure. These units include a pressure-regulator valve to maintain uniform spray pressure. Pesticides may be applied through a handgun or a short boom.



A B

Figure 28. Compressed air sprayer: (A) hand-held; (B) back-pack.

[1] kPa = kilopascal (metric unit of pressure)

Push-pull hand pump sprayers. A hand-operated plunger forces air out of a cylinder, creating a vacuum at the top of a siphon tube. The suction draws pesticide from the tank and forces it out with the air flow. This type of sprayer ranges in size from hand-held (capacity 1 L) to wheelbarrow sprayers with up to 100 L capacity tanks and a long spray hose.

Bucket or trombone sprayers. A double-action hydraulic pump is operated with a push-pull motion. The pump is used to apply liquid pesticides from a separate container. The pesticide is sucked into a cylinder and pushed out through the hose and nozzle with each stroke. Pressure up to 1,000 kPa can be obtained. The pesticide container often consists of a bucket with a capacity up to 20 L.

MOTORIZED SPRAYERS

These spray units typically use a power-driven pump to provide pressure to the pesticide in the hose rather than in the tank. These systems can be mounted on tractors, trucks, trailers or aircraft. They may be low-pressure or high-pressure types according to the pump and other components they contain. Some examples include:

Low-pressure boomless sprayers. These sprayers come in a wide variety of sizes. Working pressures are usually less than 500 kPa. They may be mounted on skids for carrying in small trucks or mounted on a trailer for pulling manually or with a vehicle. They may be equipped with a hose and a handgun with an adjustable nozzle for spot treatments or may have a central nozzle cluster that produces a wide spray swath for broadcast treatments.

Low-pressure boom sprayers (Figure 29). These sprayers are designed to distribute pesticide solutions over large areas. They are most often used in agricultural, forestry and rights-of-way pest control operations. They are used to deliver low to moderate application rates, usually 50 to 500 L/ha, at working pressures ranging from 150 to 500 kPa. The most common booms are between 6 and 10 m long and contain nozzles spaced at 50 to 100 cm intervals.

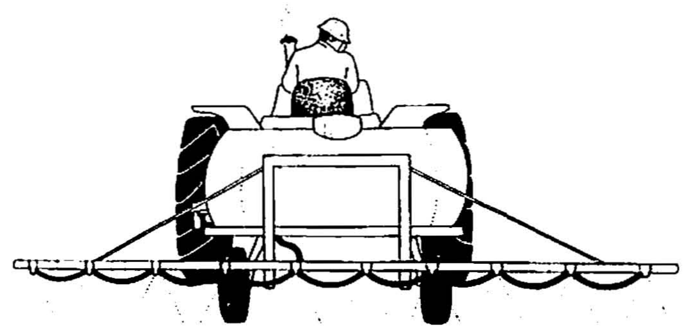


Figure 29. Low-pressure boom sprayer.

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High-pressure sprayers. These sprayers are used to spray through thick foliage, to the tops of trees and into other areas where high-pressure sprays are necessary for adequate penetration. Often called hydraulic sprayers, they can develop pressures up to 7,000 kPa. These units must be heavy-duty to withstand the high pressures. Such sprayers can be fitted with a boom and multiple nozzles, or a hose and single handgun nozzle for use in spraying individual trees or livestock.

Air-blast sprayers. A combination of air and liquid is used to deliver the pesticide to the surface being treated (Figure 30). The pesticide is pumped through nozzles into a blast of air from a high-speed fan. The pesticide is broken into fine droplets and carried to the target. These sprayers can usually be adjusted to apply high or low volumes of spray at a wide range of pressures. Normally, the spray mixture requires mechanical agitation. Drift can be a problem with the fine spray produced from these sprayers.

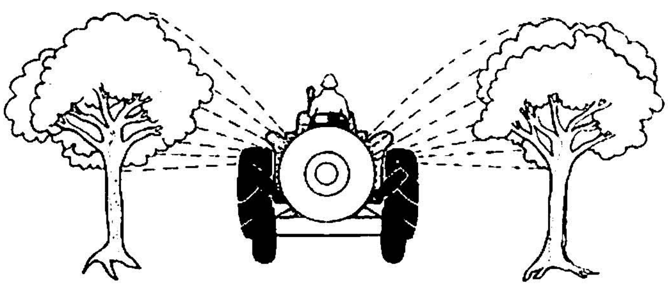


Figure 30. Air-blast sprayer.

Low-volume air sprayers (mist blowers). These sprayers are characterized by high air velocities to break up the liquid into droplets. They use low water volumes and operate at lower pressures than conventional air-blast sprayers.

Ultra-low volume (ULV) sprayers. These sprayers apply special pesticide concentrates with little or no water or other liquid carrier. Droplet sizes are smaller but droplets are more numerous than in conventional sprays. Application rates are only 5 to 6 L/ha or less. They save time by eliminating the need for mixing, but the applicator is at greater risk. Only a few pesticides are registered for ULV application.

SPRAYER PARTS AND SPRAY OUTPUT

Various components of a typical low-pressure boom spray system are illustrated in Figure 31. Some characteristics of these components are given below.

SPRAY TANKS

Tanks should have a large, screened opening for easy filling and cleaning. They should have a large drain plug, located so the entire tank can be drained. Tanks should be made of corrosion-resistant material for the pesticides used. Some pesticides known to cause corrosion or deterioration of certain materials are listed in Table 17. For accurate mixing of pesticides, the amount of spray held by a full tank should be known; the amount held by a partially full tank should be easily measured (Appendix V).

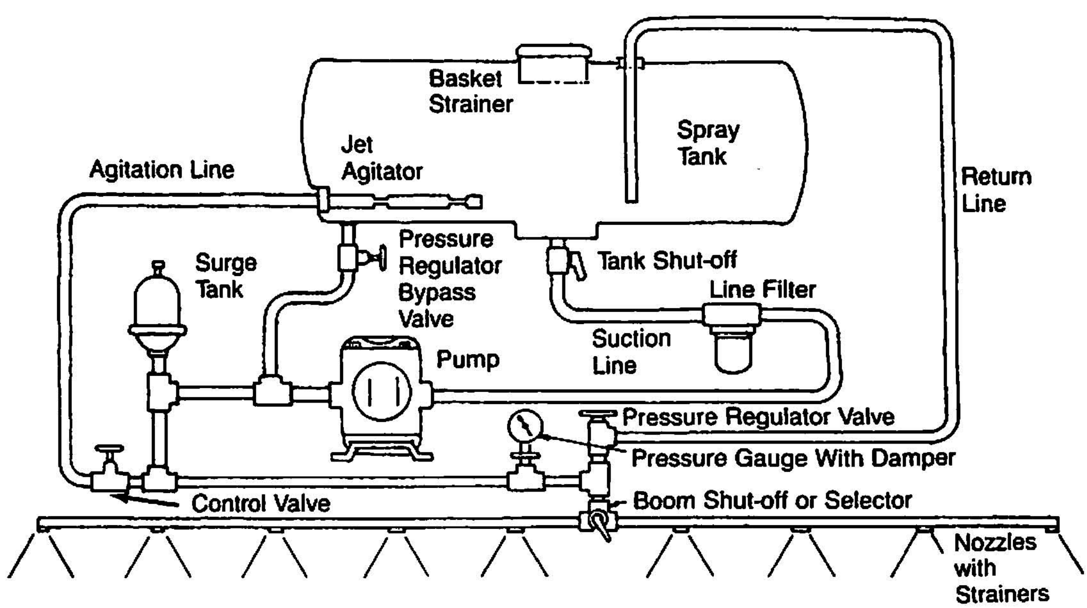


Figure 31. Components of a typical low-pressure field spray system using a diaphragm or piston pump. Roller pump would not require the surge tank.

Table 17. Spray tank susceptibility to corrosion or deterioration from various pesticides.

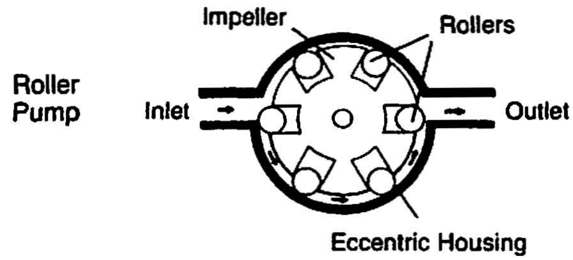
Spray Tank Material	Pesticides Causing Corrosion or Deterioration
galvanized steel	acidic formulations and pesticides such as Bordeaux mixture, carbophenothion, chlorfenvinphos, 2,4-D, dalapon, difenzoquat, endosulfan, glyphosate (may produce explosive hydrogen gas), paraquat
aluminum	difenzoquat, paraquat, dichloropropenes
polyethylene	EPTC, methoxychlor (also sunlight).
fibreglass	generally resistant
stainless steel	generally resistant

PUMPS

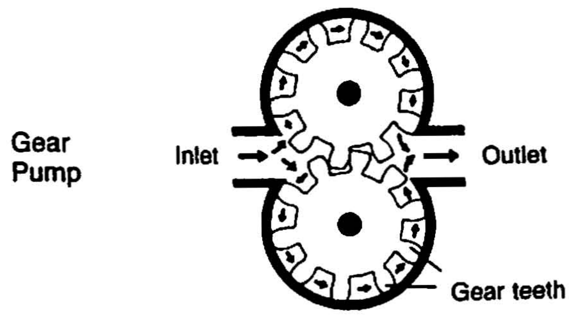
The pump must have sufficient capacity to supply the needed volume to the nozzles and to the hydraulic agitator (if necessary) and to maintain the desired pressure. The pump components should be resistant to corrosion and abrasion if materials such as wettable powders are to be used. Gaskets, plunger caps and impellers should be resistant to the swelling and chemical breakdown caused by many liquid pesticides.

A sprayer pump should not be operated at speeds or pressures above those recommended by the manufacturer. Pumps will be damaged if run dry or with a restricted inlet or outlet. Pumps depend on the spray liquid for lubrication and cooling. Some pump types include the following:

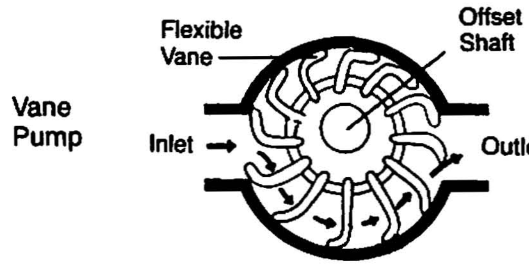
Roller pumps are among the least expensive and most widely used of all sprayer pumps. They provide moderate volumes (100 to 300 L/ha) at low to moderately high pressure (100 to 2,000 kPa). Roller pumps are positive-displacement, self-priming pumps and are often used on low-pressure sprayers. The rollers, made of nylon, teflon or rubber, wear rapidly when used for wettable powders but are replaceable. A pump that will be subject to rapid wear should have a capacity about 50% greater than that required when the pump is new. Roller pumps are best for emulsifiable concentrates, soluble powders and other non-abrasive pesticide formulations.



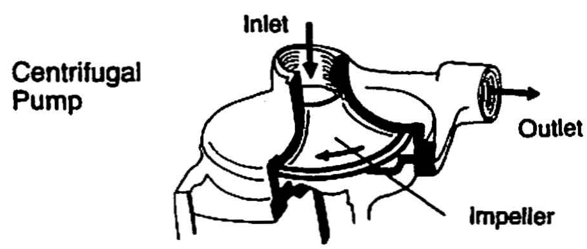
Gear pumps are used on sprayers with low operating pressures. They provide low to moderate volume (50 to 100 L/ha) at low to moderate pressures (150 to 700 kPa). Gear pumps are positive-displacement, self-priming pumps. The self-priming ability is rapidly lost as the pump wears. These pumps are designed for oil solution formulations and wear rapidly when suspensions of wettable powders are used. The parts are generally not replaceable. The pump is not affected by solvents, since all parts are metal.



Vane pumps are similar to roller pumps. They provide moderate volumes (100 to 300 L/ha) at low pressures (to 350 kPa) and can be used with wettable powders.



Centrifugal pumps are relatively inexpensive pumps adaptable to a wide variety of spray applications. Generally, they deliver high volumes (up to 2,000 L/ha) at low to moderate pressures (50 to 350 kPa); however, two-stage centrifugal pumps develop higher pressures (up to 1,400 kPa). They are used on agricultural sprayers, commercial spray-dip machines and other equipment. Centrifugal pumps are not positive-displacement pumps, so pressure regulators and relief valves are only necessary if spray pressure is to be regulated. They are not self-priming and must be mounted below the tank outlet or with a built-in priming system. Centrifugal pumps are well adapted for spraying abrasive materials because the impeller does not contact the pump housing. Many models are easily repairable.



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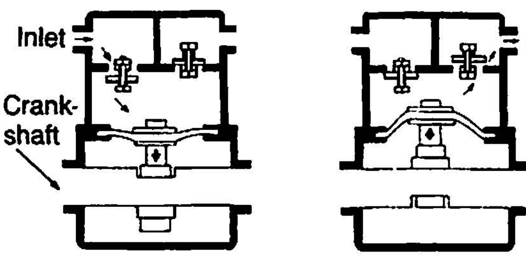
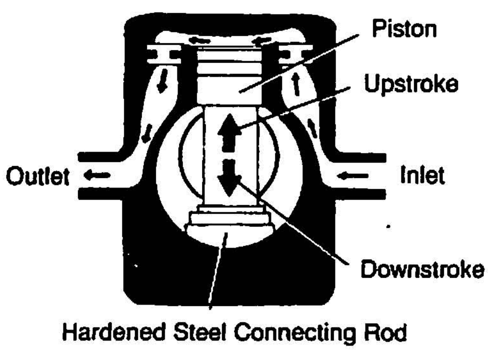
Diaphragm pumps are available with low, medium and high flow and pressure capabilities. They are excellent for use with abrasive spray mixtures. High pressure diaphragm pumps are now more popular than piston pumps. Maintenance costs are low in comparison with piston pumps of the same capacity. Diaphragm pumps may require a surge tank (Figure 31) to dampen pressure surges.



Diaphragm Pump

Piston pumps deliver low to medium volumes (20 to 650 L/ha) at low to high pressures (150 to 5,500 kPa). They are used for high-pressure sprayers or when both low and high pressures are needed. They are positive-displacement, self-priming pumps. A surge tank should be used to dampen pressure surges. They are abrasion-resistant and capable of handling wettable powders for many years, although maintenance costs may be high.



Piston Pump

AGITATORS

Every sprayer must have agitation to keep the spray material uniformly mixed. If there is too little agitation, the pesticide will be applied unevenly. If there is too much agitation, some pesticides may foam and interfere with pump and nozzle operation. The type of agitation required depends on the pesticide formulation used. There are four main types of agitation:

Manual agitation by means of a paddle or continuous shaking may suffice for small hand-operated sprayers, but is not practical for power sprayers.

Mechanical agitation is obtained with paddles attached to a shaft mounted near the bottom of the spray tank. This type of agitation assures proper mixing with all liquid spray formulations. Careful maintenance of the spray equipment is necessary to prevent premature wear of the agitator shaft bearing which could result in pesticide leakage through the packings or seals. Excessive agitation speeds can cause foaming in some spray mixtures.

Hydraulic agitation is obtained when a portion of the pump output is returned to the tank. The simplest and least effective method is by return line from the pressure regulator valve (return-line agitation). This type of agitation is practical only with emulsifiable and water-soluble pesticide formulations. It is not suitable for wettable powders or in tanks larger than 250 L unless a high-capacity centrifugal pump is used.

A second type of agitation is provided by the high-pressure flow of surplus spray material through a separate agitator line into the spray tank. The liquid flows through jet agitators positioned at the bottom of the spray tank (Figure 31). Jet agitators are not to be attached to the pressure regulator valve return line as this will cause irregular valve operation. Hydraulic agitation is less troublesome than mechanical agitation and seldom causes mechanical breakdown.

Air sparging is agitation by bubbling air through the liquid. A compressor supplies air which is discharged from a sprayer tube at the bottom of the tank. As bubbles of air rise to the surface, they create turbulence which keeps the fluid well-mixed.

PIPES AND HOSES

Suction hoses (drawing from the tank) should be reinforced so that they will not collapse. Suction hose diameters should be at least as large as the pump intake opening. The same type of hose can be used for the bypass line.

Hoses and fittings on the pressure side of the pump must be able handle pressures higher than the intended operating pressures, preferably as high as the maximum pressure the pump can develop, to withstand pressure surges.

The inner and outer layers of all hoses should be resistant to chemical deterioration by the pesticides used.

PRESSURE GAUGES

The gauge is mounted on the output side of the pump to provide the operator with a visual guide in controlling pressure. Pressure gauges should have a pressure range which is at least twice the expected operating pressure. The gauge should have a pulsation damper to smooth pressure surges from piston pumps.

PRESSURE REGULATOR VALVES

The pressure regulator controls the pressure and, indirectly, the quantity of spray material delivered by the nozzles. It also protects pump seals, hoses and other sprayer parts from damage due to excessive pressure.

The return line from the pressure regulator to the tank should be kept fully open and unrestricted and should be large enough to carry the total pump output without any pressure buildup. The pressure range and flow capacity of the regulator must match the pressure range and the capacity of the pump. Jet agitation devices should not be attached to the return line discharge. Regulators include the following types:

Throttling valves restrict pump output, depending on how much the valve is open. These valves are used only with centrifugal pumps, whose output is very sensitive to the amount of restriction in the output line.

Diaphragm pressure regulator valves open or close in response to changes in pressure, diverting various amounts of spray back to the tank to keep pressure constant. Generally their use is confined to the lower pressure ranges, where they will regulate pressures more accurately than other types. They are abrasion resistant, and may be used with wettable powders, flowables and suspensions. However, the diaphragm material must be resistant to the pesticides used.

Pressure regulator valves with spring-loaded check valves operate like diaphragm valves and are available in many pressure ranges. At low pressures, their performance is less accurate than diaphragm pressure regulator valves.

Pressure regulator unloader valves work like a spring-loaded regulator valve when the sprayer is operating and remain open when the nozzles are shut off. They are recommended where high pressures (over 1,300 kPa) are frequently used. High pressures put heavy strains on both the motor and pump. Each time the nozzles are shut off, a pressure surge occurs in the pressure lines. This pressure surge triggers the unloader valve, allowing the spray mixture to return, under low pressure, to the spray tank. Consequently, both the motor and pump are relieved of strain each time the delivery system is shut off. When the boom shut-off valve is opened, a drop of pressure in the pressure line opens the pressure unloader valve.

Pressure regulator bypass valves. Some sprayers are now equipped with pressure regulator bypass valves to relieve pressure when starting the pump. As the name indicates, this valve allows the spray mixture to bypass the pressure regulator valve and return, under little pressure, to the spray tank. The bypass valve should be installed on the pressure side of the pump, with a return line to the spray tank. If a sprayer has a pressure unloader valve, a bypass valve is not required.

FILTERS

Filters are essential on all spray equipment. Improper filtering results in costly wear and tear on spray pumps, pressure regulators and nozzle orifices. Clogged nozzles are often the result of improper filtering and cause much 'down time'. Filtering devices should be used in the spray tank filler opening, in the suction line and in the pressure line of a sprayer system as follows:

Tank screens may consist of a funnel with a screen for small sprayers. Larger sprayers often feature a filling hole screen supplied by the manufacturer. Filtering at this stage removes only the coarsest contaminants. Smaller abrasive particles pass through this screen.

Suction line filters may be installed as a 'foot screen', attached to the end of the suction line, inserted through the top of the spray tank. This system prevents excess contaminants on the bottom of the spray tank from reaching the pump, but spray mixtures can never be entirely removed from the spray tank, except by draining. This will constantly present a pesticide disposal problem. A better method of filtering at this stage is the use of a large area 'in-line' suction filter. In this method, the suction line may be attached to and drain the bottom of the spray tank. No residue will remain to be flushed from the tank bottom. Suction line filters are usually 20 to 50 mesh[1], depending on the pesticide formulation used.

Pressure line filters are available as 'in-line' filters and nozzle screens. Pressure line filters may be used in addition to suction line filters, but should never replace them. Pressure in-line filters with a 100 mesh screen are often helpful when very small nozzle orifices are used. Nozzle screens or strainers are required for all power-operated sprayers. Manufacturers' recommendations should be adhered to. These screens usually vary from 50 to 200 mesh.

SPRAY GUNS

Spray Guns (Figure 32) are available in a wide variety of models and sizes. On many hand sprayers, smaller power sprayers and mist blowers, the spray gun is either an integral part of the sprayer or is supplied as standard equipment. Spray guns may consist of a shut-off valve and a nozzle in two distinct parts or both functions may be integrated in one adjustable unit. Spray guns are made of plastic, brass, aluminum or stainless steel, or combinations of these materials. Choice of material depends on the pesticide spray mixture and pressure used, as well as the frequency of use. A spray gun should be selected to match the sprayer operating pressure. Some guns are rated for pressures between

[1] mesh size refers to the number of holes per linear inch of screen

200 and 5,000 kPa, while others may be rated for pressures less than 1,500 kPa, or a different pressure range. Spray gun nozzles must be selected to deliver spray at the appropriate volume, angle and distance. Some nozzles are adjustable to produce patterns ranging from a solid stream to a fine cone spray.

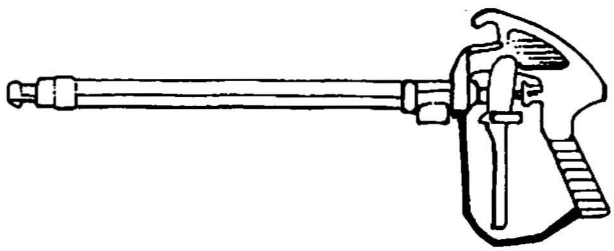


Figure 32. Typical spray gun.

NOZZLES

Sprayer nozzles serve three important functions:

- they break the liquid into droplets,
- they spread the droplets in a specific pattern, and
- they help regulate the rate of sprayer output.

Most sprayers use interchangeable nozzles. There are many types of nozzles with different combinations of output capacity, spray pattern and operating pressure.

Most nozzles are composed of four parts: the nozzle body, the strainer (screen), the tip and the cap (Figure 33). Some nozzles, called swirl nozzles or disc-core nozzles, include a swirl plate (core) between the strainer and an orifice disc which helps regulate droplet size. Swirl nozzles are used on air-blast sprayers.

The nozzle body holds the strainer and tip in proper position. Several types of tips that produce a variety of spray patterns may be interchanged on a nozzle body made by the same manufacturer.

The cap is used to secure the strainer and the tip to the body. The cap should not be overtightened.

The nozzle screen or strainer is placed in the nozzle body to filter out debris which may clog the nozzle opening. Screens come in mesh sizes from 20 to 200. The screen must have a mesh smaller than the nozzle orifice. Screens should not be finer than 50 mesh when wettable powders are used. A slotted strainer is often used in place of a screen for larger nozzle openings and cone pattern nozzles.

In some spraying operations, it is desirable to have a quick shut-off at each nozzle to prevent dripping. Special strainers equipped with check-valves are available for this purpose. A diaphragm or ball closes the nozzle opening when the pressure drops below a specified level. These diaphragm or ball check-valves may be used when turning a sprayer at the ends of rows, for spot spraying near sensitive crops or spraying indoors.

Nozzle tips are made from a variety of materials. Choice of materials depends on the abrasiveness of the spray mixture used. Wettable powders are more abrasive than emulsions. The nozzle materials below are listed in order of **increasing** rate of wear:

Alumax, Kemetal, Ceramic	Slow wear
↓	↓
Nylon	Slow wear
↓	↓
Stainless Steel	Slow wear
↓	↓
Brass	Rapid wear

Alumax, Kemetal and ceramic nozzles are expensive, but they will likely outlast the rest of the sprayer. Nylon and stainless steel nozzles will give acceptable wear with most chemicals, but each nozzle should be regularly checked for proper flow delivery. Brass tips are among the least expensive, but the metal is soft and the tips wear very quickly. As nozzle tips wear out, their spray pattern changes and rate of application increases. Tests have shown that wettable powders wear some nozzle tips sufficiently to increase the rate as much as 12% after spraying only 20 ha. If the flow from an individual nozzle varies from the manufacturer's specifications by more than 15%, the nozzle should be replaced. Like-

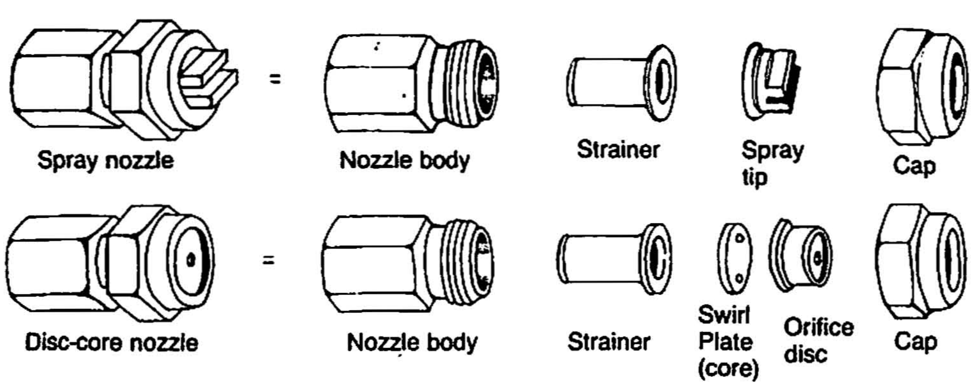


Figure 33. Parts of typical nozzles.

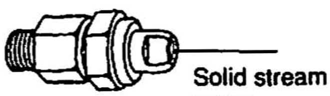
wise, if any nozzle varies from the sprayer's average nozzle output by more than 5%, it should be replaced.

There are a number of different nozzle manufacturers. Tests of different makes of nozzles have shown that some new nozzles produce unacceptable patterns, i.e. incorrect size and shape and uneven spray. Spray patterns can also change as nozzles wear. Nozzles must be replaced if spray patterns are incorrect.

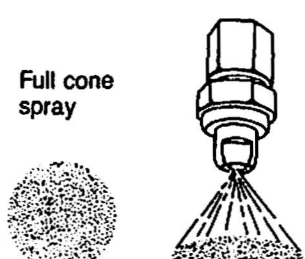
NOZZLE SPRAY PATTERNS

Spray nozzles are described according to the shape of the application pattern. There are six common patterns. Each nozzle type is available in various flow capacities and spray angles and is suited to a particular type of operation.

Solid stream nozzles are used in handgun sprayers to spray distant or specific targets such as livestock, nursery or tree pests. They are also used for crack and crevice applications (pin stream sprays) in structural pest control. When using a pin stream nozzle, it is usually desirable to keep the pressure below 150 kPa to reduce splashing.

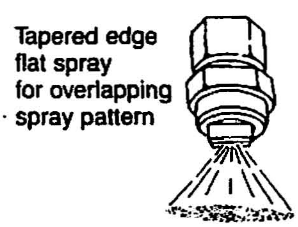


Full or solid cone nozzles are used to obtain thorough plant coverage, often required for row crops. They are available as regular or disc-core nozzles. Full cone nozzles are most often used to apply fungicides or insecticides to foliage. They are used for high volume applications where dense foliage requires a penetrating spray. They are frequently used on boom drop pipes or pendants to provide coverage of both sides of leaf surfaces (Figure 34). The spray angle may be from 30° to 120°.

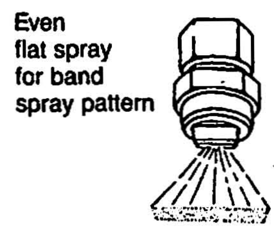


Hollow cone nozzles are used for agricultural crop spraying, particularly for spraying wettable powders, flowables and suspensions at higher pressures. They are available as regular or disc-core nozzles and are frequently used on boom drop pipes. Disc-core nozzles wear better than regular nozzles when abrasive wettable powders are used. Hollow cone nozzles generally produce a finer, more uniform spray than solid cone nozzles.

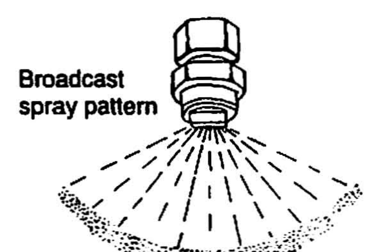
Tapered edge flat fan nozzles make a narrow oval pattern with tapered ends. They are used for broadcast herbicide and insecticide spraying at pressures between 100 and 400 kPa. The pattern is designed to be used on a boom and to be overlapped 30 to 100 percent. Spacing on the boom, spray angle and boom height determine proper overlap, and should be carefully adjusted.



Even flat fan nozzles make a narrow rectangular pattern with a relatively sharp cutoff at the edge of the pattern. They are used for band spraying. Boom height and nozzle spray angle determine the width of the ban sprayed.



Flooding nozzles deliver a wide flat spray (up to 135° wide). They are usually operated at low pressures to produce large droplets. Flooding nozzles can be mounted in various positions to produce different patterns. The most uniform application occurs when the nozzle tip is mounted 45° above the horizontal. Flooding nozzles are most often used for broadcast applications and are sometimes used alone for boomless broadcast spraying.



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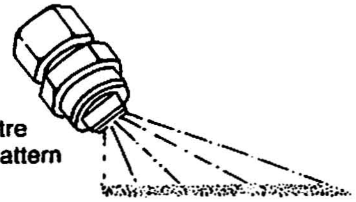
Off-centre nozzles produce a wide flat spray which is off to one side of the nozzle. The spray is relatively uniform along its width. They are often mounted on the side of trucks or short booms for spraying along roadsides or irrigation ditches.



NOZZLE FLOW RATES

Nozzle flow rate depends on the size of the nozzle orifice and the spray pressure. With most nozzles, flow rate increases as pressure increases. However, pressure must be increased considerably to achieve a small increase in flow rate. Pressure must be increased four times to double the flow rate. Tables of nozzle flow rates at various pressures are supplied by manufacturers. These tables are developed by measuring the flow rate of water. When other liquids are used, such as more dense or viscous liquids, the flow rates will be different. This is one reason why sprayers must be calibrated for each type of liquid applied.

Volume of spray to be applied per unit area is usually specified on pesticide product labels. For spraying agricultural crops with boom sprayers, herbicides are usually applied at 300 to 500 L/ha and fungicides and insecticides may be applied at 100 to 1,000 L/ha. Some treatments, such as for control of cabbage root maggot or potato late blight, require drenches of at least 1,000 L/ha. Because of the limited carrying capacity of aircraft, aerial sprays are usually applied at volumes of 25 to 200 L/ha.

Various categories of spray volumes for air-blast orchard sprayers are listed in Table 18. Most fruit tree pests and diseases can be controlled with low-volume air-blast sprays. High-volume air-blast spraying is characterized by considerable spray runoff which may be desirable for control of such bark pests as San Jose and European fruit scales.

SPRAY DROPLET SIZE

A nozzle produces a range of droplet sizes from very small to large. Droplet size is measured in microns(μ). One micron is one millionth of a metre; one thousandth of a millimetre. Average droplet sizes for various types of sprays are listed in Table 19.

Table 18. Categories of spray volumes for air-blast sprayers.

Category	Spray Volume
Ultra-Low Volume (ULV)	5 to 6 L/ha or less.
Low Volume Spraying (concentrate spraying)	Usually 550 to 850 L/ha, but may be as low as 100 L/ha. No runoff occurs.
Medium Volume Spraying	1,000 to 2,250 L/ha. Spray droplets flow together on the sprayed surface. Little or no runoff occurs.
High Volume Spraying	2,250 to 5,500 L/ha. Considerable runoff occurs.

Table 19. Typical droplet size ranges for various pesticide applications.

Category	Average Droplet Size in Microns	Examples of Uses
Fog	0.1 - 50	Thermal fog for greenhouse and structural pest control
Aerosol	1 - 50	Mosquito adulticiding by ground equipment, ultra-low volume applications
Mist	50 - 100	High-pressure sprays
Fine Spray	100 - 250	Cone and fan nozzles used for low-volume applications and air-blast sprayers
Medium Spray	250 - 400	Cone and fan nozzles for moderate-volume low toxicity sprays requiring good coverage
Coarse Spray	400 - 600	Cone and flood nozzles for large-volume and more toxic sprays
Minimum Drift Jet Stream Nozzle Spray	600 - 900	Aerial application near sensitive areas
Low Turbulence Nozzle Spray	800 - 1000	Microfoil boom applicator for aerial spraying near sensitive areas.

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18

The number of fine droplets increases as spray pressure is increased. At low pressures of about 135 kPa, low-volume spray nozzles produce very few fine droplets (about 15% by volume). The proportion of fine droplets in the spray increases rapidly as pressure is increased over 200 kPa. At pressures of 400 kPa, the spray consists of about 75% fine droplets. Air-blast sprayers produce a finer spray than boom sprayers for similar pressures and spray volumes. This is because the airstream which carries the spray to the target breaks up the droplets after they leave the nozzles.

The smaller the average diameter of droplets, the better the potential coverage will be for a given volume of pesticide spray (Table 20). However, the smaller the droplets, the greater will be the potential for spray drift. Fine droplets are easily diverted from the target by wind currents and evaporation. In order to increase coverage, it may be better to increase the volume of spray by changing nozzles, rather than increasing spray pressures to produce smaller droplets.

Table 20. Droplets per square centimetre when 25 L is evenly distributed over 1 ha.

droplet diameter in microns	number of droplets per cm^2
50	4,000
100	500
200	60
300	20
500	4

Generally, nozzle pressures should never be higher than necessary. For most applications, pressures ranging between 140 kPa and 350 kPa will produce adequate droplet sizes. Herbicides are generally applied within the range of 150 to 275 kPa to keep drift to a minimum. Insecticides and fungicides applied to vegetation often require higher pressures (300 to 2,000 kPa) to obtain thorough coverage and penetration of foliage. Different nozzle arrangements may require different pressures. A drop pendant boom (Figure 34) may require pressures of 500 to 1,000 kPa, while a simple flat boom would require pressures of up to 1,700 kPa to obtain the same leaf coverage. If ball check strainers or diaphragm check valves are used, pressure must be increased by 35 or 48 kPa respectively.

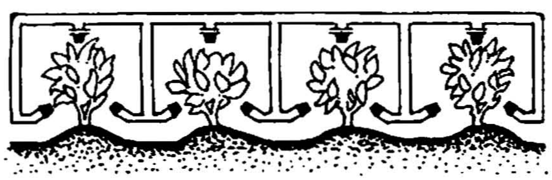

Figure 34. Schematic drawing of drop pendant spray boom for applying fungicides and insecticides to potatoes and cole crops. Note use of three nozzles for each row of plants.

CARE OF SPRAY EQUIPMENT

CLEANING

A sprayer should be cleaned before initial use when new, after each day's use, when changing pesticides and before off-season storage. New sprayers may contain metallic chips and dirt from the manufacturing process. Remove the nozzles, flush the sprayer with clean water and clean all screens and nozzles.

After each day's use, flush the sprayer tank, pump and hoses with clean water. Clean the filter, screens and nozzles. Drain the tank and allow it to dry. Use a toothbrush or other soft material to clean a nozzle tip. Never use a piece of wire, a nail or other metal object because these will damage the orifice, distort the spray pattern and increase the nozzle's output.

If a spray mixture is spilled on the machine during loading or mixing, the outside of the machine should be decontaminated immediately. Wash the contaminated area with soap (or mild detergent) and water, followed with a thorough rinse with plenty of water.

A sprayer should be thoroughly cleaned before use of a different pesticide or before off-season storage. Some pesticides such as 2,4-D are particularly persistent in the sprayer and must be removed completely to prevent possible crop damage during other spray operations. For thorough removal of most pesticides, the following procedure is recommended:

1. Put on rubber gloves, boots, hat, apron and goggles to avoid contact with pesticides during cleaning operations.
2. Wash the outside of the sprayer with soap (or mild detergent) and water, followed by a complete rinse with water. A steam cleaner can be used if available. Compacted deposits can be removed with a stiff bristle brush.
3. Remove all screens and nozzle tips and clean in kerosene or a detergent solution using a soft brush.
4. Mix about 200 g of detergent with 100 L of water in the tank. Circulate the mixture through the bypass for 30 minutes, then flush it out through the boom (when oil is used as the pesticide carrier, petroleum based solvents must be used instead of detergent solution).
5. Replace the screens and nozzle tips.
6. Fill the tank about ⅓ to ½ full of water then add 1 L of household ammonia or 200 mg of washing soda or 0.5 kg of Nutrasol to each 100 L of water. Circulate the mixture for five minutes, allowing some to go out through the nozzles. Keep the remainder of the

solution in the system overnight, then run it out through the nozzles the following morning.
7. Flush the system with a tankful of clean water by spraying through the boom with nozzles removed.
8. When the pump is not in use, fill it with light oil and store it in a dry place. If the pump has grease fittings, lubricate them moderately from time to time. Over-lubrication can break seals and cause the pump to leak.
9. Remove nozzles and screens and place them in light oil for storage.
10. Drain all parts to prevent frost damage.
11. Cover openings so that insects, dirt and other foreign material cannot get into the system.
12. Store the sprayer, hoses and boom in a dry storage area.

A number of pesticide spray mixtures have a tendency to penetrate the materials used for hoses, packings and gaskets. Therefore, if at all possible, do not use equipment which contained herbicides to apply insecticides or fungicides. If the same equipment must be used for herbicides and other pesticides, hoses should be kept separate as a minimum precaution.

All rinse water from cleaning application equipment must be disposed of in a way that will not contaminate the environment. See guidelines for disposal in Chapter 5.

MAINTENANCE

Proper equipment maintenance is essential for economic reasons, environmental safety and personal safety. Costs and hazards of equipment breakdown during pesticide applications are high. Improper maintenance results in:
- accidents,
- spills,
- hazards to personal safety,
- contamination of the environment,
- revenue loss due to 'down time',
- costs for replacement parts and labour for repairs, and
- crop loss.

Preventative maintenance starts with the selection of equipment to be purchased. Select equipment that will more than adequately do the job. Overworked equipment wears out quickly.

Pumps must have sufficient capacity to provide adequate volume and pressure. Always work the pump at the lowest required pressure and speed. Pressure drops may indicate:
- pump starvation — check suction screens and lines,
- valve or piston wear — replace worn parts,
- pressure regulating valve is defective — check and repair, or
- pump volume capacity is inadequate.

Screens of proper mesh and material should be selected for the pesticide formulation used. When selecting line and nozzle screens (filters, strainers) consider the particle size of the spray mixture, i.e. emulsifiable formulations, flowables, suspensions or wettable powders. Pump life will be prolonged and nozzle wear reduced.

Pressure regulating and unloader valves must have an adequate volume and pressure capacity. Consider the port diameters and spring capacity. Never start a pump against pressure.

Agitation must be selected which is appropriate for the pesticide formulation used, i.e. liquids or wettable powders. Proper agitation assures even mixing of the pesticide and diluent and reduces pump wear. When using hydraulic agitation with wettable powders, do not stop the pump while spray mix remains in the tank. Mechanical agitation requires additional maintenance, but is desirable if wettable powder mixes are used frequently.

Hoses, fittings and lines must be adequate for the pressures and volumes sprayed. Excessive sediment or plugged lines may cause pressure drops. Replace worn hoses.

Spray guns and nozzles should be appropriate for the material. More abrasive spray mixes require harder nozzle materials. Check nozzles regularly for wear. Avoid uneven application by replacing worn nozzles. Use nozzle strainers that match the orifice size.

Other preventative measures include:
- Overhaul pump yearly in the off-season; keep the pump and sprayer schematic diagram and parts list handy.
- Paint parts of the sprayer which will corrode, but do not paint the inside of the tank.
- Clean out the sprayer after use, especially after using wettable powders. Pesticides left in a sprayer will penetrate into hoses and gaskets, and metal tanks will corrode prematurely.
- Store unused sprayers under cover, drained and rinsed, and leave lid off spray tank.
- Use gaskets and washers of material such as teflon which will not deteriorate from pesticide mixtures.
- Keep spare parts in stock.

AEROSOL GENERATORS AND FOGGERS

Aerosol generators convert special formulations into very small, fine droplets (aerosols). Single droplets cannot be seen, but large numbers of droplets are visible as a fog or mist. Some aerosol generators, known as thermal foggers, use heat to vaporize a special oil formulation of a pesticide. As the pesticide vapour is released into the cooler air, it condenses into very fine droplets, producing a fog. Other aerosol generators (cold foggers) break the pesticide into aerosols by using mechanical methods such as rapidly spinning discs, extremely fine nozzles and high pressure (atomizing nozzles) or strong blasts of air.

This specialized equipment is often used in greenhouses, barns and warehouses as well as for biting fly and mosquito control in outdoor recreation areas. Outdoor use of aerosols is limited due to rapid drift from the target area. There is typically no residual control of pests, but re-entry is safe soon after enclosed spaces have been ventilated. Pesticides used in aerosol generators must be registered for that use. The operator, bystanders and animals must be kept out of the fog or mist.

WICK APPLICATORS

Wick applicators are used to selectively apply liquid herbicide by wiping it onto plants. Wicks are made of rope or absorbent pads and are kept wet by soaking part of the material in a concentrated herbicide mixture. For example, in one type of wick applicator, the herbicide solution is poured into a length of pipe and seeps out through rope segments (Figure 35). The herbicide can be wiped selectively onto weeds growing above crop seedlings or between crop rows. Often wick applicators are constructed by applicators to suit their own needs. Pumps, control devices and nozzles are minimal or eliminated and tanks are quite small because of the small amount of herbicide applied. They can be useful where selective weed control is required and no drift can be tolerated.

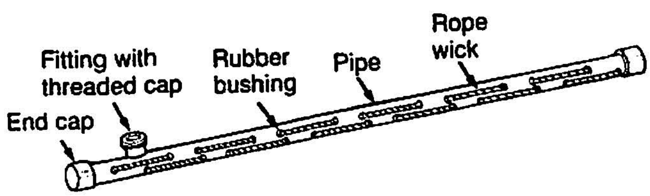

Figure 35. Example of a wick applicator.

EQUIPMENT FOR THE APPLICATION OF SOLID PESTICIDE FORMULATIONS

DUST APPLICATORS

Dust formulations may be applied by small or large, hand- operated or motorized dusters. Air is the carrier for the delivery of all dust formulations. Drift, therefore, is an important drawback for dust formulations. In structural pest control, small bulb or bellows-type hand dusters are frequently used for the delivery of minute quantities of pesticide dust in crack and crevice treatments. Single-stroke handpump dusters may be used for larger jobs such as treatment of carpenter ants in wall voids. Handcrank centrifugal dusters may be used in crawl spaces and attics. Power dusters are used where deep penetration of large areas is required. They are powered by electricity or gasoline and consist of a motor, dusthopper and radial fan. Motorized backpack sprayers (mist blowers) sometimes feature an optional tank for the application of dusts. Dust applications are not recommended for large-scale operations outdoors due to drift problems, residue problems on edible crops, and unsightliness on many ornamental crops and plants. In agriculture, dust applications are mostly used for small spot treatments.

In selecting a power duster, look for a unit which is easy to clean. It should give a uniform application rate as the hopper is emptied. The dust cloud should be directed away from the user.

GRANULE APPLICATORS

Granular Formulations are frequently used for large-scale applications, specifically for soil applications and when residual action is needed. Unlike spray and dust applications, there is little problem with drift or unsightly residues when granular applications are made. Phytotoxicity is often reduced with granular insecticide applications. Application equipment may be small or large. A hand shaker may be used for small spot treatments. Mechanical applicators distribute granules by means of forced air, spinning or whirling discs (fertilizer spreaders), multiple gravity-feed outlets (lawn spreaders, seed drills), soil injectors (furrow treatments) or ram-air (aircraft application). Granular applications may be described as:

- broadcast — even distribution over an entire area,
- spot treatment — hand application, furrow application or side-dressing, or
- soil incorporation — drilling or soil injection.

Good granular applicators have mechanical agitation over the outlet holes. This prevents clogging and helps keep the flow rate constant. Applicators should stop when forward motion stops, even if the outlets are still open. Application speed should not be too fast for ground conditions. Bouncing equipment will cause the application rate to vary. Band applicators must be checked frequently to see that band width stays the same. For example, band width may change due to applicator wheels sinking into soft soil.

Some limitations of granular applicators include the need to calibrate for each different granular formulation. Also, the spinning disc applicators often give an uneven distribution on sloping ground.

SOIL FUMIGATION EQUIPMENT

The equipment needed for applying soil fumigants depends on the kind of fumigant being used. There are two types of fumigants:
- low-pressure (low volatility) liquid fumigants (dichloropropenes and metam-sodium), and
- the highly volatile fumigant methyl bromide, which remains liquid only under pressure.

LOW-PRESSURE LIQUID FUMIGATORS

Equipment for applying low-pressure fumigants uses two basic designs for delivering the required amount of fumigant. These delivery systems are either pressure-fed or gravity-flow.
- **Pressure-fed applicators** have a pump and metering device and deliver fumigant at pressure to the nozzle openings (orifices), as with a low-pressure sprayer.
- **Gravity-flow applicators** use the size of the nozzle orifice and the pressure created by gravity to regulate the output of fumigant. Constant speed is necessary to maintain a uniform delivery rate. In most applicators, a constant head gravity-flow device keeps the pressure at the orifice(s) constant as the tank or container of fumigant empties. Needle valves, orifice plates or discs, and capillary tubes are used to adjust the flow rate.

Low-pressure fumigators usually use soil or water to keep the fumigant from vaporizing and dispersing too quickly. Some of the methods used are soil injection, soil incorporation and drenching or flooding.
- **Soil injectors** use a variety of mechanisms to place the fumigant into the soil (usually 15 cm or more) and then cover the area with more soil to seal in the fumigant. The principal mechanisms include chisel cultivators, sweep cultivator shovels, planter shoes and plows.
- **Soil incorporators** are used when applying low-volatility fumigants. The fumigant is usually sprayed onto the soil surface. The area is immediately cultivated, usually to a depth of 15 cm or less, and then compacted with a drag, float or cultipacker. Power-driven rotary cultivators are also used.
- **Drenching or flooding** uses water as a sealant. The fumigant may be applied in water as a drench, for example, with a sprinkling can or through irrigation equipment. Alternatively, the fumigant may be applied first, by spraying the soil surface, then flooding the area with water. The depth of the required water seal (usually 1 to 10 cm of wetted soil) depends on the volatility of the fumigant.

HIGH-PRESSURE FUMIGATORS

Effective application of highly-volatile fumigants depends on tightly sealing the soil with tarps, plastic film or similar covers. There are two major methods of using vapour-proof tarps:
- tarps are supported off the ground, then sealed around the edges and the fumigant is introduced under the tarp; or
- tarps are applied to the soil by the chisel applicator immediately after the fumigant is injected.

Highly-volatile fumigants must be handled in pressurized containers or tanks. The pressure in the tank maintains the pressure at the nozzle orifices. The tank is either precharged with sufficient pressure to empty its contents or an inert pressurized gas is fed into the tank during application to displace the fumigant. A pressure regulator maintains uniform pressure in the system. The fumigant must be under enough pressure to maintain its liquid state in the tank, pressure lines, manifold and metering devices. As the fumigant is discharged from the nozzles, it becomes a gas.

Extreme caution must be observed when working with fumigants due to the hazard of exposure to the highly toxic gases.

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CHAPTER QUIZ

Questions

1. What are two disadvantages of many hand-held sprayers?
2. What are typical application rates and operating pressures of low-pressure boom sprayers?
3. What is an ultra low-volume sprayer?
4. What are four considerations to be made in selecting a pump for a sprayer system?
5. When should mechanical agitation be used instead of hydraulic agitation?
6. Describe the function of a pressure regulator valve and a pressure regulator bypass valve.
7. Where should filters be placed within a sprayer system?
8. Which nozzle tip material has the longer life-expectancy: brass or nylon?
9. Match the following spray types with use descriptions: solid stream sprays, hollow cone sprays, even flat fan sprays, tapered edge flat fan sprays, off-centre sprays.

   (a) used on boom drop pipes for agricultural crops.
   (b) used for band sprays in agricultural row crops.
   (c) used for roadside spraying.
   (d) used for crack and crevice spraying.
   (e) used for broadcast spraying with overlapping spray patterns.
10. What are typical spray volumes for applying (a) herbicides, (b) insecticides from boom sprayers and (c) insecticides from air-blast sprayers?
11. How will increasing line pressure affect spray droplet size?
12. What are typical pressures for applying (a) herbicides and (b) insecticides and fungicides.
13. What solutions can be used to decontaminate a spray tank?
14. What are some disadvantages of using dust formulations?

Answers

1. Pressures and output rates usually fluctuate.
2. Typical application rates are 50 to 500 L/ha at pressures rangng from 150 to 500 kPa.
3. Applies pesticide concentrates directly — no mixing pesticide with carrier.
4. Pump capacity, corrosion resistance, operating pressure range, operating speed (RPM) range.
5. Mechanical agitation should be used for wettable powders or in tanks larger than 250 L.
6. The pressure regulator valve controls pressure in delivery lines; the pressure regulator bypass valve is used to relieve pressure for pump start-up.
7. Filler opening, suction lines, nozzles.
8. nylon.
9. solid stream sprays (d)
   hollow cone sprays (a)
   even flat fan sprays (b)
   tapered edge flat fan sprays (e)
   off-centre sprays (c)
10. (a) 300 — 500 L/ha
    (b) 100 — 1,000 L/ha
    (c) 550 — 850 L/ha
11. Increasing line pressure reduces spray droplet size.
12. (a) 150 - 275 kPa
    (b) 300 - 2,000 kPa
13. soapy water followed by ammonia in water or solvents, if oil is used as a carrier.
14. drift, unsightly residue on plants.

Chapter 19

EQUIPMENT CALIBRATION AND CALCULATIONS FOR CORRECT APPLICATION RATES

CONTENTS

INTRODUCTION

It is important to select the right pesticide and apply it at the right time for effective pest control. It is equally important to apply the right amount of pesticide to control a specific pest. The amount of pesticide applied per unit area or per plant is known as the **application rate.**

A pesticide product label provides the application rate for a specific pest. The label is a legal document. Thus pesticide products can only be used to control pests listed on the label and also can only be applied at specified rates. If higher application rates are used, there may be crop damage, harmful residues, excess runoff or damage to non-target plants or animals. If lower rates are used, the treatment may not be effective.

Preparations for pesticide treatment usually involve two procedures to ensure that application equipment will deliver the amount of pesticide specified on a product label. These procedures are:

1. Calibrate the application equipment so that it will cover an area uniformly and with the correct output.
2. Calculate the amount of pesticide and carrier to add to the tank or hopper and calculate the amount of pesticide required for the entire treatment area.

Calibration of application equipment may require adjustment of nozzles, operating pressures or ground speeds. After adjustment, equipment should be checked to measure its rate of delivery. Final adjustments may then be required to correct the delivery rate. The first part of this chapter reviews general procedures for calibrating five types of application equipment.

When equipment has been accurately calibrated to deliver the required output, relatively simple calculations are required to determine the amount of pesticide product to add to a spray tank or to apply to a specific treatment area. Several types of calculations may be required because application rates on pesticide labels are described in several ways. The second part of this chapter reviews the various ways that application rates are described and how to calculate pesticide requirements in each case.

EQUIPMENT ADJUSTMENT AND CALIBRATION

INTRODUCTION

The first step in preparing for pesticide application is to select a pesticide and to determine the required **delivery rate** of the application equipment. When using granular pesticides, the delivery rate is the amount of granules discharged per unit area. The delivery rate must be adjusted to give the application rate specified on the product label (e.g. 45 kg/ha).

When pesticides are applied as a spray, the equipment delivery rate is the **spray volume** applied per unit area. The operator must select the spray volume that is appropriate for the proposed treatment. Some label directions indicate a specific spray volume, e.g. "apply 5 L pesticide in 600 L of water per hectare". Other label directions do not indicate a specific spray volume, e.g. "apply 5 L pesticide in up to 500 L of water per hectare" or "in 200 to 600 L of water per hectare". When the spray volume is not specified, the operator must consider such factors as the following:

- the coverage required (spraying to runoff requires a greater spray volume than spraying only to wet surfaces);
- the surface to be treated (dense foliage or porous surfaces may require a greater spray volume);
- droplet sizes (a high spray volume generally means course sprays can be used); and
- mixing requirements (a high spray volume may require large spray tanks or frequent stoppng to mix spray solutions).

If spray volumes are not specified, herbicides are generally sprayed in 300 to 600 L of carrier/ha. Insecticides and fungicides are generally sprayed in 1,000 L of carrier/ha. Aerial applications may use lower spray volumes, e.g. 25 to 200 L/ha are commonly used.

The three main factors which determine delivery rate are: output, ground speed and swath width.

Equipment output is the amount of pesticide discharged per unit time (e.g. kg/min or L/min). For granular spreaders, operator instructions generally indicate what output setting to use and what speed to drive in order to deliver a specific swath width and application rate. In liquid spray equipment, the output is dependent on the number of nozzles, the nozzle opening sizes and line pressure. The nozzle manufacturers typically provide charts which show the combination of nozzle type and pressure which will produce a desired output (L/min). However, these output values should be checked in the field during equipment calibration. Most charts of output are based on the flow characteristics of water. Where the spray mix has a different weight or viscosity (thickness) than water, the sprayer should be calibrated with water, then output *should* be checked using the spray mix.

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Ground speed of the equipment is inversely related to its delivery rate. If you double the speed the application equipment travels over the ground, the delivery rate (kg/ha or L/ha) is halved. Motorized equipment speeds are typically between 3 and 12 km/h. If the speed is too fast, drift is increased, if speed is too slow, application time may be too long. Motorized equipment must be operated at a speed suited for the equipment. Tractor or truck speedometers are often inaccurate in the field due to wheel slippage. It may be necessary to check the forward speed under field conditions by recording the time taken to drive a measured distance. The gear and throttle setting or rpm should be recorded for use during pesticide application.

Swath width is the width over which spray droplets or granules are distributed as the equipment moves along its path. In broadcast applications, the pesticide is applied uniformly over the treatment area in overlapping passes. Swath width is measured from the center of overlap between each pass. In band applications, the pesticide is applied to a strip such as a crop row. The swath width is the width of the band(s) applied in one pass.

Nearly all pesticide application equipment (except ready-to-use aerosol cans or hand dusters) requires calibration. **Calibration** is the adjustment of equipment output and the measurement of delivery rate in a test which approximates typical operating conditions. Calibration should be done when new equipment is to be used, when the pesticide product or dilution is changed and at regular intervals to determine whether wear has changed pesticide output. Sprayers with brass nozzles should be recalibrated after about 25 hours of use. Sprayers with stainless steel nozzles should be recalibrated after about 50 hours of use. Calibration should be done more frequently when abrasive wettable powders are used.

Details of equipment calibration are described for five types of applicators in the following sections.

PORTABLE PRESSURE SPRAYERS

Portable pressure sprayers include hand-carried compressed air sprayers and backpack sprayers. They may be used for spraying individual shrubs or trees, small plots of ground or floors and walls of buildings.

The major considerations before calibration are the operating pressure and spray pattern. Some sprayers are equipped with pressure gauges. Pressures should be about 100 to 170 kPa for herbicides and 275 to 310 kPa for insecticides. When nozzles are adjustable, they should be set to produce a coarse spray for herbicides. This means there should be about 10 droplets per cm^2 and most droplets should be between 0.7 and 2.2 mm in diameter when applied to sample cards[1]. Nozzles should be set to produce a medium-fine spray for insecticides. Droplets should be more dense and smaller than for herbicide sprays.

Calibration of portable pressure sprayers is required to check the spray pattern, droplet size and spray volume per unit area.

[1]Suggested material for sample cards is Kromekote paper (shiny side up).

Calibration Procedure

1. Partially fill the sprayer with clean water. If sample cards are being used to check spray patterns, add a dye such as Rhodamine B to the water.

2. Spray sample cards to check droplet pattern. If necessary, adjust or change nozzles and pressure to achieve the desired spray droplet pattern.

3. Measure the effective swath width, using a consistent method of holding the wand or spray gun. For example, in a field, walk at a steady pace moving the wand slowly from side to side about 30 cm above the ground.

4. Fill the spray tank with a known quantity of water (i.e., use a dipstick marked at l L intervals) and pump to the pressure used when applying the pesticide.

5. Spray a test area characteristic of the treatment area. This may be several trees or a specific area of floor in a building or a specific area of ground. Ideally at least two adjacent swaths, 50 to 100 m long should be applied in a field. Walk at a steady pace and wet foliage as specified on the pesticide label. If the pesticide is to be sprayed to the point of runoff, apply until the spray drips off the foliage and runs down the branches and stem. (This rate is used only with ornamentals, not food plants). When spraying a baseboard, apply to uniformly wet the surface.

6. After the area is sprayed, release the sprayer pressure and measure the amount of water used.

7. Calculate spray volume applied. If individual trees are sprayed, determine how much spray will be required for each tree. If ground area is to be sprayed, calculate how much spray is required per unit area of ground. Use the following formula:

$$\text{Spray volume (L/ha)} = \frac{\text{spray used in test area (L)}}{\text{size of test area (m}^2\text{)}} \times 10{,}000\ \text{m}^2\text{/ha}$$

or,

$$\text{Spray volume (L/100 m}^2\text{)} = \frac{\text{spray used in test area (L)}}{\text{size of test area (m}^2\text{)}} \times 100$$

8. Make adjustments if the spray volume per unit area is not suitable. Walking more slowly will increase the spray volume per unit area; walking more quickly will reduce the spray volume.

MOTORIZED PRESSURE SPRAYERS

Most motorized pressure sprayers, including boom sprayers for broadcast or band treatments and boomless broadcast sprayers, require similar adjustment decisions and calibration steps. The three main variables which determine spray volume applied are nozzle output, ground speed and swath width. These variables are related as shown in the following formula:

$$\text{Spray volume (L/ha)} = \frac{\text{nozzle output (L/min)} \times 600^{1}}{\text{speed (km/h)} \times \text{swath width (m)}}$$

Usually nozzle output or ground speed are adjusted to obtain the required spray volume. Spray volume is the amount of pesticide spray to be applied per unit area.

Nozzle output depends on the size of the nozzle opening and pump pressure. Nozzle manufacturers help applicators choose the right tip for each type of treatment by providing detailed charts of tip performance. Such charts often show the nozzle tip that will produce a specified spray volume (L/ha) for a given ground speed (km/h), pressure (kPa), output (L/min) and nozzle spacing as shown in Table 21. Nozzles should be selected which match as closely as possible the spray volume, ground speed, pressure and nozzle spacing required.

Some charts of nozzle specifications only list their output rates for a given pressure. In such a case it is necessary to calculate the output (L/min) which will give the desired spray volume (L/ha). Use the formula:

$$\text{Output (L/min)} = \frac{\text{spray volume (L/ha)} \times \text{speed (km/h)} \times \text{swath width (m)}}{600}$$

For example: What should the output (L/min) of a nozzle be in order to apply 110 L/ha with a swath width of 50 cm and a ground speed of 10 km/h?

Answer: $\text{Output (L/min)} = \frac{110\ \text{L/ha} \times 10\ \text{km/h} \times 0.5\ \text{m}}{600} = 0.92\ \text{L/min}$

Nozzle tips should be installed on a boom using the spacing and boom height specified by the manufacturer. Nozzle tips should be aligned carefully as misalignment is a common cause of uneven coverage. The boom must also be level. If not, the spray pattern will be uneven.

When using overlapping nozzles on a boom, manufacturers typically recommend a 30% overlap[2] of spray from adjacent nozzles. The height of the boom alters the percent overlap. The boom height should be set at the height recommended by the nozzle manufacturer, then adjusted during calibration if necessary (Figure 36). Note that selecting nozzles with a wide spray angle permits a lower boom height, thus reducing the amount of spray drift. Increasing the line pressure increases the spray angle of some nozzles which then requires readjustment of boom height. The boom height may also have to be adjusted periodically if spraying a crop with a variable height.

[1] A constant to convert km/h to m/min and to convert L/m² to L/ha:

$$\frac{60\ \text{min}}{1\ \text{h}} \times \frac{1\ \text{km}}{1{,}000\ \text{m}} \times \frac{10{,}000\ \text{m}^2}{1\ \text{ha}} = 600$$

[2] Recently there has been a trend to use wide angle nozzles (110°) and 100% overlap of spray patterns. This 100% overlap reduces the variability of the spray deposit if there are small changes in boom height during application.

Table 21. **Chart of spray volumes for various flat fan nozzle types, pressures and ground speeds (from BCMAF Field Crop Guide).**

Delavan Nozzles 65 & 80°	Teejet Nozzles 65° & 80°	Pressure (kPa)	Output (L/min)	Spray Volume (L/ha) at 6 km/h	8 km/h	10 km/h	12 km/h
LF-0.67	650067 & 800067	200	0.22	43	32	26	22
		275	0.25	51	38	31	25
LF-1	6501 & 8001	200	0.32	64	48	39	32
		275	0.38	76	57	45	38
LF-1.5	65015 & 80015	200	0.48	97	73	58	48
		275	0.57	113	85	68	57
LF-2	6502 & 8002	200	0.64	129	97	77	64
		275	0.76	151	113	91	76
LF-3	6503 & 8003	200	0.97	193	145	116	97
		275	1.13	227	170	136	113
LF-4	6504 & 8004	200	1.29	258	193	155	129
		275	1.51	302	227	181	151

Note: Nozzles spaced at 50 cm.

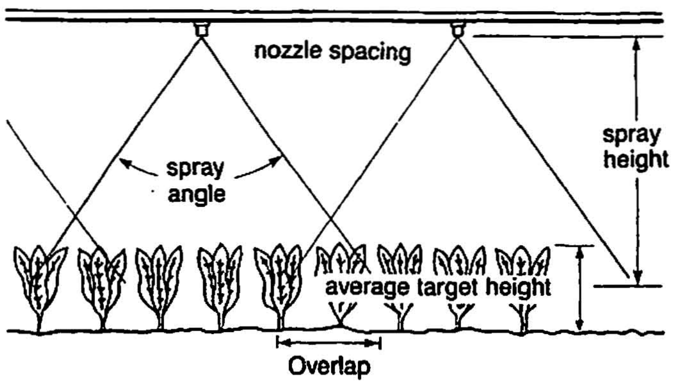

Figure 36. Measurement of spray boom height and spray pattern overlap.

Swath width of a boom sprayer with overlapping spray patterns is the width between nozzles (or drop pipes) times the number of nozzles. Note that the swath width will be wider than the distance between outermost nozzles (Figure 37).

On a boom sprayer used for band applications, the boom height influences the width of the band the nozzle sprays. The boom height must be adjusted to achieve the desired band width for the angle of nozzle selected. Swath width of a band sprayer is the sum of the widths of the nozzle spray patterns (Figure 37).

On a boomless sprayer, nozzle selection charts often specify the swath width produced by nozzles at a given height. An overlap percentage may also be recommended for adjacent swaths. The effective swath width includes half the width of overlap of adjacent swaths.

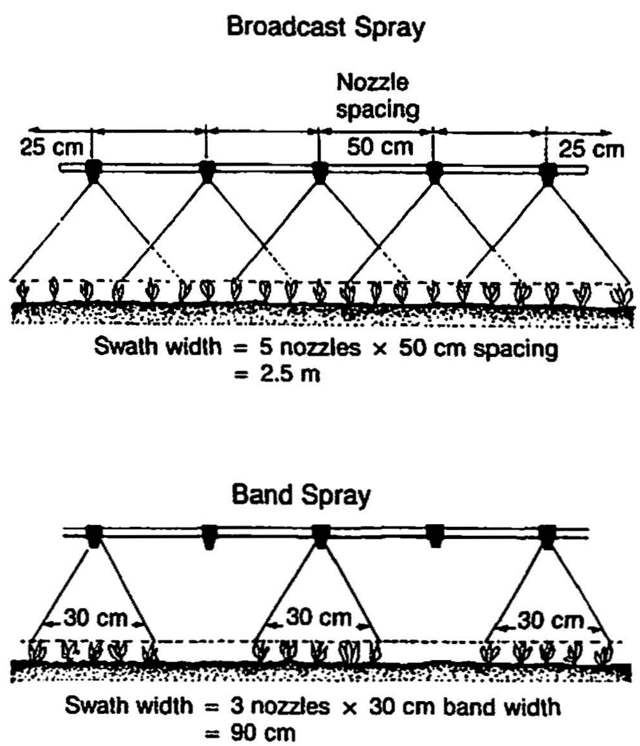

Figure 37. Measurement of swath width.

When the sprayer is set up, it should be calibrated to ensure that it is functioning properly under treatment conditions.

Calibration Procedure

1. Check nozzle patterns. Fill the spray tank about half full of water. Run the sprayer a few minutes to make sure the lines are full and all air has been expelled. Adjust the pressure regulator or the flow control valves so the desired operating pressure is developed and observe the pattern of spray on the ground. Clean or replace any nozzle tips with an uneven spray pattern.

2. Check nozzle output. With the sprayer stationary and operating at the proper pressure, collect spray from each nozzle for a specific time period (e.g. 1 min). Special measuring cups are available for this purpose. Record the volume in each measuring cup and calculate the average. Clean or replace any tip producing an output 5% above or below the average. Replace the whole set of tips when output varies from manufacturer's specifications by more than 15%.

3. Determine the spray volume (L/ha) applied to a test area or use step 4 to determine spray volume applied by the ground speed and output (L/min) method.

   (a) Measure and stake out a distance of 200 m or more in the treatment area or a similar area.

   (b) Fill the sprayer tank with water and ensure supply lines and the boom are full. Record the water level on a measuring stick.

   (c) Spray between the stakes in both directions at the selected speed and pressure. Turn the sprayer on at the first stake and off at the last stake in each direction. Note the transmission gear used as well as the throttle setting, rpm or speedometer reading (if accurate), so the same speed can be used during pesticide application.

   (d) Carefully measure the amount of water required to refill the tank to the original mark on the measuring stick. This is the amount needed for spraying the total distance travelled (i.e. twice the distance between stakes).

   (e) Calculate the spray volume per unit area with the following formula:

$$\text{Spray volume (L/ha)} = \frac{\text{water sprayed (L)} \times 10{,}000\ \text{m}^2/\text{ha}}{\text{swath width (m)} \times \text{distance travelled (m)}}$$

For example: What is the spray volume delivered by a sprayer which used 62 L to spray a distance of 400 m with a swath width of 3.5 m?

Answer: $$\text{Spray volume (L/ha)} = \frac{62\ \text{L} \times 10{,}000\ \text{m}^2/\text{ha}}{3.5\ \text{m} \times 400\ \text{m}} = 442\ \text{L/ha}$$

4. As an alternative to step 3, determine spray volume per unit area by the ground speed and output (L/min) method. If the ground speed of the sprayer can be accurately determined, a quick check on spray volume applied can be determined from nozzle output.

   (a) Ground speed must be measured by travelling a known distance (e.g. stake out a distance of 200 m or more). Record the time (in seconds) taken to travel the distance several times and average the results. Use the same throttle setting and transmission gear each time.

   (b) Calculate the ground speed (km/h) for the throttle setting and transmission gear used with the following formula:

$$\text{Speed (km/h)} = \frac{\text{distance travelled (m)} \times 3.6^{1}}{\text{time (sec)}}$$

   (c) Determine nozzle output (L/min) for the sprayer. If all nozzles have the same output, collect the flow from any one nozzle for a specific time, e.g. 1 min., then multiply that flow times the number of nozzles to obtain the sprayer output. To be more accurate, determine the flow from all nozzles for a longer period, e.g. 5 min. Measure the water level in the tank before spraying, then measure the amount required to refill the tank to this level after spraying (use a dipstick).

   (d) The spray volume applied (L/ha) can be calculated from the following formula:

$$\text{Spray volume (L/ha)} = \frac{\text{output (L/min)} \times 600}{\text{speed (km/h)} \times \text{swath width (m)}}$$

For example: What spray volume (L/ha) would be applied if the ground speed was 6.5 km/h, the sprayer output was 10.5 L/min and the swath width was 4 m?

Answer: $$\text{Spray volume (L/ha)} = \frac{10.5\ \text{L/min} \times 600}{6.5\ \text{km/h} \times 4\ \text{m}} = 242\ \text{L/ha}$$

5. Adjust spray volume applied. If calibration shows that equipment is not delivering the desired spray volume (L/ha), adjustments should be made and the sprayer retested. Adjustments to spray volume can be made in one of three ways:
   - Changing pump pressure. Lower pressure means less spray delivered; higher pressure means more spray delivered. Only minor adjustments in pressure should be made because adjustment will change the spray droplet size.
   - Changing nozzle tips. Changing nozzle output (L/min) is the preferred method for making a large adjustment to spray volume per hectare.

[1] A constant to convert m/sec to km/h:

$$\frac{60\ \text{sec}}{\text{min}} \times \frac{60\ \text{min}}{\text{h}} \times \frac{1\ \text{km}}{1{,}000\ \text{m}} = \frac{3{,}600}{1{,}000} = 3.6$$

- Changing sprayer speed. Slower speed means more spray delivered per unit area; faster speed means less spray delivered. This is a practical method for most small adjustments to spray volume. Use the following formula:

$$\text{Required speed (km/h)} = \frac{\text{present speed (km/h)} \times \text{present spray volume (L/ha)}}{\text{desired spray volume (L/ha)}}$$

AIR-BLAST ORCHARD SPRAYERS

Air-blast sprayers use a high-speed, fan-driven airstream to disperse the spray through foliage. A series of nozzles inject the spray into the airstream which breaks up the droplets and blows them into the tree. Some sprayers direct spray to only one side at a time. Other sprayers direct the spray to both sides and require only one pass between tree rows.

Setting up air-blast sprayers for specific orchard conditions requires considerable knowledge. The most important output adjustments and calibration steps are reviewed in this section. More details are provided in Agriculture Canada Publication No. 1635 (1977).

Air-blast sprayers may be used to apply a range of spray volumes per unit area, but the typical output is 560 to 840 L/ha. There are three main factors which govern spray volume.

Volume of airstream. Large trees require a greater volume of air (e.g. 3.3 m^3/sec for trees up to 5.5 m high, 9 m apart) and dwarf trees require a smaller volume of air (e.g. 1.4 m^3/sec for trees up to 4 m high, 4.5 m apart). Use air volumes recommended in equipment manuals.

Ground speed of sprayer. Factors to consider when selecting speed of a sprayer are tree size and spacing, density of foliage, wind conditions and sprayer efficiency. The speed must be slow enough to allow the spray-laden airstream to establish itself up through the foliage. Larger trees with larger spacing between rows will require a slower speed. Use recommended speeds between 1.5 and 5.0 km/h. Too fast a speed will provide inadequate coverage in the top and centres of trees.

Nozzle output. Nozzle output (L/min) is determined by pump pressure and nozzle opening size. For low-volume spraying, pump pressure is usually about 690 kPa. A lower pressure (about 105 kPa) is used with air-shear nozzles. The nozzle opening affects both output and breakup of the spray. If the nozzles are enlarged through wear, the output will increase and spray breakup will be deficient. Nozzles should be checked and replaced before serious wear occurs.

A set of spray nozzles must be selected with an output (L/min) which will deliver the correct spray volume (L/ha) at the desired ground speed. The required nozzle output can be calculated from the following formula:

$$\text{Output per side (L/min)} = \frac{\text{spray volume (L/ha)} \times \text{space between rows (m)} \times \text{speed (km/h)}}{1{,}200^{1}}$$

For example: What should the output be for all the nozzles on one side of an air-blast sprayer where the desired spray volume is 560 L/ha, the speed is 3.2 km/h, row spacing is 6 m and operating pressure is 690 kPa?

Answer: $$\text{Output of all nozzles on one side (L/min)} = \frac{560 \text{ L/ha} \times 6 \text{ m} \times 3.2 \text{ km}}{1{,}200^{1}} = 8.96 \text{ L/min}$$

When the sprayer output (L/min) has been calculated, a set of nozzles can be selected from manufacturer's charts. The specified output of the individual nozzles must add up to the required output for the sprayer. Air-blast sprayers usually require six or seven nozzles arranged in an arc on manifolds on each side. The nozzles on the upper half of a manifold should emit about two thirds of the spray. Review the operating manual or the Agriculture Canada bulletin (1977) for more details on nozzle selection and arrangement.

After a set of nozzles has been selected, the spray volume applied by the sprayer should be calibrated using water. Calibration should also be repeated at the beginning of each season.

Calibration Procedure

1. Determine ground speed. Fill the spray tank half-full of water and determine the tractor gear and rpm that gives the ground speed that you require. Speed should be measured by recording the time taken to travel a known distance. Use the following formula:

$$\text{Speed (km/h)} = \frac{\text{distance travelled (m)} \times 3.6}{\text{time (sec)}}$$

Another method is to determine the number of tree spaces per minute you will pass at the desired speed. Use the following formula:

$$\text{Tree spaces/min} = \frac{\text{speed (km/h)} \times 16.7^{2}}{\text{tree spacing (m)}}$$

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[1] A constant to convert L/ha × m × km/h to L/m² × m × m/min = L/min. Multiply by ½ for output to one side = ½ the space between rows:

$$\frac{1 \text{ L}}{10{,}000 \text{ m}^2} \times \frac{1{,}000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{1}{2} = \frac{1}{1{,}200}$$

[2] A constant to convert km/h to m/min:

$$\frac{1{,}000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ hr}}{60 \text{ min}} = 16.7$$

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For example: How many tree spaces should you pass in one minute if your tree spacing is 7 m and you wish to travel at 2 km/h?

Answer: $$\text{Tree spaces/min} = \frac{2 \text{ km/h} \times 16.7}{7 \text{ m}}$$
$$= 4.8 \text{ tree spaces/min}$$

This means the sprayer should pass 4.8 tree spaces in one minute to be travelling at 2 km/h. Check this by determining how long it takes to travel the 4.8 tree spaces. If you covered the distance in less than a minute, slow down. If you covered the distance in more than a minute, speed up. Record the rpm and transmission gear used to give the correct speed.

2. Determine the sprayer output (L/min). Measure the amount of water discharged from the tank for a specific period of sprayer operation. Fill the spray tank with some water and mark the level on a measuring stick. Spray out the water for 10 minutes at the desired pump pressure. Measure the water left in the tank or, the amount required to refill the tank to the original level, and calculate how much was sprayed out. Divide the amount sprayed out by 10 to give the flow rate in litres per minute.

3. Calculate the spray volume per unit area with the following formula:

$$\text{Spray volume for 2-sided sprayer (L/ha)} = \frac{\text{output (L/min)} \times 600}{\text{space between rows (m)} \times \text{speed (km/h)}}$$

For example: What spray volume (L/ha) would be applied if the sprayer output is 28 L/min, the ground speed is 3.2 km/h, row spacing is 6 m and operating pressure is 690 kPa?

Answer: $$\text{Sprayer volume (L/ha)} = \frac{28 \text{ L/min} \times 600}{6 \text{ m} \times 3.2 \text{ km/h}}$$
$$= 875 \text{ L/ha}$$

4. Adjust spray volume applied if necessary. If the spray volume is not suitable, adjust the pressure slightly or change one or more nozzles and repeat the 10 minute output check.

GRANULAR APPLICATION EQUIPMENT

Granular application equipment include broadcast spreaders, band spreaders and soil injectors. Granules may be distributed by gravity feed, whirling discs (spinners) or air-blast methods. The delivery per unit area (kg/ha) depends on the ground speed of the equipment, the swath width and the output (kg/min) of granules. Equipment output depends on the size of the adjustable hopper openings, the size, weight and shape of the granules and the roughness of the terrain. Equipment should be calibrated for each batch of product used and for new field conditions.

Equipment should be adjusted initially by following the manufacturer's instructions in the equipment manual. Use recommended output settings for the type of granules and use the recommended speed, taking into consideration the application site. Soft, muddy or uneven surfaces require lower speeds.

Calibration Procedure

1. Check the swath width and application pattern. Fill the hopper with some granules. Drive a short distance at the desired speed. Measure the width of the swath and check for uniform distribution along the swath width. If granule pattern is uneven, adjustments may be required to the speed of the spinner or the spot on the spinner where the granules land.

2. If the spreader can be operated while the tractor is stationary, use this method to measure delivery rate (kg/ha), otherwise use method 3 below.

   (a) Fill the hopper about half-full of granules.

   (b) Determine your exact ground speed during application. Calibrate your speed by driving a measured distance, e.g. 200 m, with the spreader shut off. Record the throttle setting and gear you use. Note the time it takes in seconds. Calculate actual speed by using the following formula:

$$\text{Speed (km/h)} = \frac{\text{distance travelled (m)} \times 3.6}{\text{time (sec)}}$$

   (c) Run the spreader while the unit is stationary and collect the granules discharged from one tube or opening for a timed interval, e.g. 2 min. Weigh the granules and calculate the output per minute.

   (d) Calculate the delivery per unit area using the following formula:

$$\text{Delivery rate (kg/ha)} = \frac{\text{output (kg/min)} \times 600}{\text{speed (km/h)} \times \text{swath width (m)}}$$

3. Another method to determine delivery per unit area is to measure the output while driving a measured distance.

   (a) Fill the hopper half-full of granules.

   (b) Mark out a distance of 200 m or more.

   (c) Collect the material discharged from the spreader in a bag or box while driving the tractor over the 200 m distance.

   (d) Weigh the granules discharged into the container and calculate the output per hectare by the following formula:

$$\text{Delivery rate (kg/ha)} = \frac{\text{amount applied to test area (kg)} \times 10{,}000 \text{ m}^2\text{/ha}}{\text{distance travelled (m)} \times \text{swath width (m)}}$$

4. Adjust the applicator delivery rate. If calibration shows the equipment is not delivering within 5% of the required application rate, adjust the ground speed during application or adjust the granule output setting on the spreader and recalibrate. If the required output of granules was 45 kg/ha, then 5% = 0.05 × 45 = 2.25 kg/ha. The lowest acceptable delivery rate would be 44 - 2.25 = 41.75 kg/ha. The highest acceptable rate would be 44 + 2.25 = 46.25 kg/ha.

In order to calculate the speed required to obtain the desired delivery rate, use the following formula:

$$\text{Required speed (km/h)} = \frac{\text{present speed (km/h)} \times \text{present delivery rate (kg/ha)}}{\text{desired delivery rate (kg/ha)}}$$

AERIAL APPLICATION EQUIPMENT

Aerial application equipment includes sprayers and granule spreaders mounted on fixed-wing aircraft or helicopters. Applications are generally made at heights of 3 to 10 m above the tops of plants at 128 to 200 km/h.

Aerial spray equipment should be calibrated for each treatment project to determine whether the aircraft is delivering the required volume of spray. Typical spray volumes are 25 to 200 L/ha. It is also necessary to check droplet size and distribution and to determine nozzle flow and swath width.

Droplet size range and number per unit area will vary depending on nozzle type, orifice size and nozzle orientation to the wind. Boom pressure, aircraft speed and flying height will also affect the droplets.

Before calibration, nozzles must be selected which will give the desired output (L/min). First, it is necessary to calculate the output for all the nozzles. Use the following formula:

$$\text{Output (L/min)} = \frac{\text{spray volume (L/ha)} \times \text{speed (km/h)} \times \text{swath width (m)}}{600}$$

For example: The aircraft will travel at 160 km/h, the pesticide spray is to be applied at 80 L/ha and the effective swath width is 15 m. What should the nozzle output of the system be?

Answer: $\text{Output (L/min)} = \frac{80 \text{ L/ha} \times 160 \text{ km/h} \times 15 \text{ m}}{600}$

$= 320 \text{ L/min}$

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Nozzles are selected which, together, will achieve the desired output for the system. Manufacturers' charts are used to select individual nozzles with the appropriate droplet type, angle of spray and output for a specific line pressure.

Nozzles are usually arranged along a boom to provide a uniform spray pattern. Most nozzles are spaced 15 to 20 cm apart. However, several nozzles should be grouped close together, 90 to 120 cm to the right of the aircraft centreline because of the clockwise propeller rotation. No nozzles should be located between 90 to 120 cm to the left of the centreline. This will even out the spray distribution on the ground. Nozzles should not be placed beyond 3/4 of the distance from the fuselage to the wing tip or rotor tip due to wind vortices in this area.

When the system is set up, sprayer calibration involves the following steps.

Sprayer Calibration Procedure

1. Pressurize the spray system. Put about 75 L of carrier to be used (e.g. water or oil) into the tank. While stationary, bring the system up to the desired pressure and spray out. As soon as the pressure starts to drop, as the tank empties, shut the system off. The system is now pressurized for calibration.

2. Determine the system output (L/min). Add a measured volume of carrier using measuring pails or a flow meter. Load sufficient spray for approximately one minute of spraying. Start the sprayer and record the time taken for the pressure to drop, then shut off the sprayer. Calculate the output per minute.

3. Conduct a spray test to determine swath width, spray coverage and droplet size spectrum. One method is to add a tracer dye to water in the spray tank. The aircraft is flown at the selected airspeed and height and the spray system is operated at the selected pressure. A pass is made over a sample line which consists of a row of target cards or a continuous strip of paper (e.g. adding machine paper) laid out at right angles to the direction of flight. The aircraft should spray at the desired height over the centre of the sample line which is at least 25 m long.

4. The sample cards or paper can be analyzed for quantity of the tracer dye. A gradual reduction in spray density toward the edge of the spray pattern is ideal as this allows for swath overlap. The point where the spray density is one-half that of the centre of the swath marks the edge of the effective swath.

5. Droplet size can be determined from the size of dye stains on standardized spray cards (i.e. Kromekote paper). Measure the size and density of dye stains on a number of sample cards in the path of the test swath. An ideal pattern for herbicides is 10 droplets per cm^2, most droplets 0.7 to 2.2 mm in diameter, no droplets larger than 7 mm and few droplets smaller than 0.3 mm.

6. Using the calibrated nozzle output and swath width, calculate the spray volume applied (L/ha) using the following formula:

$$\text{Spray volume (L/ha)} = \frac{\text{output (L/min)} \times 600}{\text{speed (km/h)} \times \text{swath width (m)}}$$

Where the spray volume is not within 5% of the desired amount (as may be required by the product label), adjust the flow rate or speed and recalibrate.

7. If droplet size is not adequate, make adjustments and retest. To increase droplet size:
   - orient the nozzles straight back with respect to the flight direction,

- lower spray pressure (not below about 150 kPa) and add nozzles to keep the same output,
- change the nozzles to a larger orifice size and reduce the number of nozzles to keep the same output, or
- if evaporation is high, wait until cooler weather so more spray will reach the ground.

To reduce droplet size:
- orient the nozzles straight down or slightly forward with respect to the flight direction,
- increase spray pressure (not above 400 kPa) and reduce nozzle numbers to keep the same output, or
- change the nozzles to a smaller orifice size and increase the number of nozzles to keep the same output.

Granular spreaders are calibrated to determine their output and to check the swath pattern as follows.

Spreader Calibration Procedure

1. Determine the spreader output per minute. Operate the spreader for a timed interval, e.g. 2 min. If the spreader can be operated on the ground, the granules can be caught in a large cloth or paper bag and weighed. If a flight test is required, the spreader can be operated in the air for the timed interval and the quantity needed to refill the hopper is weighed. Blank granules (without pesticide) should be used in such a test.

2. Adjust the gate setting on the spreader to change the output (L/min) if necessary. Use the following formula to calculate the required output:

$$\text{Output (kg/min)} = \frac{\text{delivery rate (kg/ha)} \times \text{speed (km/h)} \times \text{swath width (m)}}{600}$$

3. Check the swath pattern. Use large containers, e.g. buckets, spread in a row at right angles to the direction of flight. The quantity of blank granules caught in each container is measured with a sensitive balance or the volume determined in a narrow graduated cylinder. From these readings and the spacing of the containers, the swath pattern can be graphed on paper. Adjustments are made if the granule pattern is uneven and the test is repeated to check adjustments.

PESTICIDE USE CALCULATIONS

Pesticide use calculations are required to answer the following kinds of questions:
- How much pesticide should be added to a spray tank?
- How large an area will one tank of spray or one hopper of granules cover?
- How many tankfuls or hoppers full are required for the treatment?
- How much pesticide is required for the treatment?
- How would a spray mix be changed to a different percent concentration of pesticide?

Generally, pesticide use calculations are based on the calibrated delivery rate of the application equipment. If you know exactly how much a sprayer is delivering per hectare, you can calculate exactly how much pesticide is required.

The mathematics used to answer these questions is simple. However, there is some variation in the calculations required for different types of pesticides. In the following examples, calculations are shown for pesticides with different types of application rates.

If you do not already use the metric system, the first step in all the examples below is to convert measurements to metric units. This includes the size of the treatment area and the capacity of the spray tank or hopper. Use the following formulae (Appendix II):

Areas

Field size (acres) × 0.405 = Field size (ha)
Field size (yd^2) × 0.836 = Field size (m^2)

Capacity

Tank size (imperial gallons) × 4.55 = Tank size (L)
Tank size (U.S. gallons) × 3.97 = Tank size (L)

GRANULAR PESTICIDES

The application rate for granular pesticides is usually expressed as an amount of product to apply to a specific area. No mixing is required, so these calculations are very easy.

For example: A label specifies you should use 75 kg of granular product per hectare. Your treatment area is 2.1 ha. You have adjusted the spreader and calibrated it so that it has a delivery rate of 77 kg/ha which is within 5% of the required application rate. The hopper holds 30 kg. The application is to be a broadcast treatment, i.e. the entire field is to be treated.

Step 1. Determine how large an area one hopperful will treat. If you are treating a large area, it is a good idea to determine the area which can be treated by one hopperful. Then, check that this area was in fact covered after applying the hopperful.

Divide the hopper capacity by the calibrated delivery rate.

30 kg ÷ 77 kg/ha = 0.39 ha covered by one hopperful
= 3900 m^2 (1 ha = 10,000 m^2)

Step 2. Determine how much pesticide is required for the total treatment.

Multiply the field size times the calibrated delivery rate.

2.1 ha × 77 kg/ha = 161.7 kg pesticide required

Step 3. Determine how many hopperfuls are required.

Divide the total pesticide required by the capacity of the hopper.

161.7 kg ÷ 30 kg = 5.4 hopperfuls required.

Note that if the spreader delivery rate was calibrated to be 770 g per 100 m², you must first convert this rate to delivery per 1 m² or 1 ha in order to use the formula in steps 1 and 2 above. Thus to find the area treated by one hopper in step 1, first convert g/100 m² to g/m², e.g.

$$\text{Delivery rate} = \frac{770 \text{ g}}{100 \text{ m}^2} = 7.7 \text{ g/m}^2$$

Then, divide the hopper capacity (30 kg = 30,000 g) by the calibrated delivery rate, e.g.

$$30{,}000 \text{ g} \div 7.7 \text{ g/m}^2 = 3{,}896 \text{ m}^2$$
$$= 0.39 \text{ ha covered by one hopper}$$

For a **band treatment**, where only crop rows or spaces between crop rows are treated, an additional step may be required. If the calibrated delivery rate is for the treated bands only, the delivery rate per total area of field must be calculated.

For example: The calibrated delivery rate per band is 77 kg/ha, the crop rows are spaced at 50 cm and the band width is 15 cm (Figure 38).

Step 1a. Convert pesticide applied per band to pesticide applied per total area.

Multiply band delivery rate times the width of a band divided by the distance between rows.

$$77 \text{ kg/ha} \times \frac{15 \text{ cm}}{50 \text{ cm}} = 23.1 \text{ kg/ha}$$

In this example, the application rate on the label would be 75 kg/ha. The calibrated delivery rate in the treated bands is 77 kg/ha. The delivery rate when averaged over the whole field would be 23.1 kg/ha. Use the delivery rate per total area when calculating pesticide use in Steps 1 to 3 above.

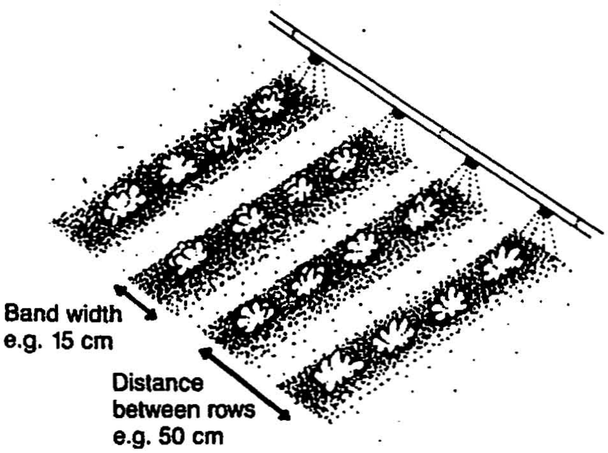

Figure 38. Relation between band widths and distance between crop rows.

For some band treatments, the application rate is given as the amount of pesticide to apply per length of crop row (e.g. apply 40 g/100 m row). Calculate pesticide requirements per length of row as in Steps 1 to 3 above.

For example: Calculate how much pesticide is required to treat 20,000 linear metres of crop row if the application rate is 40 g/100 m row.

Multiply the application rate times the length of crop row.

Application rate = 40 g/100 m = 0.4 g/m
0.4 g/m × 20,000 m = 8,000 g = 8 kg pesticide required

PESTICIDES APPLIED IN SPRAY MIXTURES

Application rates for pesticides applied in spray mixtures are either given as the pesticide concentration in the spray mixture or the amount of pesticide to apply per unit area. When the amount of pesticide per unit area is specified, the rate of dilution may be specified or may be left to the discretion of the operator. When the application rate is expressed as a concentration, instructions may be given to mix a certain amount of pesticide per volume of spray, or to make a spray solution with a specified percent active ingredient. Calculations to determine pesticide requirements are shown below (A-E) for each of these types of application rate.

A. The pesticide is to be mixed in a specified volume of spray

Label directions may indicate the amount of pesticide to mix in a carrier such as water or oil, with instructions to cover the area being treated. This type of direction is given for many pesticides used for structural pest control, for spraying ornamentals or for spot treatments using herbicides.

For example: The application rate on the label specifies you should add 7 L of liquid concentrate per 100 L of water[1]. Your spray tank holds 10 L. You calibrate your sprayer and determine its delivery rate is 4 L per 100 m². A broadcast treatment over 300 m² is required.

Step 1. Calculate how much spray is required in total.

Multiply the sprayer delivery rate times the total treatment area.

Delivery rate = 4 L/100 m² = 0.04 L/m²
0.04 L/m² x 300 m² = 12 L spray required

[1]Note that an application rate of 7 L **per**, or **in** 100 L of water means 7 L of product with 93 L of water to make 100 L of spray mix. It would be different if the label read "add 7 L of pesticide with or to 100 L of water". Then, the total spray mix would make 107 L.

Step 2. Calculate how many spray tankfuls are required.

Divide the total required spray by the tank capacity.

12 L spray ÷ 10 L tank capacity = 1.2 tanks required

Step 3. Calculate how much pesticide to add to the spray tank. (The first tankful will hold 10 L of spray, the second will be a partial tankful of 2 L).

Multiply the dilution rate by the tank spray volume.

Dilution rate = 7 L pesticide/100 L spray = 0.07 L/L spray

0.07 L/L × 10 L = 0.7 L (700 mL) pesticide should be added

Step 4. Calculate how much pesticide is required in total.

Multiply the dilution rate times the total spray required.

0.07 L pesticide/L spray x 12 L spray = 0.84 L (840 mL) pesticide required

Note that if the application rate was given as 70 g wettable powder per 100 L, you would follow the same steps. Thus, to calculate how much pesticide powder to add to a 10 L spray tank, multiply the dilution rate times the spray volume.

Dilution rate = 70 g/100 L = 0.7 g/L

0.7 g/L x 10 L spray = 7 g pesticide required

Note that if the calibrated sprayer output was an amount of spray per individual tree (e.g. 2 L/tree) you would perform the same calculations in Steps 1 through 4. Thus, to calculate how much spray you need for 50 trees, multiply the sprayer output per tree times the total number of trees.

2 L spray/tree × 50 trees = 100 L spray required in total

B. The pesticide is to be mixed in a variable volume of spray and applied at a specified rate per area

This rate is often specified for herbicides. The amount of carrier mixed with the herbicide is not as critical as the amount of pesticide applied per unit area.

For example: The label requires application of 1.8 L of liquid concentrate in 200 to 600 L of water per ha. You calibrate the sprayer and find it delivers 412 L of spray per ha which is sufficient for your needs. Your spray tank holds 500 L of spray. The total treatment area is 5 ha.

Step 1. Calculate how much spray is required in total.

Multiply the sprayer delivery rate (L/ha) times the total treatment area.

412 L/ha x 5 ha = 2,060 L spray required

Step 2. Calculate how large an area one tank will cover (use the same procedure for a full tank of 500 L or a partial tank).

Divide the volume of spray in the tank (L) by the sprayer delivery rate.

500 L ÷ 412 L/ha = 1.214 ha will be covered

Step 3. Calculate how much pesticide to add to a spray tank.

Multiply the application rate (L/ha) times the number of hectares covered by the spray tank.

1.8 L/ha × 1.214 ha = 2.18 L pesticide *should be* used

Step 4. Calculate how much pesticide is required in total.

Multiply the application rate times the number of hectares to be treated.

1.8 L/ha x 5 ha = 9 L pesticide required

Step 5. Calculate how many tankfuls are required.

Divide the total spray required by the tank capacity.

2,060 L ÷ 500 L/tankful = 4.12 tankfuls required

Step 6. Calculate how much pesticide to add to the partial tank of 0.12 × 500 = 60 L.

Use the formulae in Steps 2 and 3.

For a **band treatment**, where only crop rows or spaces between crop rows are treated, additional calculations are required. The pesticide application rate and the spray volume per hectare are for the treated bands only. The application rate and spray volume per hectare for the treatment area must be calculated.

For example: The application rate is 1.8 L/ha of pesticide product, the calibrated spray volume is 412 L/ha. The crop rows are spaced at 50 cm intervals and the band width is 15 cm (see Figure 38).

Step 1a. Convert the pesticide applied per band area to pesticide applied per total area.

Multiply application rate times the width of a band divided by the distance between rows.

$$1.8 \text{ L/ha} \times \frac{15 \text{ cm}}{50 \text{ cm}} = 0.54 \text{ L/ha}$$

Step 1b. Convert the spray volume per hectare for the band area to spray volume per hectare for the total treatment area.

Multiply calibrated spray volume per band area times the width of a band divided by the distance between rows.

$$412 \text{ L/ha} \times \frac{15 \text{ cm}}{50 \text{ cm}} = 123.6 \text{ L/ha}$$

In this example of a band treatment, the application rate would be 0.54 L/ha, averaged over the whole field. The spray volume would be 123.6 L/ha averaged over the whole field. Use these values when calculating pesticide use requirements in Steps 1 to 6 above, for a band treatment.

Note that the application rate may specify an amount of pesticide to mix in a variable amount of spray per length of crop row (e.g. apply 375 g of wettable powder in 150 to 750 L of water per 1,000 m of crop row). The same steps should be followed as in the example above. You must know the calibrated spray volume (e.g. 400 L of water per 1,000 m crop row), the length of row to be sprayed and size of the spray tank.

C. The pesticide is to be mixed in a specified volume of spray to apply to a specified area

This type of application rate may be required for some herbicides, insecticides or fungicides where both the concentration of the pesticide in the spray and the amount of spray applied per unit area are critical. The calculation steps are the same as in Section B above where the application rate does not specify spray volume. Calculations must be based on calibrated spray volumes per unit area in both cases.

For example: A label specifies you should use 2.5 kg of wettable powder in 150 L of water per 1,000 m². You have adjusted the sprayer so the calibrated delivery rate is 144 L/1,000 m², which is within 5% of the required output. The spray tank holds 800 L and the treatment area is 4 ha.

Step 1. Calculate how much spray is required in total.

Multiply the spray volume (L/ha) times the total treatment area (ha).

$$\text{Spray volume (L/ha)} = \frac{144 \text{ L}}{1{,}000 \text{ m}^2} \times 10{,}000 \text{ m}^2\text{/ha}$$
$$= 1{,}440 \text{ L/ha}$$
$$1{,}440 \text{ L/ha} \times 4 \text{ ha} = 5{,}760 \text{ L spray required}$$

Step 2. Calculate how large an area one tank will cover (use the same procedure for a full tank or a partial tank).

Divide the volume of spray in the tank by the spray volume (L/ha).

$$800 \text{ L} \div 1{,}440 \text{ L/ha} = 0.55 \text{ ha will be covered}$$

Step 3. Calculate how much pesticide to add to a spray tank.

Multiply the application rate (kg/ha) times the number of hectares covered by the spray tank.

$$\text{Application rate} = \frac{2.5 \text{ kg}}{1{,}000 \text{ m}^2} \times 10{,}000 \text{ m}^2\text{/ha}$$
$$= 25 \text{ kg/ha}$$
$$25 \text{ kg/ha} \times 0.55 \text{ ha} = 13.75 \text{ kg pesticide required}$$

Step 4. Calculate how much pesticide is required in total.

Multiply the application rate (kg/ha) times the number of hectares to be treated.

$$25 \text{ kg/ha} \times 4 \text{ ha} = 100 \text{ kg pesticide required}$$

Step 5. Calculate how many spray tankfuls will be required.

Divide the total required spray by the tank capacity.

$$5{,}760 \text{ L} \div 800 \text{ L/tankful} = 7.2 \text{ tankfuls required}$$

Step 6. Calculate how much pesticide to add to the partial tank of 0.2 × 800 L = 160 L.

Use the formulae in Steps 2 and 3.

D. The application rate is expressed as a percent active ingredient

Various publications recommend application rates in terms of the pesticide active ingredient. Such rates are often used for control of structural pests.

For example: A pest control manual recommends a 2% active ingredient (a.i.) solution be applied to wet surfaces for control of a structural pest. The pesticide product contains 400 g a.i. per L of product. The spray tank is 5 L. You calibrate the sprayer in a test area and determine that 15 L of spray will be required in total.

Step 1. Calculate the amount of pesticide product to add to a full tank (5 L) of spray.

Divide (a) the required volume of active ingredient in the spray tank by (b) the % concentration of the active ingredient in the product to obtain (c) the volume of pesticide product to add to 5 L of spray.

(a) Determine the required volume of active ingredient in the spray tank. Multiply the required percent active ingredient by the volume of the spray tank.

$$\text{Required percent a.i.} = 2\% = \frac{2}{100}$$

$$\frac{2}{100} \times 5 \text{ L} = 0.1 \text{ L a.i. required to make a 2\% concentration in 5 L}$$

(b) Determine the % active ingredient in the product.

Multiply the ratio of active ingredient to product by 100,

$$\text{i.e. } \frac{400 \text{ g}}{1 \text{ L}} \times 100\%$$

The units in the ratio must be the same (both must be a weight or a volume). One litre of pure water weighs 1 kg, therefore you could assume 1 L of pesticide product weighs 1 kg. To be more accurate, weigh a known volume of pesticide, e.g. 1 L of pesticide may weigh 1.11 kg

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$$\text{Therefore } \frac{400 \text{ g a.i.}}{1 \text{ L pesticide}} = \frac{400 \text{ g}}{1.11 \text{ kg}} \times 100\%$$
$$= 36\% \text{ a.i. in the product}$$

(c) Determine the amount of product required to obtain 0.1 L a.i. in the spray tank. You need more product than active ingredient, therefore divide the required volume of active ingredient in the spray tank by the % concentration of active ingredient in the product.

$$\text{Product required} = 0.1 \text{ L a.i.} \div 36\%$$
$$= 0.1 \text{ L a.i.} \div \frac{36}{100}$$
$$= 0.28 \text{ L required to make 5 L of 2\% spray}$$

Step 2. Determine how much pesticide product you need to add to make 15 L of 2% a.i. spray.

Divide the total spray quantity required by the volume of the spray tank and multiply by the amount of product which must be added to the spray tank.

$$\frac{15 \text{ L}}{5 \text{ L}} \times 0.28 \text{ L} = 0.84 \text{ L of product required to make 15 L of 2\% spray}$$

E. Changing the concentration of a spray mixture

On rare occasions it may be necessary to change the concentration of spray solution, either to use up left over spray on a treatment requiring different dilutions, or because a mistake was made in the initial mixing operation. Two examples are given below to indicate the calculations involved.

Example 1. You have 50 L of a 2% spray solution in a tank. How much pesticide product do you need to add to the tank to make 100 L of a 5% solution. The pesticide product contains 40% active ingredient.

Step 1. Determine the amount of active ingredient in the 50 L of 2% spray, the active ingredient required in 100 L of 5% spray and then how much you need to add to the 50 L of 2% spray.

You have 2% × 50 L = 1 L a.i. in the tank

You need 5% × 100 L = 5 L a.i. in the tank

You must add 5 L − 1 L = 4 L a.i.

Step 2. Determine how much 40% a.i. pesticide product you need to add to increase the active ingredient by 4 L.

Divide the volume of active ingredient by 40%.

$$4 \text{ L} \div 40\% = 4 \text{ L} \div \frac{40}{100} = 10 \text{ L pesticide}$$

product required to make 100 L of 5% spray

Example 2. You have 50 L of 5% spray in a tank. How much water should you add to the 50 L to make a 2% spray.

Step 1. Determine the amount of active ingredient in 50 L of 5% spray.

You have 5% × 50 L = 2.5 L a.i. in the tank

Step 2. Determine how much 2% spray can be made with 2.5 L a.i..

Divide 2.5 L by 2%.

$$2.5 \div 2\% = 2.5 \div \frac{2}{100} = 125 \text{ L}$$

Step 3. Determine how much water to add to 50 L to make 125 L.

125 L − 50 L = 75 L must be added to obtain a 2% solution.

USEFUL PUBLICATIONS

The Crop Production Guides published by the Ministry of Agriculture and Fisheries contain summaries on equipment calibration and pesticide use calculations. For more details, consult the following publications:

Anderson, D.T., D.E. Clark and J.J. Sexsmith. 1974. *Field Sprayers*. Canada Department of Agriculture Publication 1482. Supply and Services Canada, Ottawa. 40 pp.

Henigman, J.F. and J.D. Beardsley. 1985. *Forest Pesticide Handbook of British Columbia. Volume 3.* Pesticide Application Techniques. British Columbia Ministry of Forests. Victoria, B.C. 101 pp.

Hughes, H.A. 1976. Crop Chemicals. *Fundamentals of Machine Operation*. John Deere & Co. Moline, Illinois. 269 pp.

Marshall, J., A.D. McMechan and K. Williams. 1977. *Air-blast Orchard Sprayers*. An operation and maintenance manual. Agriculture Canada Publication 1625. Supply and Services Canada, Ottawa. 25 pp.

CHAPTER QUIZ

Questions

1. Define what is meant by equipment calibration. When should equipment be calibrated?

2. A farmer wishes to treat his 60 m^2 garden for potato beetle. The label calls for 2 mL of 50% insecticide per litre of water. What is the first step in calculating how much pesticide product will be used?

3. Describe how you would calibrate a hand-held pressure sprayer with a capacity of 10 L.

4. What should the nozzle output (L/min) be on a boom sprayer with a 4 m swath width and a ground speed of 8 km/h to apply a spray volume of 400 L/ha?

5. Describe how you would calibrate the speed of a motorized pressure sprayer.

6. Describe why you need to calibrate granular spreaders and what you need to measure.

7. In calibrating a granular spreader you found that it discharged 7.5 kg granules per minute. The swath width of your spreader is 10 m at a PTO speed of 625 rpm at a tractor speed of 8 km/h. The application rate on the label is 50 kg/ha.

   a) What is the delivery rate (kg/ha) of the spreader as calibrated?

   b) What ground speed should you use in order to achieve the application rate specified in the label?

Answers

1. Equipment calibration involves checking the delivery rate of the equipment and making adjustments, if necessary. Equipment should be calibrated when it is new, or when adjustments are made such as to nozzles, speed or pressure, or if the spray properties are changed. It should also be calibrated at intervals to check for changes in delivery rate with use.

2. Determine the spray volume applied per unit area, i.e. calibrate the sprayer.

3. — select a test plot, e.g. 5 m x 5 m in size,
   — spray the test area with water and measure water used,
   — check that the spray pattern and droplet size are appropriate,
   — determine the volume of spray that would be used per unit area,
   — compare this volume with the rate on the label, and
   — adjust sprayer if necessary.

4. To calculate nozzle output, use the following formula:

$$\text{Output (L/min)} = \frac{\text{spray volume (L/ha)} \times \text{speed (km/h)} \times \text{swath width(m)}}{600}$$

$$= \frac{400\ \text{L/ha} \times 8\ \text{km/h} \times 4\ \text{m}}{600}$$

$$= 21.3\ \text{L/min}$$

5. Record the time taken to travel a measured distance (e.g. 200 m). Then use the following formula:

$$\text{Speed (km/h)} = \frac{\text{distance travelled (m)} \times 3.6}{\text{time (seconds)}}$$

6. Calibration of granular applicators is required to ensure the delivery rate (kg/unit area) is within 5% of the rate specified on the label. Calibration involves measurement of swath width, checking granule distribution and measuring delivery per unit area.

7. a) Application rate of spreader:

$$\text{Delivery rate (kg/ha)} = \frac{\text{output (kg/min)} \times 600}{\text{swath width (m)} \times \text{speed (km/h)}}$$

$$= \frac{7.5\ \text{kg/min} \times 600}{10\ \text{m} \times 8\ \text{km/h}}$$

$$= 56.25\ \text{kg/ha}$$

   b) Speed to obtain application rate of 50 kg/ha:

$$\text{Required speed (km/h)} = \frac{\text{present speed (km/h)} \times \text{present delivery (kg/ha)}}{\text{required delivery rate (kg/ha)}}$$

$$= \frac{8\ \text{km/h} \times 56.25\ \text{kg/ha}}{50\ \text{kg/ha}}$$

$$= 9\ \text{km/h}$$

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8. What are four ways application rates can be expressed?

8. — pesticide product per volume of carrier,
— pesticide product per area of land,
— pesticide product per area of land per volume of spray,
— amount of pesticide per length of row, and
— percent active ingredient per volume of spray.

9. A gardener needs to control cutworms on vegetables in an area measuring 150 m by 30 m. The label of a 5% granular soil insecticide indicates she should use 80 g/10 m². How much pesticide product does she need?

9. Pesticide required in treatment area:
area to be treated = 150 x 30 = 4,500 m²
application rate = 80 g/10 m² = 8 g/m²
pesticide required = 8 g/m² x 4,500 m²
= 36,000 g = 36 kg

10. The label recommendation on a 25 kg bag of 25% WP diazinon calls for the mixing of 2 kg of this product in 200 L of water. How many grams of this product would you need to make a 25 L tank of spray mix?

10. Pesticide required to make 25 L of spray:
dilution rate = 2 kg/200 L = 0.01 kg/L
pesticide required = 0.01 kg/L x 25 L
= 0.25 kg
= 250 g

11. A gardener marks off an area of 2 x 4 m and uses 1.3 L of water to cover the area in a calibration test with his 5 L pressure sprayer.

a) How much spray solution does he require for his 9 x 10 m garden?

b) How much pesticide does he need in each tankful of spray if the label requires 150 mL of pesticide per 10 L of water?

c) How many tankfuls of spray does he need?

d) How much pesticide does he need in total?

11. a) Spray required for 9 m x 10 m garden:
test area = 2 m x 4 m = 8 m²
calibrated spray volume applied = 1.3 L/8 m² = 0.162 L/m²
treatment area = 9 m x 10 m = 90 m²
spray solution required = 0.162 L/m² x 90 m²
= 14.62 L

b) Pesticide required to make 5 L tank of spray:
dilution rate = 150 mL/10 L = 15 mL/L
pesticide required per 5 L tank = 15 mL/L x 5 L
= 75 mL

c) Tankfuls of spray required $= \frac{14.62 \text{ L}}{5 \text{ L}}$

= 2.9 tankfuls

d) Pesticide required for total treatment = 15 mL/L x 14.62 L

= 219 mL (rounded off)

12. A berry grower has a 4 ha field of strawberries. He wants to apply endosulfan to control aphids. The label specifies using 1.4 L per hectare. How much pesticide product should he apply to the field?

12. Pesticide required for 4 ha = 1.4 L/ha x 4 ha
= 5.6 L

13. A farmer requires a wettable powder weed killer to be sprayed at 3.5 kg in 350 L of water per hectare over his 6 ha field. His sprayer holds 580 L. How much herbicide is required for the treatment?

13. Pesticide required for 6 ha = 3.5 kg/ha x 6 ha
= 21 kg

14. A landscaper wishes to control weeds in a lawn. The pesticide label specifies the use of 5 mL of product in 5 L of water to cover 10 m². The total lawn area is 500 m². In calibrating the sprayer, it used 8 L of water to cover 25 m².

a) How does the spray volume (L/ha) applied in the calibration test compare with the spray volume specified on the label?

b) How should the applicator alter his speed?

c) How much pesticide is needed for the job?

14. a) Compare sprayer delivery rate to label requirements:
spray volume applied in calibration = 8 L/25 m² = 0.32 L/m²; label spray volume = 5 L/10 m² = 0.5 L/m².
In the calibration test, the sprayer used less spray per unit area than specified on the label.

b) The applicator should slow down to apply more spray per area.

c) Pesticide required to treat 500 m² = 5 mL/10 m² x 500 m²
= 0.5 mL/m² x 500 m²
= 250 mL

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15. The label recommendation on a 50% wettable powder pesticide container calls for 60 g of pesticide product per 100 m^2. You have calibrated your 20 L backpack sprayer and know that you apply 15 L of spray per 50 m^2. How many grams of the wettable powder do you need to make a full tank of spray solution?

15. Amount of pesticide to add to 20 L backpack sprayer:
test area treated with 15 L = 50 m^2
spray volume applied = 15 L/50 m^2 = 0.3 L/m^2
area treated by 20 L tankful = 20 L ÷ 0.3 L/m^2
= 66.67 m^2
pesticide application rate = 60 g/100 m^2 = 0.6 g/m^2
amount of pesticide to add to 20 L = 0.6 g/m^2 x 66.66 m^2
= 40 g (rounded off)

16. You wish to calibrate the output of your boom sprayer prior to a spray program. You fill your 350 L tank with water and select a speed of 8 km/h, a pressure of 120 kPa and a 2.7 m boom with 7 nozzles which are 45 cm on centre. You mark out a test strip, one-half kilometre long. When you have sprayed this test strip with water, you measure that you have used 44.2 L. The pesticide label specifies 2.25 L of product in 200 to 300 L of water per hectare. Your treatment area is 2.5 ha.

a) What is the area of the test strip?

b) What is the spray volume applied in L/ha?

c) How much pesticide is required to make one 350 L tankful of spray?

16. a) Area of test strip:
swath width = 7 nozzles x 0.45 m spacing = 3.15 m
area of strip = 3.15 m x 500 = 1575 m^2

b) Spray volume applied = 44.2 L/1575 m^2
= 0.02806 L/m^2
= 280.6 L/ha

c) Pesticide required to make 350 L of spray:
350 L of spray will cover 350 L ÷ 280.6 L/ha = 1.247 ha
pesticide application rate = 2.25 L/ha
pesticide required for 350 L = 2.25 L/ha x 1.247 ha
= 2.8 L (rounded off)

17. You have set up the nozzles and calibrated your air-blast sprayer and found that the output is 10.1 L/min per side. You want to spray at 4 km/hr. Distance between tree rows is 5 m. The label of the pesticide you wish to apply requires an application rate of 5.5 kg of pesticide product per hectare.

a) What is the spray volume applied per hectare?

b) How much pesticide would you need to treat 8 ha?

c) How much pesticide would you add to a 1,000 L tank?

17. a) Spray Volume (L/ha) for 2 sides

$$= \frac{\text{output (L/min)} \times 600}{\text{width between rows (m)} \times \text{speed (km/h)}}$$

$$= \frac{20.2 \text{ L/min} \times 600}{5 \text{ m} \times 4 \text{ km/h}}$$

= 606 L/ha

b) Pesticide required for 8 ha = 5.5 kg/ha x 8 ha
= 44 kg

c) Pesticide required for 1,000 L tank:
1,000 L spray covers 1,000 L ÷ 606 L/ha = 1.65 ha
pesticide required to treat 1.65 ha = 1.65 ha x 5.5 kg/ha
= 9.075 kg

18. The label specifies 7 mL of pesticide are to be added to 1 L of water. The guaranteed concentration of active ingredient in the pesticide product is 650 mL/L. What is the percent concentration of active ingredient in the spray mix?

18. Percent concentration of active ingredient in the spray mix:

$$\text{% a.i. in the product} = \frac{650 \text{ mL}}{1 \text{ L}} \times 100\%$$

$$= \frac{650 \text{ mL}}{1{,}000 \text{ mL}} \times 100\%$$

= 65%

amount of active ingredient in 7 mL of product = 7 mL x 65%
= 4.55 mL

$$\text{% a.i. in spray} = \frac{4.55 \text{ mL}}{1 \text{ L}} \times 100\%$$

$$= \frac{4.55 \text{ mL}}{1{,}000 \text{ mL}} \times 100\%$$

= 0.455%

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19. The guarantee of a pesticide emulsifiable concentrate is 360 g/L . How much concentrate do you require to make 80 L of a 2.5% spray mixture? Assume 1 L of pesticide weighs 1 kg.

20. You have sprayed 2,500 L of a spray mix. You mixed 500 g of wettable powder with 32% active ingredient per 1,000 L of water. How many grams of active ingredient have you used?

21. How many kilograms of active ingredient are there in 50 L of a 0.75% spray mix? Assume 1 L active ingredient weighs 1 kg.

19. Amount of concentrate to make 80 L of 2.5% spray mix:

$$\% \text{ a.i. in pesticide} = \frac{360 \text{ g}}{1 \text{ L}} \times 100\%$$
$$= \frac{360 \text{ g}}{1 \text{ kg}} \times 100\% = \frac{360 \text{ g}}{1{,}000 \text{ g}} \times 100\%$$
$$= 36\%$$

amount of active ingredient in 80 L tank = 80 L × 2.5%
= 2 L

amount of pesticide required to make 80 L of spray = 2 L ÷ 36%

$$= 2 \text{ L} \div \frac{36}{100}$$
$$= 5.55 \text{ L}$$

20. Amount of active ingredient:
dilution rate in spray mix = 500 g/l,000 L
= 0.5 g/L
total pesticide used in 2,500 L spray = 0.5 g/L x 2,500 L
= 1,250 g

amount of active ingredient used = 32% x 1,250 g

$$= \frac{32}{100} \times 1{,}250 \text{ g}$$
$$= 400 \text{ g}$$

21. Amount of active ingredient = 50 L x 0.75%
= 0.375 L
= 0.375 kg

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SECTION V

PROTECTING THE ENVIRONMENT

Chapter 20

BEE POISONING BY PESTICIDES

CONTENTS

INTRODUCTION

When pesticides are applied outdoors, there is a danger of poisoning honey bees, wild bees and other beneficial insects. Economic losses from bee poisoning may result from weakened or killed hives and reduced honey production, as well as poor pollination of flowers and reduced crop production. Certain species of wild bees are the only effective pollinators of alfalfa. Special care must be taken to protect them from pesticides where alfalfa is grown for seed.

The farmer, the beekeeper, and the pest control industry should cooperate closely to keep losses of beneficial insects to a minimum. For protection of these insects, use only the safest of the recommended pesticides.

CAUSES OF BEE POISONING

Most bee poisoning occurs when pesticides are applied to crops during the blooming period. Other ways bees may be exposed to pesticides include:

- drift of pesticide sprays or dusts onto adjacent crops or weeds that are in bloom,
- contamination of flowering cover crops and weeds when orchards are sprayed with pesticides,
- contamination of water which bees drink on foliage or flowers, and
- contamination of pollen or nectar which may be stored in the hive and later fed to brood and newly-emerged workers.

BEE POISONING SYMPTOMS

The most obvious symptom of bee poisoning is the appearance of excessive numbers of dead bees in front of a hive, although there are a number of other common symptoms. Poisoning by some pesticides will cause bees to behave aggressively. They may fly at people in a threatening manner and attempt to sting. Stupefaction and paralysis are common symptoms of chlorinated hydrocarbon and organophosphorous insecticide poisoning. Bees poisoned with carbaryl, a carbamate insecticide, may slow down and appear as though they have been chilled. Beekeepers may recognize carbaryl poisoned bees as 'crawlers' that move about in front of the hive but are unable to fly. Such bees may take two or three days to die. Dead brood in or in front of the hive is typical of carbaryl poisoning.

One forager returning to a hive with a load of contaminated pollen or nectar can cause extreme agitation within the hive and death of a number of bees. Several such foragers can seriously disrupt and damage the hive. Often the queen is superseded because of the agitation of the worker bees. Queenless hives in the fall have been associated with the use of a variety of insecticides including carbaryl and parathion. Severely weakened or queenless colonies will not live through the winter.

TOXICITY OF PESTICIDES TO BEES

Two important considerations in assessing the toxicity of a pesticide to bees are the toxicity of the pesticide immediately after application and the length of time the pesticide remains toxic. Knowledge of pesticide toxicity to bees is based on both laboratory and field tests. Some general observations include the following:

- Dust formulations of pesticides are more harmful to bees than sprays. Sometimes bees collect any type of fine dust material when pollen is not readily available. Under such conditions, they may actually carry pesticide dusts back to the hive.
- Emulsifiable concentrate formulations usually have a shorter residual hazard to bees than wettable powders.
- Oil-based formulations are more hazardous to bees than water-based formulations.
- Bait formulations of pesticides, prepared with material such as apple pomace, may be hazardous if attractive to bees.
- Granular formulations are least toxic.
- The organochlorine insecticides differ significantly in their residual poisoning effects on honey bees. For example, lindane has a long residual toxicity, whereas methoxychlor and endosulfan have moderate residual toxicity and can be used on crops in bloom if applied when the bees are not foraging.
- The organophosphorous insecticides also differ in regard to their residual poisoning effects on honey bees. For example, azinphos-methyl, diazinon and parathion are too hazardous to honey bees to use on crops that are in or near full bloom, whereas temephos, trichlorfon, ethion, tetrachlorvinphos and phosalone have short residual toxicity and can be used on flowering crops if they are applied when bees are not foraging.
- The carbamate insecticide carbaryl is probably the most dangerous insecticide for honey bees. It has a fairly long residual effect; field tests have shown it is extremely toxic to bees for up to 12 days. It is no longer recommended as a preblossom spray on any fruit trees.
- The dinitro insecticides are relatively nontoxic to bees.
- The pyrethroids (fenvalerate and deltamethrin) should not be applied when bees are foraging.
- The hazard of systemic insecticides to bees is chiefly from contact with sprayed plant parts. Dimethoate spray is extremely toxic to bees, but is probably safe when applied on tree trunks. Demeton also has a high toxicity, but may be used safely when bees are not foraging.
- Dichlorvos resin strips for fly control should not be used in a honey extracting facility or inside any building where honeycombs are stored, as beeswax readily absorbs and retains residues of this insecticide.
- The miticides tetradifon, dicofol, chinomethionat, and cyhexatin are not hazardous to bees if applied to crops in flower.
- Fungicides have not proven toxic to honey bees. Dodine, dichlone and other fungicides applied at twice the recommended dosage did not kill bees.
- Most herbicides, including 2,4-D and related compounds, are not hazardous to bees. However, the alkanolamine salts and the isopropyl ester formulations of phenoxy herbicides are toxic. The dinitro herbicides and endothall are highly toxic to bees. The herbicides amitrole, atrazine and simazine have a moderate toxicity and may be a hazard to bees if sprayed on open flowers.

GENERAL CONSIDERATIONS IN PREVENTION OF BEE POISONING

A knowledge of bee behaviour and activity will be helpful in the prevention of pesticide poisoning. During daylight, bees usually fly from the hive when temperatures are above 13° to 16°C. Foraging does not occur at night, although the bees may cluster on the outside of the hive if the temperature is above 21°C. A strong wind may cause clustered bees to enter the hive at temperatures above 21°C. Bees in crowded hives are more likely to cluster than those in uncrowded hives.

The time and intensity of bee activity in a given crop depends on abundance and attractiveness of the flower. For example, alfalfa in bloom may be attractive to bees all day, while cucumbers are usually only attractive to bees in the morning and early afternoon.

The time of application of the pesticide may be important in preventing bee poisoning. Applications of pesticides when bees are foraging in the field are usually very hazardous. Applications over hives in hot weather, when bees are clustering on the outside of the hives, may cause severe losses. Applications during the night and early morning, before bees are foraging, are safest.

Location of bees is important. Hives located in a field to which pesticide has been applied will usually sustain more losses than hives which do not have pesticide applied to them directly. Usually poisoning of bees is not significant in hives 400 m or more away from a sprayed field unless the crop sprayed is the only one attractive to bees in the area. In that case, injury may occur to hives even 2 or 3 km away. Pesticide drift to neighbouring fields that are attractive to bees may also cause bee losses. In general, the further hives are from the area of application, the less critical is the time of spraying.

Spraying large areas and/or repeating pesticide applications in the same area may increase bee losses. With few exceptions, pesticides applied as dusts are more hazardous to honey bees than those applied as sprays. Fine sprays are less toxic than coarse sprays. Pesticide applications by aircraft over bees in flight are more hazardous than applications by ground equipment. Granular applications are usually the safest method of treatment.

BEEKEEPER-GROWER COOPERATION

In modern agriculture, the beekeeper often depends on the grower for bee forage and the grower depends on the beekeeper for pollination. Cooperation and understanding of each other's problems are essential. The timing or selection of materials in the grower's pest control program can often be modified so that little or no bee poisoning will occur. Usually, this can be done without unduly increasing the cost of control or inconveniencing the grower.

Beekeepers should become acquainted with the farmer on whose land they are placing hives. They should find out about his pest control practices and other control programs (e.g. treatment of mosquitoes) that might occur nearby.

When the grower rents hives for pollination of his crop, definite verbal or written agreements can be made. Such contracts should include details of the responsibility of the beekeeper in providing strong and effective pollinating hives and of the farmer in safeguarding the bees from pesticide poisoning.

RECOMMENDATIONS TO REDUCE BEE POISONING

The following are some of the ways in which interested persons can help reduce poisoning of honey bees:

What the Pesticide Applicator Can Do:

- Do not apply pesticides that are toxic to bees on crops in bloom, including cover crops in orchards, adjacent crops or weeds (Table 22-A).
- With aerial applications of pesticides, ensure that no pesticide drift occurs onto adjacent blossoming fields where bees may be foraging. Ground application is generally less hazardous than aerial application because there is less drift of the pesticides and smaller areas are treated at one time.
- Certain pesticides can only be applied in the late evening, night or early morning while bees are not actively foraging, (Table 22-B and 22-C). When high temperatures cause bees to start foraging earlier in the morning or remain foraging later in the evening than usual, the pesticide application time should be shifted accordingly.
- Evening applications are generally less hazardous to bees than early morning applications. Thus more toxic pesticides should be applied in the evening only (Table 22-B).
- Do not apply pesticides when temperatures are expected to be unusually low. Pesticide residues will remain toxic to bees for a much longer time under such conditions.
- Do not dispose of unused pesticides such as dusts or baits where they might become a bee poisoning hazard.
- Use pesticides that are relatively non-hazardous to bees whenever such choices are consistent with other pest control considerations.
- Choose the less hazardous pesticide formulations. In order of decreasing hazard, these are dusts, wettable powders, emulsifiable concentrate sprays and granular formulations.
- Contact the beekeeper before applying hazardous pesticides and ask him to remove his hives from the area or to keep the bees confined during the application period when such measures are feasible.
- For control of flowering weeds, select herbicides and formulations known to be least harmful to bees. Spraying in late afternoon or evening will also reduce the hazard, since bees will not visit the flowers after they have become curled.

What the Grower Can Do:

- Mow or beat down orchard ground cover in bloom before applying pesticide sprays hazardous to bees. It is especially important to remove ground cover blooms before the first cover spray on apples, which is applied during a critical bee foraging period. At this time, bees will fly several kilometres to obtain pollen and nectar from even a few blooms of dandelion, mustard, etc.
- Carbaryl used as a fruit thinner 15 to 25 days past full bloom of apple trees is hazardous to bees if ground cover flowers become contaminated.
- When insect pests have been damaging a crop every season, use a preventative program of early season application before pest numbers increase and foliage growth and weather conditions reduce the effectiveness of pesticides. Such a program is usually less dangerous to pollinating bees and other beneficial insects as well.
- Learn about the beekeeper's problems with pesticide poisoning and enter into mutually advantageous agreements with him in order to protect bees which pollinate crops. Learn about the pollination requirements of the crops you raise.

What the Beekeeper Can Do:

- Do not leave unmarked hives of bees next to orchards or fields which may be treated with hazardous pesticides. **Post your name, address, and phone number** in printing large enough to be read at some distance in all apiaries, so you can be contacted readily to move the hives when pesticides *hazardous to bees* are to be applied.
- Do not move hives back into parathion-treated fields until at least 36 hours after the application. Tests have shown that about 90 percent of the killing of bees by parathion occurs during the first 24 hours after application.
- Choose apiary sites that are relatively isolated from intensive pesticide applications and not normally subjected to pesticide drift. When removing honey bee colonies from orchards, legume seed fields and berry fields to be treated with toxic pesticides, establish

holding yards at least 5 km from treatment sites.

- Learn about pest control problems and programs so you can develop mutually beneficial agreements with growers concerning pollination service and prudent use of pesticides.
- Use pyrethroid-based aerosols for fly control in buildings where combs are stored. Do not use *Vapona* "No Pest Strips" which will contaminate beeswax and kill bees when the combs are put in colonies later.
- If a short residual pesticide (Tables 22-C and 22-D) is applied near hives, there will be little problem if it is applied in the evening or early morning, unless there is spray drift over the hives.
- If a long residual pesticide (Tables 22-A and 22-B) is applied near hives, hive protection is desirable. Although most beekeepers will find it impractical, the following approach may be considered. Cover hives with burlap the night before the pesticide is sprayed until 2 to 3 days after the application. Before placing burlap on each hive, fill a super of combs with water using a fine spray from a garden hose or sprayer. Place this super of combs on the hive with a ventilating screen on top. Prop up the hive lid. Place burlap over the hive and pull the edges out like a tent, using stones to keep it in place. Keep the burlap wet. By doing this bees cannot get out nor can poisoned field bees get in.

Table 22. Insecticide use precautions to protect honey bees.

A. Do NOT apply on crops or weeds in bloom

aldicarb (G)	dinoseb	naled (D)
azinphos-methyl	fenitrothion	parathion
carbaryl	fensulfothion	permethrin
carbofuran (SU) — (apply at least 4 weeks before bloom)	lindane	phorate (G)
chlorpyrifos	malathion (D)	phosmet
deltamethrin	malathion ULV	propoxur
diazinon	methamidophos	
dichlorvos	formetanate hydrochloride	
dimethoate	methidathion	
	methomyl (D)	
	mevinphos	

B. Apply ONLY during late evening[1] (see caution below)

acephate	naled (WP)
malathion (EC)	

[1]Late evening applications allow time for pesticides to dry during night before bees resume foraging.

C. Apply ONLY during late evening, night, or early morning (see caution below)

carbaryl ULV (0.55 kg/ha)	fenvalerate[2]	oxamyl
chlorpyrifos[2]	fonofos	oxydemeton-methyl
demeton	malathion[2]	phosalone
dichlorvos[2]	methomyl	pirimicarb
disulfoton (EC)	methoxychlor	propoxur[2]
endosulfan	naled (EC)	tetrachlorvinphos
ethion	oil sprays (superior type)	trichlorfon

[2]Concentrate applications at mosquito abatement rates

D. Can be applied at any time with reasonable safety to bees

Bacillus thuringiensis	diflubenzuron	propoxur (G)
carbaryl (G)	dinocap	pyrethrins
carbofuran (G)	disulfoton (G)	rotenone
chinomethionat	fensulfothion (G)	sodium fluorosilicate baits
cyhexatin	lime sulphur	sulphur
dicofol	malathion (G)	tetradifon
dienochlor	nicotine sulphate	
	propargite	

CAUTION: Unusually low temperature at time of application and immediately following application may cause insecticides to remain toxic to bees up to 20 times longer than during reasonably warm weather. High temperatures in the early morning and late evening may extend active foraging by bees and adversely affect bees on treated crops.

The bees are able to set up a circulation system and they have access to water which they evaporate to cool the hive. **Note, if the above materials are not at hand, do not just close the bees in the hive as they will overheat. Overheating will cause hive death and usually melt the combs so they will sag and be useless.**

POISONING OF WILD BEES

A few research studies have been published on the effects of pesticides on wild bees. This work has shown some differences in toxicity of pesticides to various wild bees compared to honey bees. Work on the effects of pesticides on the alfalfa leafcutting bee, *Megachile pacifica*, and the alkali bee, *Nomia melanderi*, has been the most extensive to date.

Alfalfa leafcutting bees. Store the nest units in a cool room or root cellar for a few days while a field is being treated. Nests with females in the ends of the tunnels can be moved at night. This bee is nearly inactive at 21°C. Leafcutter nest shelters can be constructed so they can be easily covered or closed during pesticide applications to reduce the drift of pesticide dusts or sprays into the nest shelters. When placing leafcutters on fields in a rotation plan, do not move nest shelters into fields until at least one week after dimethoate, carbofuran, or malathion ultra low volume treatments.

Alkali bee and other wild bees. Do not allow pesticide dusts or sprays to drift onto alkali bee nest sites or flowering crops on which these bees are foraging. Do not spray pesticide on, or burn adjacent wild land or fence rows around red clover, alsike, alfalfa, cranberry, blueberry, and raspberry fields. Such areas provide nest sites for the bumble bees that aid in pollinating these crops. A classification of the relative hazard of insecticides to wild bees is presented in Table 23.

Special Precautions:
- Phorate (G), disulfoton (G), and mevinphos should not be used where there is a possible fumigation hazard to alfalfa leafcutter bee shelters, alkali bee nest sites or honey bee apiaries.
- Undiluted or ultra low volume (ULV) malathion applications can remain toxic to honey bees for at least five days, and to alfalfa leafcutting bees for at least seven days.
- Bees are temporarily inactivated by direct contact with oil sprays and some losses may occur.
- Alfalfa leafcutting bees are much more sensitive to pesticides after they have been in the field for three weeks or more. Time late applications six to seven weeks after the start of activity in the field to coincide with the natural lull between peaks of bee emergence.

CHAPTER QUIZ

Questions

1. What is the most common way that bees are poisoned by pesticides?
2. Place these formulations in order of their hazard to bees: granular, dust, wettable powder, emulsifiable concentrate.
3. What is considered the most dangerous insecticide for honey bees?
4. Are herbicides toxic to bees?
5. Why should some pesticides be applied during late evening, night or early morning to prevent bee poisoning?
6. During high temperatures, do bees forage for longer or shorter day lengths than during low temperatures?
7. Do low temperatures make pesticide residues persist for longer or shorter periods after application?
8. When should you apply the following pesticides to prevent honey bee poisoning: (a) malathion (emulsifiable concentrate); (b) dimethoate; (c) malathion (granular); (d) methoxychlor?
9. Why should growers be concerned about protection of wild bees?

Answers

1. When pesticides are applied to crops on which bees are foraging during the blooming period.
2. Most to least hazardous: dust, wettable powder, emulsifiable concentrate, granular.
3. carbaryl
4. Most are not, but dinitrophenols and endothall are highly toxic.
5. Because bees are not foraging at these times.
6. Bees forage for longer day lengths — earlier in the morning and later at night.
7. longer
8. (a) during late evening if plants in bloom; (b) not when plants are in bloom; (c) no time restrictions; (d) during late evening, night or early morning.
9. Because they can be important for crop pollination

Table 23. Insecticide use precautions to protect wild bees.

Alfalfa Leafcutting Bees	Alkali Bee	Bumble Bees
A. Do NOT apply on crops or weeds in bloom		
acephate aldicarb(G)[1] azinphos-methyl carbaryl carbofuran(SU) dimethoate disulfoton endosulfan ethion formetanate hydrochloride[2] malathion methamidophos methidathion methomyl[3] methoxychlor(D) mevinphos parathion permethrin phosmet propoxur tetrachlorvin-phos(D)	aldicarb(G)[1] azinophos-methyl carbaryl carbofuran(SU) chlorpyrifos diazinon dimethoate endosulfan formetanate hydrochloride[2] malathion ULV methamidophos methidathion methomyl[3] mevinphos parathion permethrin propoxur tetrachlor-vinphos(D)	aldicarb(G)[1] azinphos methyl carbaryl carbofuran(SU) diazinon dimethoate malathion ULV methidathion parathion
[1]apply at least 4 weeks before bloom [2]1.12 kg/ha or more [3]0.56 kg/ha or more		
B. Apply ONLY during late evening (see caution at end of Table 20—D)		
demeton dicofol methomyl[1] methoxychlor(WP) naled(EC) propargite tetrachlorvinphos(EC)	acephate malathion(EC) methomyl[1] methoxychlor(WP) oxamyl phosmet	acephate malathion(EC) naled(EC)
[1]0.28 kg/ha or less		
C. Apply ONLY during late evening, night or early morning (see caution at end of Table 20—D)		
deltamethrin demeton fenvalerate formetanate hydrochloride[1] methoxychlor(EC) oxamyl oxydemeton-methyl phorate(G) phosalone pirimicarb tetradifon trichlorfon	deltamethrin demeton disulfoton(EC) fenvalerate formetanate hydrochloride[1] methoxychlor(EC) oxydemeton-methyl phorate(G) phosalone pirimicarb tetrachlor-vinphos(EC) trichlorfon	deltamethrin demeton disulfoton(EC) fenvalerate formetanate hydrochoride[1] methomyl oxydemeton-methyl trichlorfon
[1]0.56 kg/ha or less		
D. Can be applied at any time with reasonable safety to bees		
carbofuran(G) dicofol disulfoton(G) propargite propoxur(G)	carbofuran(G) dicofol disulfoton(G) propargite propoxur(G) tetradifon	carbofuran(G) dicofol disulfoton(G) propargite propoxur(G)

Chapter 21

TOXICITY OF PESTICIDES TO NON-TARGET PLANTS

CONTENTS

INTRODUCTION

Insecticides, miticides and fungicides are used on plants to control pests and diseases, but such pesticides can injure the plants they serve to protect. More frequently, herbicides are misapplied, causing injury to plants which are not meant to be treated (non-target plants). Pesticide-caused injury to plants is known as **phytotoxicity**. Such injury may be as minor as a slight burning or browning of leaves or may be as severe as death of the whole plant.

There are a number of possible reasons for pesticide injury to desirable plants. Pesticide sprays may drift through the air or move through the soil to sensitive plants near the treatment area. They may persist in the soil and cause injury if sensitive plants are cultivated some time after an application. Pesticide injury may result from incorrect pesticide dilution or too high an application rate. Some pesticides become phytotoxic when mixed and applied together with incompatible pesticides. Pesticide additives such as emulsifiers may be used to improve mixing and application, but can make a pesticide phytotoxic to sensitive plants at normally recommended application rates. Some basic precautions to prevent phytotoxicity include:

- check the label for cautions about phytotoxicity to plants to be treated or plants within range of spray drift;
- be careful to mix and apply pesticides according to label directions;
- do not combine different pesticides unless it is known they are compatible; and
- be careful to prevent drift or leaching that will be toxic to desirable plants, e.g.
  - — use coarse sprays,
  - — do not spray when windy, and
  - — leave a buffer zone between treatment areas and desirable sensitive plants.

INSECTICIDES

Organophosphorous compounds are the most widely used insecticides. Phytotoxicity to some organophosphorous materials is well-documented and not usually related to mammalian toxicity. For example, carbophenothion can be phytotoxic to some apples, cherries, apricots and greenhouse ornamentals. Dimethoate can be phytotoxic to chrysanthemums, hops, cherries and plums. Fensulfothion is generally phytotoxic at slightly above recommended application rates. Naled injures the flowers of cucumbers or tomatoes. All organophosphorous insecticides must be used with caution, according to label directions, and after considering the sensitivity of the plant species to be sprayed.

Inorganic sulphur-containing insecticides can cause burning and chlorosis of plant tissues if overused. The dormant spray containing lime sulphur may cause leaf yellowing, browning and defoliation of fruit trees if applied during the growing season.

FUNGICIDES

A number of fungicides are phytotoxic when used at greater than recommended application rates and some are not to be used on sensitive plants. Several fungicides including dodine, folpet and maneb are phytotoxic to certain species or varieties of fruit trees. The zinc-based fungicides, zineb and ziram, may be phytotoxic to zinc-sensitive plants. Certain fungicides such as those containing sulphur and dinocap may cause injury if applied during high temperatures. Bordeaux sprays have a tendency to dwarf plants. Phytotoxicity of some fungicides (e.g. dichloran) increases when mixed with other pesticides.

HERBICIDES

The greatest hazard associated with herbicides is the phytotoxic effect on non-target plants caused by incorrect or inaccurate application. Temporary visible injury to crops or temporary stunting may at times be considered an acceptable adverse effect. However, long-term damage to desirable plants may represent a serious loss. Phytotoxicity of herbicides is influenced by many factors such as:

- **Application method.** Use methods that reduce exposure of non-target plants to herbicide drift[1] and leaching.
- **Mode of action.** Sensitivity of non-target plants can vary with herbicide activity (e.g. contact or translocated) or uptake (e.g. by foliage or roots).
- **Persistence.** Accumulation and persistence in the soil are an important consideration with some residual-type herbicides.
- **Volatility.** Evaporation aids in dissipation of herbicides but may also increase chances of injury to nearby desirable plants.
- **Temperature.** Volatility usually increases with higher temperatures. Frequently temperature influences effectiveness and subsequent breakdown of a herbicide.
- **Composition and structure of the soil.** Soil moisture, organic matter and microorganisms, as well as ground slope, all have a bearing on herbicide persistence and possible leaching.
- **Weather conditions.** Wind velocity and direction, rain, overcast skies, and sunlight may all influence herbicidal action.

A number of herbicides remain in the soil and can be phytotoxic long after they are applied. For example, amitrole and dalapon herbicides must be applied for weed control on agricultural crop land in the fall for spring planting and, even so, there is danger of a herbicide carry-over effect on sensitive crops. Atrazine and simazine, used for corn or strawberry cultivation, may be damaging to other crops planted over a year after use. Picloram should not be applied to land used for cultivated crops or other desirable plants as it can remain phytotoxic for 1 to 5 years after application. Check the herbicide label and Crop Production Guides of the Ministry of Agriculture and Fisheries for information on potential phytotoxicity.

Some hazards of phytotoxicity from selected herbicide groups include the following:

Phenoxy herbicides. 2,4-D, MCPA and dichlorprop are the better-known herbicides in this group. Curling and cupping of leaves are typical initial symptoms of injury. Box elder, deodar cedar, grapes, cucumbers, tomatoes, mustard crops, stone fruits and tulips are all highly sensitive. Persistence in the soil may prove injurious to subsequent crops. Leaching and surface runoff can also injure plants adjacent to treated areas. Temperature, soil composition and pH influence persistence of these compounds in the soil. Persistence is longest in cold, dry soils with a pH near 7 (neutral).

Small quantities of spray or vapour drift can also injure sensitive vegetation. Injury from vapours is dependent on the volatility of the herbicide and sensitivity of the plants. Amine formulations which are mixed with water are less volatile than ester formulations which are mixed with oil or emulsifiers to facilitate mixing with water. High tempertures increase volatility. Many desirable plant species are highly sensitive. For example, deodar cedars *(Cedrus deodara)* may sustain 2,4-D vapour damage even from amine formulations. New growth curls up, droops and becomes necrotic. Trees may recover later in the season by developing lateral buds.

Triazine and triazole herbicides. These herbicides are used as soil sterilants at medium to high concentrations. Lower concentrations are used for selective weed control. Symptoms of injury include chlorosis and necrosis of leaves and die-back of shoots. Even when injury is not pronounced, growth of desirable species, particularly transplants or seedlings, may be suppressed. A frequent problem is injury to trees near treatment areas, resulting from leeching of these herbicides into the zone of root absorption. Applications of atrazine for weed control in corn may seriously affect some subsequent crops, such as cucumbers and tomatoes, for a number of years. Fruit trees are sensitive even at low application rates. Breakdown in the soil is mainly through microbial decomposition. Higher temperatures increase decomposition, but also phytotoxicity.

Aliphatic acids. Dalapon and sodium salts of TCA are the main herbicides in this group. Although effective for seedling grass control, they are phytotoxic to many desirable plants. Direct contact with foliage or roots may cause phytotoxicity. Also, seed germination and seedling growth of desirable species may be affected for months after treatment, depending on plant species and the application rate. Dalapon damage to peach trees through root uptake has been reported. Grapes may sustain damage from foliar applications.

Substituted ureas. Diuron, terbacil and linuron are the main representatives of this group. These herbicides are used for preemergence weed control at low rates and as soil sterilants at high rates. Residues in the soil may impair growth of desirable plants the year following application. Excessive dosages cause wilting, chlorosis, necrosis and dieback. New tissue is affected first. Persistence in the soil can be from several months to over a year, depending on the herbicide and application rate used.

Paraquat. Paraquat is a contact herbicide which breaks down the chlorophyll in plants and therefore can cause injury to almost all plant foliage. Use extreme caution to avoid paraquat drift.

[1] See section on herbicide spray and vapour drift in Chapter 12.

CHAPTER QUIZ

Questions

1. What is meant by pesticide phytotoxicity?
2. Name 3 ways insecticides or fungicides may be phytotoxic.
3. Name 2 ways herbicides may be phytotoxic.
4. Name 3 cultivated plants sensitive to phenoxyacetic herbicides such as 2,4-D.
5. What are 3 concerns about soil sterilants with regard to phytotoxicity?

Answers

1. pesticide-caused injury to a desirable plant
2. (a) some are phytotoxic to specific sensitive plants
   (b) some are phytotoxic at slightly higher than recommended application rates (i.e. they cannot be over-applied)
   (c) some may be phytotoxic when used during high temperatures
3. (a) may drift to non-target plants,
   (b) may remain in soil to affect future crops.
4. grapes, cucumbers, tomatoes, mustard crops, stone fruits
5. (a) may leach to root zone of valuable plants,
   (b) may suppress growth of desirable plants when used for selective control,
   (c) may affect growth of subsequent crops in treated areas.

Chapter 22

THE EFFECTS OF PESTICIDES ON WILDLIFE AND FISH

CONTENTS

INTRODUCTION

British Columbians enjoy a comparative abundance of fish and wildlife. It is difficult to estimate the value of these resources. Ministry of Environment studies in 1983 to 1986 indicated that approximately $942 million was spent annually in British Columbia on fish and wildlife related recreation. Some people will contend that our fish and wildlife resource is 'priceless'. However, its value, in economic terms, is also well worth protecting. In order to maintain this valuable resource it is vital that fish, birds and mammals, as well as their habitat, are protected from the adverse effects of pesticides.

The variety of pesticides and amount used have increased considerably in the last two decades. This increase has had positive effects on crop production and public health. However, certain pesticides and their residues have created unforeseen damage to the environment. There have been numerous documented incidents of fish and wildlife kills from improper use of pesticides. Such incidents have involved pesticides in agriculture, forestry, landscaping, mosquito control and wood preservation as well as improper disposal of pesticides. It is possible that a number of fish and wildlife mortalities due to pesticides have not been noticed or documented.

In addition to the concern about direct mortality of fish and wildlife, there is a concern about possible effects from long-term exposure to low levels of some pesticides in the environment. It can be difficult to demonstrate environmental damage from low-level exposure because it may occur some time after and be indirectly related to pesticide release into the environment. Exposure to a low level of pesticide may ultimately cause death or may result in **sublethal effects** which do not cause direct mortality. Sublethal effects may, however, reduce population numbers through sterilization or the inability of an animal to escape from its prey.

Another impact which may result from pesticide use is alteration of physical habitat or a food source. Herbicides are generally considered more likely to damage fish and wildlife habitat than to affect these animals directly. It is also important to realize that one species cannot be removed from the natural environment without affecting, to some degree, other plants and animals in that environment.

TOXICITY OF PESTICIDES TO WILDLIFE AND FISH

ACUTE TOXICITY TO WILDLIFE

Acute toxicity is the degree to which a chemical is poisonous as a single dose or series of doses within a short time period, i.e. a few days. The acute toxicity of pesticides to wildlife on land is expressed as a mean lethal dose (**LD_{50}**) which is the amount of pesticide that kills 50% of test animals. The LD_{50} can be expressed as oral, dermal or inhaled intake and is based on a single exposure. Usually, the larger an animal, the greater the lethal dose required to kill it. Therefore, LD_{50} is measured in milligrams of toxicant per kilogram of body weight of the animal tested (mg/kg body weight). For example, the very toxic insecticide parathion has an LD_{50} around 2 mg/kg for the mallard duck. A lethal dose for 50% of these animals (weighing about 1 kg each) would be 2 mg per bird. The LD_{50} of parathion for the mule deer is 30 mg/kg. The lethal dose for 50% of these animals (weighing about 40 kg each) would be 30 mg/kg x 40 kg = 1200 mg per animal.

Toxicity values of some commonly used herbicides and insecticides for various wildlife species are listed in Tables 24 and 25. LD_{50}'s can vary considerably between species. The value for each species represents that animal's unique ability to accommodate or detoxify and excrete that particular chemical. The relationship between the **threshold of toxicity** at which the first toxic effects occur, and the LD_{50}, is also different for each species. Wildlife LD_{50} values should, therefore, only be used as indicators of relative toxicity.

Table 24. Toxicity values of herbicides to wildlife.

Herbicide	Animal	Acute Oral LD_{50}(mg/kg)
amitrole	rat	1,100
	mallard	2,000
	pheasant	5,000
atrazine	rat	1,780
	mallard	2,000
	pheasant	5,000
dicamba	rat	1,000
	pheasant	673-800
dichlobenil	rat	2,700
	mallard	2,000
	pheasant	1,000-2,500
2,4-D	rat	300-670
	mule deer	400-800
	mallard	1,000
	pheasant	472
diquat	rat	215-440
	mallard	564
glyphosate	rat	4,300
	quail	3,850
hexazinone	rat	1,700
	guinea pig	860
	mallard	7,500
MCPA	rat	700
paraquat	rat	100
picloram	rat	8,200
	mallard	2,000
	pheasant	2,000
fenoprop	rat	1,070
simazine	rat	5,000
triclopyr	rat	713
	mallard	1,698

Table 25. Toxicity values of insecticides to wildlife.

Insecticide	Animal	Acute Oral LD_{50}(mg/kg)
carbaryl	rat	400
	mule deer	200-400
	mallard	2,180
	pheasant	2,000
carbofuran	rat	5
	mallard	0.40
	pheasant	4.2
chlordane	rat	200-590
	mallard	1,200
DDT[1]	rat	113
	mallard	2,240
	pheasant	1,296
diazinon	rat	300
	mallard	3.5
	pheasant	4.3
dimethoate	rat	185-245
	mule deer	200
	mallard	41.7
endrin[1]	rat	5-43
	mallard	5.6
	pheasant	1.8
fenitrothion	rat	130
	mule deer	727
	quail	27.4
lindane	rat	88-200
	mallard	2,000
malathion	rat	1,000-1,500
	mallard	1,485
methoxychlor	rat	5,000-6,000
	mallard	2,000
	pheasant	5,000
parathion	rat	3-30
	mule deer	22-44
	mallard	1.9-2.1
	pheasant	12.4
	sharp-tailed grouse	4.0-10.0
pentachlorophenol	rat	125
	pheasant	4,000-5,000
rotenone	rat	132-1,500
	mallard	2,000
	pheasant	1,414
temephos	rat	1,000-2,000
	mallard	80-100
	pheasant	31.5
trichlorfon	rat	450
	quail	700-800

[1]No longer used in British Columbia.

ACUTE TOXICITY TO FISH

The acute toxicity of pesticides to fish has traditionally been expressed as the **median lethal concentration (LC_{50})**, which is the concentration of the chemical in water that will cause the death of 50% of a population of test fish in a given time, usually 96 hours. This concentration is usually expressed as parts per million (ppm) or the number of milligrams of toxicant per litre of water (mg/L).

Toxicity values of some insecticides and herbicides for various fish species are listed in Tables 26 and 27.

Unfortunately, a single LC_{50} test has limited value as an indicator of the potential harm that a chemical could cause. There can be large variability in LC_{50} test results between different species. Even individuals of the same species can have different tolerance to a toxicant. Variations can be due to different ages, sex, testing procedures or condition of the test animals. For example, the fry of some fish are more susceptible to toxicants than adults.

Too much emphasis can be placed on the LC_{50} value as a measure of toxicity. It is a common error to assume that concentrations below the LC_{50} value are not toxic. The **threshold of toxicity**, or concentration at which the first toxic effect occurs, may be considerably lower than the LC_{50}. The relationship between the threshold of toxicity and the LC_{50} is different for each species.

The LC_{50} value does provide a useful comparison of the toxicity of pesticides to aquatic organisms. How-

Table 26. Toxicity values of insecticides to fish.

Insecticide[1]	Fish	Exposure time (hrs.)	LC_{50} (mg/L)
acephate *(Orthene 75-S)*	trout	96	770
azinphos-methyl *(Guthion)*	trout	96	0.014
Bt	trout	48	550 +
carbaryl	trout	96	4.38
cypermethrin	salmon	96	0.002
DDT[2]	salmon	96	0.004
diazinon	salmon	96	3
dimethoate	trout	96	9
endosulfan	trout	48	0.001
endrin[2]	salmon	96	0.0005
fenitrothion[2]	trout	96	1.4
fenvalerate	trout	96	0.0012
lindane	trout	48	0.002
malathion	salmon	96	0.043
pentachlorophenol	salmon	96	0.03
permethrin	salmon	96	0.012
propoxur *(Baygon)*	trout	96	0.22
rotenone	salmon	24	0.15
temephos	brook trout	48	1.5

[1]Where LC_{50} is for product (active ingredient plus a carrier in most cases), that name is listed in brackets; where LC_{50} is for active ingredient, that name is listed alone.

[2] Not used in British Columbia.

Table 27. Toxicity values of herbicides to fish.

Herbicide[1]	Fish	Exposure time (hrs.)	LC_{50} (mg/L)
amitrole	salmon	48	3,250
atrazine	salmon	96	20
dicamba	trout	48	35
2,4-D acid	salmon	96	6-135
	trout	48	1
2,4-D diethanolamine	trout	96	263
2,4-D dimethylamine	trout	96	59
2,4-D dimethylamine + 5% diesel oil	trout	96	35
2,4-D iso-octyl ester	trout	96	70
2,4-D iso-octyl ester + 5% diesel oil	trout	96	27
2,4-D iso-octyl ester + 10% diesel oil	trout	96	28
2,4-D iso-octyl ester + 20% diesel oil	trout	96	8.9
diesel oil	trout	96	10,000
dinoseb	trout	96	0.055
triclopyr *(Garlon amine)*	trout	96	240
triclopyr *(Garlon ester)*	trout	96	0.74-2.24
glyphosate	trout	96	38-97
glyphosate *(Roundup)*	trout fingerlings	96	1.3-42
hexazinone	trout	96	370-420
fosamine ammonium *(Krenite)*	trout	96	1,000
MSMA	salmon	48	8.4
picloram	trout	96	70
simazine	salmon	96	6.6
2,4,5-T[2]	salmon	96	13.5-36
	trout	48	1.3-12

[1]Where LC_{50} is for product, that name is listed in brackets; where LC_{50} is for active ingredient, that name is listed alone.

[2]No longer used in British Columbia.

ever, when assessing the hazard of a particular pesticide, the LC_{50} and threshold of toxicity for a number of species, as well as other indirect effects on habitat should be considered.

CHRONIC TOXICITY

Chronic toxicity is the degree to which a chemical is poisonous as a series of repeated doses over a long time period. A pesticide may be chronically toxic when present in concentrations which have no immediate detectable effect. Repeated exposure to these small amounts of chemicals can eventually cause the death of an animal (e.g. liver failure) or may cause sublethal effects and weaken an animal to predation or interfere with its reproduction. Examples of sublethal effects include a loss of appetite, restricted growth, impaired sense of smell, damage to liver and kidneys, or abnormal behaviour. Chronic toxicity may be enhanced if pesticides are persistent and accumulate in organisms. Unfortunately, tests to measure the behavioral and physiological responses to low concentrations of pesticides are costly, time consuming and difficult to conduct in many field situations. However, chronic toxicity can be as damaging to a wildlife or fisheries resource as a direct kill.

In general, chronically toxic and environmentally persistent pesticides and their residues present a greater threat to wildlife and aquatic life than acutely toxic, short-lived pesticides. Some persistent chemicals can become sufficiently concentrated along a food chain to affect the normal reproduction and/or behaviour of a given species (see Figure 39). The organochlorines and their residues are a case in point. This group of pesticides, of which DDT is an example, are only moderately toxic to wildlife; however, most are highly persistent in the environment and accumulate along the food chain. The discovery that populations of certain bird species were rapidly declining in areas of high organochlorine insecticide use resulted in legislation in the early 1970's which restricted the use of these pesticides.

TOXICITY OF DIFFERENT CLASSES OF PESTICIDES TO WILDLIFE AND FISH

INSECTICIDES

As a general rule, insecticides are more acutely toxic to fish and wildlife than herbicides. Although there is considerable overlap in toxicity between the major groups of insecticides, the organophosphorous and carbamate compounds are generally more acutely toxic than the organochlorines to wildlife. However, the organochlorines are more acutely toxic to fish species. Some additional characteristics of these groups of insecticides are as follows:

Organophosphorous pesticides. Typically, organophosphorous pesticides are less persistent in the environment than organochlorine pesticides and are not concentrated along the food chain. Fish kills are usually caused by direct application of organophosphorous compounds to water. However, sublethal effects are also possible. Where these compounds are used, particularly on a large scale, such as for controlling forest insects, the lowest effective rates of application should be used to minimize possible sublethal effects on non-target species. For example, fenitrothion is an organophosphorous insecticide commonly used to control forest defoliators in eastern Canada. It can be applied in one treatment, at a rate of 200 mL/ha, or in two treatments at 100 to 150 mL/ha, 4 to 6 days apart. Although fenitrothion is not acutely toxic to fish at the higher application rate, it may be desirable to treat twice at the lower rate to minimize the potential for sublethal effects. Decreases in fish food biomass have been documented following fenitrothion treatments and in laboratory studies fenitrothion caused behavioral changes in trout (cessation of feeding), at one tenth of the 96 hour LC_{50} (1.4 mg/L).

The organophosphorous pesticides could have acute or chronic effects on wildlife. In laboratory tests,

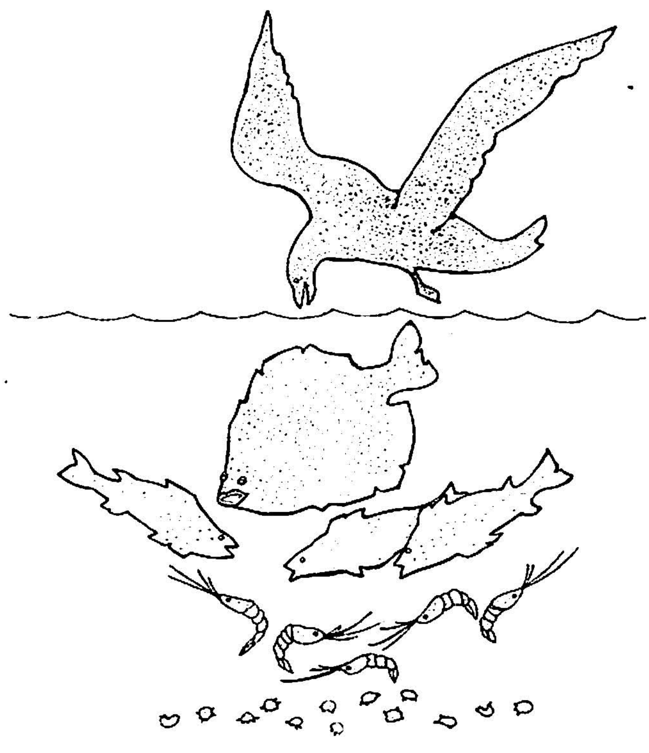

Figure 39. Concentration of an organochlorine pesticide in different levels of a food chain (stipling depicts pesticide). Plankton absorb a pesticide from the water and other organisms from each level in the food chain concentrate the pesticide in the food they eat. This applies only to a pesticide which accumulates in body tissues and is not rapidly broken down.

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organophosphorous pesticides have been demonstrated to cause delayed neurotoxicity in chickens. Teratogenic effects (deformation of embryos) have been observed in some animals from high doses of several organophosphorous compounds.

In the natural environment, both acute and chronic effects have been demonstrated in songbird populations following spraying with fenitrothion for forest insect control. Adult birds exhibited symptoms of cholinesterase depression (a characteristic acute effect of organophosphorous pesticide poisoning) which caused erratic behavior and reduced feeding and survival of nestlings. Such effects were most severe in areas where adjacent swath's accidentally overlapped, resulting in double the application rate (overswathing).

Carbamates. Toxic effects of carbamates to fish and wildlife are similar to organophosphorous compounds. Carbamates are generally non-persistent in the environment and do not accumulate in biological systems. Chronic effects, similar to those mentioned for organophosphorous pesticides in birds, have also been reported for some carbamates (e.g., carbaryl). The acute toxicities of carbamates to fish and wildlife vary from moderate to high.

Organochlorines. Most organochlorine pesticides have a low acute toxicity to wildlife but some have been shown to drastically reduce bird populations. This applies particularly to birds at the top of food chains such as falcons, hawks and eagles. The chlorinated hydrocarbons such as DDT, endrin and lindane are extremely toxic to fish, have a long residual life and are cumulative in the environment. Environmental residues are passed through the food chain and magnified at each level (Figure 39). Due to their adverse environmental effects, these compounds are generally no longer considered acceptable for use in forest or agricultural pest control. The use of the very persistent pesticides is no longer allowed in British Columbia.

Pyrethroids. During the last several decades, the pyrethroids have been developed to replace certain organochlorine pesticides and other synthetic pesticides with environmental impacts or high toxicity to mammals. Some pyrethroids are very similar in structure and mode of action to pyrethrum, the botanical pesticide obtained from crysanthemum flowers. These pyrethroids have rapid insect knock-down effects but are unstable and short-lived in the environment. Recently, however, several chlorinated synthetic pyrethroids have been developed which have a persistence of several weeks to months in certain soils. These pesticides, including cypermethrin, deltamethrin and fenvalerate, are useful in agriculture because of their potency against insects, their persistence and low toxicity to mammals. However, they are also extremely toxic to fish, shellfish and other aquatic organisms.

Use of synthetic pyrethroids has the potential to contaminate fish-bearing waters or wetlands as a result of dirct spray drift and as a result of storm and irrigation-water runoff from sprayed fields. They may kill fish and aquatic invertebrates important as fish or waterfowl food. Under temporary registration, a 100 m setback around all bodies of water for aerial applications and a 15 m setback for ground applications is required when using these pesticides. As well, applications should not be made when rains are forecast within 24 hours of application.

HERBICIDES

Herbicides are generally less acutely toxic to fish and wildlife than most other pesticides. Many organisms, both plant and animal, possess the ability to detoxify or bring about the decomposition of organic herbicides. Although most herbicides are decomposed rapidly, persistence of some herbicides in wetlands has been reported. Some herbicides are toxic to aquatic insects and crustaceans and, if released in sufficient quantities, could destroy species which are an important fishfood source. Examples are atrazine, 2,4-D, diuron and picloram. A few herbicides, e.g. dinitrophenols, are extremely toxic to fish (the 96 hour LD_{50} of dinoseb for trout is 0.055 mg/L).

Research has demonstrated that the degree of toxicity of many herbicides is related to their formulation. Ester formulations of the phenoxy compounds are more toxic to fish than water-soluble amines (Table 26).

Chronic exposure to some herbicides causes detrimental effects at much lower concentrations than short-term exposure. Picloram has been shown to have an LC_{50} to lake trout of about 70 mg/L when exposed for 96 hours. Chronic exposure for 60 days reduced survival and growth at 0.035 mg/L.

Herbicides may also indirectly affect wildlife and fish by altering the physical environment. An example of this damage is the removal of streamside vegetation which can cause bank erosion or loss of shade cover, resulting in increased water temperatures. Another example is the loss of emergent vegetation from herbicide use in wetland areas, resulting in a reduction or alteration of nesting sites for many birds. Loss in non-target vegetation could also mean reductions in forage or insects used as a food source by birds and other wildlife. Reduction of vegetation which is preferred browse for deer, especially in critical winter and spring range areas, can cause harm to some populations.

There is little information on the sublethal effects of herbicides on birds. However, there are indications from laboratory studies that detrimental effects are possible. For example, amitrole was found to reduce reproduction in mallards at doses of 25% of the LD_{50}. High dosage rates of 2,4-D were found to depress reproduction in mallards. These laboratory tests did not simulate field conditions but did indicate that residues of these pesticides in the environment should be kept to a minimum.

WOOD PRESERVATIVES

Wood preservatives are all relatively toxic chemicals and are particularly hazardous to aquatic organisms. The most hazardous are pentachlorophenol, sodium-tetrachlorophenate (for sapstain protection) and creosote, which are widely used in British Columbia. The major concern for environmental contamination is the potential for spills from storage tanks or during applications, or runoff from freshly-treated wood or contaminated wastes.

Exposure to pentachlorophenol can result in both short-term and long-term effects. Pentachlorophenol is very persistent in the environment, which means that the pesticide can continue to leach from contaminated soils for years. The potential impact of pentachlorophenol spills is apparent from the observation that solutions used at wood protection facilities are acutely toxic to sensitive organisms after a million-fold dilution. Chronic effects on aquatic organisms occur at concentrations far below the level of acute toxicity. For example, diminished growth of fish has been observed with long-term exposure to pentachlorophenol at concentrations as low as 0.0017 mg/L.

Creosote can also cause acute and chronic effects in aquatic organisms. A three million-fold dilution of creosote would be required to assure the absence of acute effects on rainbow trout. There is evidence that long-term exposure to polyaromatic hydrocarbons, a major constituent of creosote, has resulted in a high incidence of tumours in certain fish populations.

RECORDED WILDLIFE AND FISH KILLS IN BRITISH COLUMBIA

There are records of a number of fish and wildlife kills due to pesticides in British Columbia (Table 28 and 29). They may represent only a small portion of the actual numbers and kinds of animals that have been acutely or chronically affected by pesticides. Most modern pesticides degrade rapidly. Unless the dead animal is preserved properly and analyzed within a short period, it is often impossible to determine the exact cause of death. Furthermore, poisoned or stressed animals often hide or are quickly preyed upon by other animals. Generally, only kills of large animals are reported. Small organisms at the lower end of food chains, e.g. algae, aquatic invertebrates and insects, are often not noticed and kills are seldom reported.

With knowledge of the toxicity of pesticides and ways to reduce their impact on the environment, the potential for direct and indirect pesticide caused mortality of fish and wildlife can be greatly reduced.

Table 28. Examples of pesticide-related fish mortalities.

Year	Pesticide	Program	Location	Reported Mortalities	Fish Species Killed
1956-57	DDT	forest spray	Vancouver Island	45,000	salmonids
1960	copper sulphate	swimmer's itch	Cultus Lake	100 +	salmonids
1963	DDT	mosquito control	Shuswap Lake	3 mill.	salmonids
1963	pentachlorophenol	lumber treatment	Sooke Basin	1,000	ocean perch
1964	lindane	garbage dump	L. Campbell R.	2,500	salmonids
1971	dinitrophenol	aerial agriculture spray	Marshall Creek	2,000	salmonids
1972	chlorophenols	pole treatment	L. Campbell R.	2,500	salmonids
1972	chlorophenols	lumber treatment	Victoria harbour	tons	anchovy, herring
1973	chlorophenols	lumber treatment	Mamquam Ch., Squamish	500	salmonids
1973	chlorophenols	pole treatment	Surrey		cutthroat trout
1975	copper triethanolamine	lake treatment	Sardis	many	trout, catfish
1975	malathion	aerial mosquito control	Delta Golf Course	100 +	stickleback
1979	azinphos-methyl	agriculture	Summerland	500	brook trout
1984	chlorophenols	wood preservation	Surrey	10,000	salmonids
1985	chlorophenols	wood preservation	Brunette R.	2,000 +	salmon
1985	chlorophenols	wood preservation	Duncan Bay	100	salmon

Table 29. Examples of pesticide-related wildlife mortalities.

Year	Pesticide	Program	Location	Reported Mortalities	Wildlife Species Killed
1967	DDT	apple orchard	Okanagan	-	cedar wax wings
1968	methyl trithion		Stanley Park	-	ducks
1973	carbofuran	agriculture	Richmond	60	ducks
1974-75	carbofuran	agriculture	Ladner	1,400	ducks
1974	diazinon	agriculture	Okanagan	8	Canada geese
1975	diazinon	garbage dump	Victoria	-	Brewer's black bird & seagulls
1977	aldicarb, endosulfan	agriculture	Victoria	16	mallards
1977	carbofuran	agriculture	Delta	150	ducks
1979-80	fensulfothion	agriculture	Steveston	150	ducks
1982	fensulfothion	agriculture	Aldergrove	13	Canada geese
1982	fensulfothion	landscape pest control	Richmond	27	small birds

CHAPTER QUIZ

Questions

1. What are sublethal effects?
2. Define acute toxicity.
3. How is LD_{50} measured for wildlife?
4. What would the approximate lethal dose be for a 0.5 kg rat for the following pesticides: diazinon, glyphosate?
5. How is acute toxicity of pesticides to fish measured?
6. List the following in order of relative toxicity to fish from least to most toxic: diazinon, fenitrothion, atrazine, picloram.
7. Are concentrations below the LC_{50} value acutely toxic?
8. Define chronic toxicity and give an example.
9. What is the main concern about environmentally persistent pesticides?

Answers

1. Sublethal effects are toxic effects of a pesticide that do not cause direct mortality.
2. Acute toxicity is the degree to which a chemical is poisonous as a single dose or series of doses within a short time period.
3. LD_{50} is measured in milligrams of toxicant per kilogram of body weight of the animal tested.
4. The approximate lethal dose of diazinon for a 0.5 kg rat = 0.5 kg x 300 mg/kg = 150 mg; the approximate lethal dose of glyphosate for a 0.5 kg rat = 0.5 kg x 4,300 mg/kg = 2,150 mg = 2.15 g per animal.
5. Acute toxicity of pesticides to fish are measured as an LC_{50}— the concentration of a pesticide in water that will cause the death of fifty percent of test fish in a given time period.
6. From least to most toxic to fish: picloram (LC_{50} — 70.0 mg/L), atrazine (LC_{50} — 20.0 mg/L), diazinon (LC_{50} — 3 mg/L), fenitrothion (LC_{50} — 1.4 mg/L).
7. Yes, the threshold of toxicity or concentration at which the first toxic effects occur can be considerably lower than the LC_{50}.
8. Chronic toxicity is the degree to which a chemical is toxic over a long period of time, often as a result of repeated exposure to low concentrations.
9. The main concern about environmentally persistent pesticides is that they could be accumulated along the food chain and be concentrated sufficiently in an organism to affect its reproduction or behavior.

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10. Which of the following generally applies to organophosphorous pesticides, and which to organochlorines?

    a) — low toxicity to wildlife, high toxicity to fish, persistent.

    b) — acutely toxic to wildlife, low toxicity to fish, non-persistent.

10. a) — organochlorine, b) — organophosphorous

11. Name some detrimental effects herbicides could have on *fish and wildlife.*

11. — some herbicides are toxic to aquatic insects and crustaceans and could destroy important fish food species if misused.
    — some herbicides are acutely toxic to fish.
    — some herbicides may indirectly affect wildlife by altering their physical environment by causing bank erosion or loss of shade cover or food sources.
    — some herbicides may cause sublethal effects in birds.

Chapter 23

GUIDELINES TO PROTECT THE ENVIRONMENT DURING PESTICIDE APPLICATIONS

CONTENTS

INTRODUCTION

The following guidelines describe basic precautions to protect bystanders and fish and wildlife from pesticide exposure during pesticide applications. Some of these precautions may be included on pesticide product labels. Other precautions may be specified on the Pesticide Use Permits issued by the Pesticide Control Branch. Ultimately, use of the appropriate safety precautions during any treatment is the responsibility of the applicator. Particular care must be taken when:

- the treatment area is large;
- a hazardous chemical is used;
- the treatment is close to populated areas or ponds, lakes, streams, rivers or wells used as a drinking water source; or
- the treatment is close to fish or wildlife habitat.

GENERAL GUIDELINES

PESTICIDE SELECTION

For all pest control programs, the possibility of controlling the pest species by non-chemical methods should be considered. This alternative is particularly important for pest control near sources of drinking water or waters inhabited by fish. Examples of non-chemical control techniques are the mechanical clearing of weeds competing with forest conifer seedlings and weeds along rights-of-way, the harvesting of trees that are infested with insect pests, or the physical alteration of mosquito breeding areas.

Once the necessity of pesticide use has been established, a pesticide should be selected which is:

- target-specific,
- of lowest possible toxicity,
- as non-persistent as possible, and
- not cumulative in the tissues of plants or animals.

Certain pesticide additives such as wetting agents, thickeners or emulsifiers may enhance the toxicity of pesticides, particularly to aquatic organisms. Additives must be used with caution or avoided.

APPLICATION RATE AND TREATMENT AREA

All pesticide applications must be restricted to the smallest possible area to achieve the desired degree of control. Under no circumstances should the manufacturer's recommended application rate be exceeded.

METHOD OF APPLICATION

An application method should be used that will apply the pesticide to the target species with minimum contamination of the surrounding area. Spot treatments, such as individual tree injection, generally result in less non-target contamination than broadcast treatments. Spray drift is minimized by applying pesticides at low pressures and with nozzles that produce large droplet sizes. Wind speed should be less than 8 km/h. Vapour release is minimized if pesticides are applied when temperatures are coolest.

Boundaries of treatment areas near water bodies and other sensitive areas should be easily located. If boundaries are not plainly visible, they should be marked prior to pesticide application so that concealed water bodies will be protected. Flagging must be visible enough to be easily recognized. Portions; of a treatment area should be omitted where water bodies could be contaminated due to difficulties in marking application boundaries.

Equipment used in spray operations must be in good working order to prevent accidental spills. Applicators should ensure that sprayers will effectively shut off at treatment boundaries. Use boom sprayers that have good shutoff valves and retractable booms, to avoid spraying roadside streams and water-filled ditches,

STORAGE AND HANDLING OF PESTICIDES

Pesticides must be stored in locked facilities to ensure that they will not be subject to vandalism. Pesticides should not be mixed, loaded or stored where any spillage or leakage may enter storm drains or any water body. Similarly, spray equipment must not be washed in any natural water body or waters leading to storm drains. Pesticide containers must recycled or disposed of in approved landfills. Pesticide rinse water must be added to the spray tank. Pesticide wastes must be disposed of as hazardous wastes (see recommendations on disposal in Chapter 5).

PESTICIDE-FREE ZONES AND BUFFER ZONES AROUND WATER BODIES

In British Columbia, most pesticide applications must maintain a 10 m "**pesticide-free zone**" around bodies of water[1] and dry steams. Some exceptions to the 10 m distance are permissible under the *Integrated Pest Management Act* Regulations but, for most applications, the pesticide applicator must prevent the entry of pesticides into the 10 m pesticide-free zone by direct application, drift, runoff or leachate.

The pesticide-free zone is to ensure that pesticides do not contaminate natural waters and to prevent damage to surrounding vegetation. It ensures that water used for domestic purposes will be free of pesticide contamination and that fish and other aquatic organisms are protected from the harmful effects of pesticides. A 10 m pesticide-free zone will also protect streamside vegetation which provides food, shade and cover for fish, and an important habitat for wildlife. Such vegetation often contributes to bank stability. A pesticide-free zone eliminates concerns about the potential for accidental excess treatment or spills adjacent to water bodies. Application equipment should always remain outside the 10 m pesticide-free zone.

The 10 m pesticide free zone is measured from the margin of a watercourse in which there is water or from the margin of a basin holding water. It is measured from the high water level for tidal waters. The margin of a watercourse or water basin is the level frequently wetted during the season of high water and where there is usually a conspicuous break in the terrestrial vegetation.

A pesticide-free zone must usually be surrounded by a '**buffer zone**'. The buffer zone is a strip of land between the pesticide-free zone and the treatment area which may be required to prevent drift, runoff or leaching of pesticides or residues into the pesticide-free zone (see Figure 40). Pesticides are not applied directly to the buffer zone, but it must be wide enough to contain all pesticide or residue drift, runoff or leaching in the direction of the 10 m pesticide-free zone.

---

[1] Bodies of water include:

(a) water in a watercourse such as a river, stream or creek;
(b) water in the basin of a lake, marsh or slough;
(c) marine or estuarine water; or
(d) water in a ditch

but do not include human-made, self-contained water bodies (e.g. ponds and dugouts).

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It is the responsibility of the pesticide applicator to ensure that the buffer zone is wide enough to maintain the 10 m pesticide-free zone at all times. The buffer zone width will depend on such factors as the type of equipment used, its speed, the terrain and weather conditions. Some minimum buffer zone widths suggested to preserve the 10 m pesticide-free zone are listed in Table 30. On sloping terrain, these widths are to be measured horizontally rather than along the ground. In practice, the widths may vary along a watercourse as the slope of the land, wind speed or other factors vary.

It may be necessary for the applicator to establish the necessary buffer zone widths through monitoring. In aerial or ground spraying of vegetation, for example, sample cards of Kromekote paper are useful to establish the distance of pesticide drift. Rhodamine B or another suitable dye is added to the spray mixture so that spray landing on the Kromekote cards can be identified. Cards are laid out at intervals from the boundary of the 10 m pesticide free zone into the treatment area. The boundary of the buffer zone can be adjusted based on spray drift detected on the sample cards.

Table 30. Suggested buffer zones[2] for the protection of the 10 m pesticide-free zone

Equipment	Suggested Minimum Width of Buffer zone (m)[3]
Individual Tree Treatment	
Hack/squirt, frilling, notching, drilling, lance injection etc.	0
Mistblower	
Backpack	5
Truck mounted	5
Powerhose	
Truck mounted	5
Granular Spreader	
helicopter	50
fixed wing	50
Boom Sprayer	
Truck mounted	5
helicopter	100
fixed wing	200

[2] From field observations and measurements by the Environmental Protection Service, Pacific Region, Environment Canada.
[3] Actual size of required buffer zone required will vary with equipment used, terrain and weather conditions.

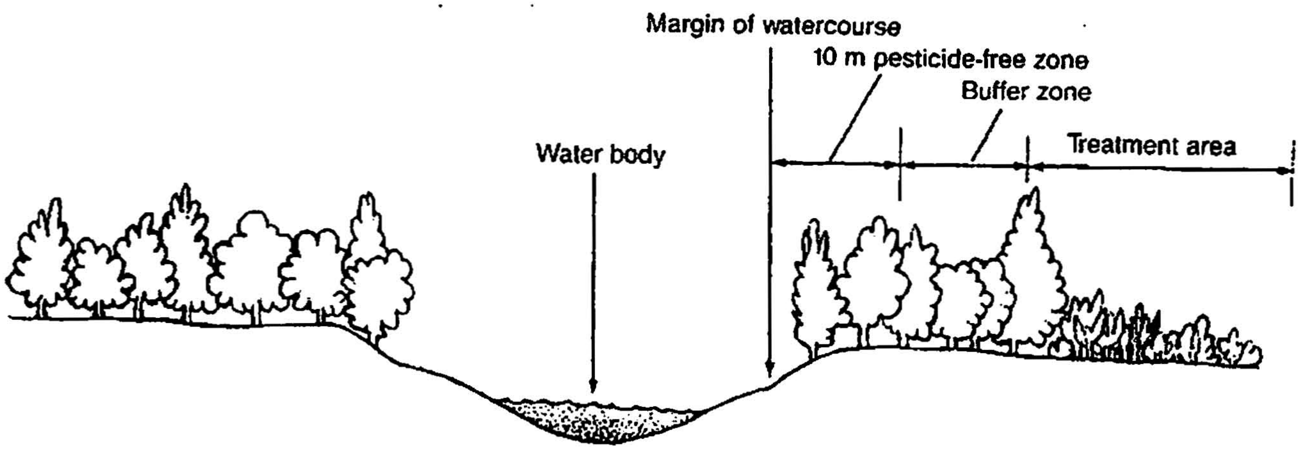


Figure 40. Relation between a 10 m pesticide-free zone (PFZ), buffer zone and treatment area.

GUIDELINES FOR SPECIFIC CATEGORIES OF PESTICIDE USE

In all pesticide treatments, it is the responsibility of the applicator to take appropriate precautions to protect the environment as may be required under local treatment conditions. The applicator must be aware of and attempt to eliminate the potential for exposure of bystanders, domestic animals, desirable plants, aquatic life and terrestrial wildlife. The following guidelines provide some recommendations for specific areas of concern for various treatment categories.

FORESTRY

Ground-Based Operations

- Prevent entry to a treatment area during application using road barriers or using sentries where there is any possibility of human exposure.
- Post signs on major access routes and advertise as required to describe the pesticide use to people who wish to enter the treatment area.
- Avoid spraying when berries are ripening if there is any potential of contaminating wild berries picked for human consumption.
- Maintain a 10 m pesticide-free zone and appropriate buffer zone along water bodies.
- Survey treatment areas near watercourses or water bodies and clearly mark the boundary of the pesticide-free zone. It may also be necessary to mark the boundary of the buffer zone.
- Consider ways to protect wildlife habitat or forage vegetation where they may be adversely affected. Where possible, forage vegetation should be protected by spot herbicide treatment of target species. In critical habitats, a portion of the treatment area may have to be set aside for forage production.

Aerial Operations

- Observe all precautions outlined for ground-based operations.
- Use only pesticides registered for aerial use.
- Select the type of aircraft with the capabilities to do the job. Helicopters are preferred over fixed-wing where steep terrain is involved.
- The boundaries of buffer zones should be marked so they are clearly visible from the air.
- The pilot should conduct a thorough pre-treatment aerial inspection of the treatment site, in the company of a project supervisor, to ensure the pilot's familiarity with the target area.
- An experienced ground crew should be present to monitor drift (such as with Kromekote sample cards) and to inform the pilot of changing conditions or excess drift.
- Begin the first spray swath, wherever possible, in an upstream direction along the border of the proposed treatment area, as shown in Figure 41. This practice is to reduce drift to the buffer zone and ensure that the 10 m pesticide-free zone is not contaminated.

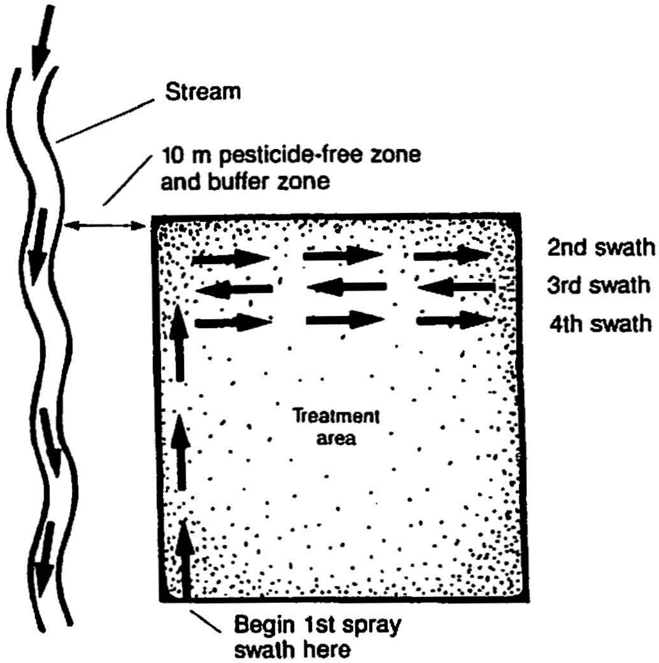


Figure 41. Suggested spray procedure to reduce drift toward the 10 m pesticide-free zone.

RIGHT-OF-WAY, INDUSTRIAL AND NOXIOUS WEED CONTROL

- Prevent entry of a treatment area during application using road barriers or using sentries where there is any possibility of human exposure.
- Post signs on major access routes and advertise as required to describe the pesticide use to people who wish to enter the treatment area.
- Do not spray when bystanders are likely to be near. Do not spray areas near public roadways where school children are present, particularly between the hours of 7:30 to 9:00 a.m. and 2:30 to 4:30 p.m.
- Avoid spraying when berries are ripening if there is any potential of contamination of wild berries picked for human consumption.
- Know the persistence of the herbicide and how it will affect potential future use of the land. For example, picloram herbicides may persist for up to 5 years, during which time the soil cannot be used for growing crops or ornamentals.
- Where a contractor is treating private land, he should notify the landowner of the herbicide used and the appropriate re-entry period for humans or domestic animals or the delay in use of the land for agriculture or grazing.
- Avoid drift onto adjacent land. Note the sensitivity of some cultivated plants to some herbicides. A buffer

zone may be required between the treatment area and adjacent land. For the protection of desirable plants (e.g. conifers alongside an industrial site) select the season of least sensitivity to the desirable plants (e.g. conifers are less sensitive when they have hardened off in late summer).
- Maintain a 10 m pesticide-free zone and appropriate buffer zone along all water bodies.
- Survey treatment areas near watercourses or water bodies and clearly mark the boundary of the pesticide-free zone. It may also be necessary to mark the boundary of the buffer zone.

AGRICULTURAL PEST CONTROL

- Do not spray fields occupied by farmworkers and ensure adequate re-entry times are observed by workers and bystanders, i.e. as directed on the pesticide label, or according to W.C.B. recommendations (Chapter 3). It may be necessary to post warning signs (see example in Figure 9, Chapter 3).
- Apply pesticides at a time of day when bystanders are least likely to be near (i.e. early morning before school children are out). Do not spray areas near public roadways where school children are present, particularly between the hours of 7:30 to 9:00 a.m. and 2:30 to 4:30 p.m.
- Leave adequate buffer zones between spray operations and sensitive areas such as public roadways and adjacent private properties to prevent bystander exposure and injury to, or contamination of, animals and vegetation.
- Protect children and domestic animals from baits. Conceal bait by using covers or placing bait in the ground. Bait which must be placed on the ground should be scattered to reduce the hazards associated with a clump of bait.
- Ensure fencing is adequate to keep domestic and farm animals out of treated areas as may be required on labels.
- Do not contaminate domestic water supplies or fish-bearing waters directly or indirectly via runoff, leaching or drift; select application equipment, droplet size and weather to minimize drift. Pesticides should not be mixed or applied, or application equipment washed, within 30 m of wells or ponds used for domestic water supplies.
- Do not drain equipment rinse water and excess chemicals into water-filled ditches or sewers. Rinse water should be applied to the treatment area, or following guidelines for disposal of unused pesticides in Chapter 5.
- For aerial spraying, use a ground crew field observer to monitor drift or any other unexpected occurrence.
- Choose pesticides least likely to affect beneficial insects (see Chapter 20 on ways to reduce bee poisoning).
- Minimize spraying to fence rows and field edges which are often the habitat of songbirds and other animals.

MOSQUITO CONTROL

- Evaluate the potential for physical alteration of the larval environment (i.e. draining areas of standing water) to control mosquitoes. If adjacent to fish habitat, such alterations must be approved by regulatory agencies.
- Consider larval control using surface-acting agents or chemical larvicides as the second choice where physical alteration is not possible.
- Do not apply pesticides to waters used for domestic supply or frequented by fish; 10 m pesticide-free zones must be maintained around all these waters, unless otherwise permitted by regulatory authorities.
- Consider use of adulticides (e.g. malathion) only as a last resort, when a larviciding program is impossible or has failed to produce the desired results.
- Apply adulticides using ground-based equipment, if practical.
- Before aerial applications, provide adequate public notice so that affected residents will know of the program and can take any necessary protective measures.
- Maintain a contact person at a publicized telephone number to receive questions and provide advice during aerial applications.
- Do not conduct aerial applications when residents and bystanders are unprotected and exposed to the spray.
- If necessary, advise residents with home gardens in the vicinity of spray operations to wash produce or leave produce unharvested for specified time periods.
- Beekeepers in proposed treatment areas should be notified when insecticide use may pose a hazard to their colonies.

LANDSCAPE AND GARDEN PEST CONTROL

- Do not spray when bystanders are likely to be near. Do not spray areas near public roadways where school children are present, particularly between the hours of 7:30 to 9:00 a.m. and 2:30 to 4:30 p.m.
- Take precautions to prevent exposure of bystanders to pesticides as dictated by site-specific factors, e.g. tenants of buildings adjacent to sprayed areas should be directed to close windows and doors until the application is completed and vapours disperse, and to exclude domestic pets from treated areas for a suitable time period (generally until pesticides are dry).
- Prevent drift and runoff onto private land bordering treatment areas. Areas of particular conflict are where adjacent land has
  - — cultivated plants grown for human consumption,
  - — cultivated plants sensitive to herbicide drift, or
  - — trees or shrubs which may be damaged by herbicide leaching to roots.
- Use equipment least likely to produce drift (i.e. coarse sprays), and leave a suitable buffer zone between treatment areas and adjacent property. No spray droplets should fall on adjacent properties where treatments are not authorized.

- Inform the landowner and tenants of private land about the pesticide used and any safety precautions to be observed.
- Post public areas with signs indicating where treatments have occurred, if anyone could be exposed to the pesticide.
- Do not contaminate domestic water supplies or fish-bearing waters directly or indirectly via runoff, leaching or drift. Do not spray when wind speeds are greater than 8 km/h and select application equipment and droplet size to minimize drift. Pesticides should not be mixed or applied, or application equipment washed, within 30 m of wells or ponds used for domestic water supplies.
- Do not let equipment rinse water and excess chemicals run into water-filled ditches or sewers. Rinse water should be applied to the treatment area, or following guidelines for disposal of unused pesticides in Chapter 5.

STRUCTURAL CONTROL

- Inform the landowner or building owner and tenants (if any) about the pesticide to be used, the purpose of the application and any safety precautions; to be observed.
- Make certain building residents know how long to wait before re-entry to treated building areas after a treatment. Observe re-entry times specified on the label or, if not specified, wait until pesticide sprays are thoroughly dry (time depends on building heat and humidity).
- Ensure that children and domestic pets are prevented from entering a building or treated area before the safe re-entry time.
- Specify that treated interiors of buildings should be aired out before re-entry.
- Select alternative pesticide products if people are allergic to a particular pesticide.
- Do not apply dusts in a way that will leave concentrated deposits that might be contacted by people or domestic pets.
- Place baits in a way that they cannot be contacted by children or pets.
- Use caution in treating food preparation areas. Applicators should be certain they are thoroughly familiar with label precautions. It is usually necessary to remove or cover food and food preparation surfaces and to treat commercial establishments during non-operating hours. Some sprays can only be used to treat in cracks and crevices.
- Do not dispose of spray equipment rinse water or left over pesticides in a manner that may contaminate domestic water supplies or fish-bearing waters (see guidelines for disposal of unused pesticides in Chapter 5).

WOOD PRESERVATION

Commercial treatment of logs and lumber is a common practice. Most wood preservative pesticides are very toxic to fish. Contamination of fish-bearing waters has occurred frequently in the past.

- Use extreme caution to prevent contamination of domestic water sources or any fish-bearing waters directly or indirectly through leaching, or in application methods such as spraying, dipping, soaking, steeping or pressure treatment.
- Isolate commercial wood protection/preservation facilities at least 50 m from surface water bodies and site on flat ground with suitable soil composition and low groundwater table.
- Use strong, corrosion-resistant, leak-proof storage tanks and provide for drip collection during the application process and for wood immediately following treatment.
- Enclose tanks of concentrated preservatives in locked compounds to prevent entry of unauthorized persons.
- Wood preservation storage tanks should be routinely checked for leaks.
- Provide facilities for spill containment around wood preservative storage areas.
- Dispose of wastes contaminated with wood preservatives only with the authorization of Environmental Management Branch of the B.C. Ministry Water, Land and Air Protection.

CHAPTER QUIZ

Questions

1. List some major considerations to minimize environmental and bystander exposure with regard to (a) pesticide selection, (b) application rate and treatment area, (c) method of application, and (d) storage and handling of pesticides.

2. Would there be concern about environmental damage if pesticide spray is deposited in a pesticide buffer zone, as defined in this Handbook?

3. What is the minimum distance you would likely leave between a water body and the treatment area using a boom sprayer on a truck? What could alter this distance?

4. Name some ways bystander exposure or environmental impact may occur that you should be concerned about in your category of pesticide use.

5. Name two ways that damage to wildlife habitat could be avoided when using a herbicide that can affect wildlife forage.

Answers

1. (a) Select pesticides which are target specific, least toxic, least persistent and do not accumulate in biological tissues.
(b) Restrict treatments to smallest area and lowest possible application rate.
(c) Apply pesticides in a way that minimizes non-target contamination.
(d) Lock up pesticide storage areas, prevent contamination of water bodies, dispose of containers away from water.

2. There is no concern if spray drifts into the buffer zone providing it does not enter the pesticide-free zone.

3. A 10 m pesticide-free zone plus a 5 m buffer zone = 15 m total. The buffer zone might have to be increased in certain weather conditions or if the application equipment produces small spray droplets.

4. (a) forestry: human entry too soon after applications; humans eating treated plants/berries; damage to forage vegetation; pesticide contamination of pesticide-free zone or water bodies.
(b) right-of-way, industrial and noxious weed control: human entry too soon after applications; exposure of bystanders, especially school children; humans eating contaminated plants/berries; impacts on future land use; exposure of domestic animals; impact on desirable vegetation adjacent to treatment areas; contamination of the pesticide-free zone or water bodies.
(c) agricultural pest control: exposure of farmworkers; exposure of bystanders, especially children; contamination of adjacent sensitive areas; exposure of domestic animals; contamination of domestic water supplies or fish-bearing waters; destructionion of beneficial insects.
(d) mosquito control: contamination of water bodies and pesticide-free zones; exposure of bystanders; contamination of gardens.
(e) landscape and garden pest control: exposure of bystanders, particularly children; exposure of desirable plants/animals on property adjacent to treatment area; contamination of domestic water supplies or fish- bearing waters.
(f) structural control: human entry too soon after applications; exposure of pets or children to dusts or baits; allergic reactions from sensitive people; contamination of food preparation areas; contamination of domestic water supplies or fish-bearing waters.
(g) wood preservation: contamination of domestic water supplies or fish-bearing waters; exposure of humans.

5. (a) spot treatment of target vegetation only rather than a broadcast spray to protect wildlife forage species.
(b) in critical habitats a portion of the treatment area may have to be set aside for wildlife forage production.

APPENDIX I: LIST OF CONTRIBUTORS TO FOURTH EDITION (1979) OF HANDBOOK FOR PESTICIDE APPLICATORS AND DISPENSERS.

Coordinating and Editing Authors

A.V. Miller,
Pesticide Control Inspector,
Pesticide Control Branch.

S.M. Craig,
Pesticide Control Officer,
Pesticide Control Branch.

Contributors

J.C. Arrand,
Entomology-Plant Pathology Branch,
British Columbia Ministry of
Agriculture, Victoria.

Dr. R.A. Costello,
Entomology-Plant Pathology Branch,
British Columbia Ministry of
Agriculture, Surrey.

H.E. Cox,
Pesticide Control Branch,
British Columbia Ministry of
Environment, Kelowna.

S.M. Craig,
Pesticide Control Branch,
British Columbia Ministry of
Environment, Kelowna.

R.S. Cranston,
Field Crops Branch,
British Columbia Ministry of
Agriculture, Kamloops.

Dr. H.S. Gerber,
Entomology-Plant Pathology Branch,
British Columbia Ministry of
Agriculture, Surrey.

E.C. Hughes,
Field Crops Branch,
British Columbia Ministry of
Agriculture, Surrey.

Dr. L.D. Kornder,
Division of Occupational Health,
British Columbia Ministry of
Health, Vancouver.

D.J. Ormrod,
Entomology-Plant Pathology Branch,
British Columbia Ministry of
Agriculture, Surrey.

B. Pearce,
Field Service Branch,
Fisheries and Oceans Canada,
Vancouver.

Dr. H.S. Pepin,
Research Branch,
Agriculture Canada, Vancouver.

P.J. Procter,
Entomology-Plant Pathology Branch,
British Columbia Ministry of
Agriculture, Summerland.

M.W. Stimmann,
Environmental Toxicology,
University of California, Davis.

O. Langer,
Environmental Protection Service,
Environment Canada, Vancouver.

J. Litewka,
Environmental Toxicology,
University of California, Davis.

W.R. McCallum,
Pesticide Control Branch,
British Columbia Ministry of
Environment, Surrey.

D.M. McCutcheon,
Apiary Branch,
British Columbia Ministry of
Agriculture, Surrey.

A.V. Miller
Pesticide Control Branch,
British Columbia Ministry of
Environment, Surrey.

R.L. Morley,
Fish and Wildlife Branch,
British Columbia Ministry of
Environment, Victoria.

R.G. Mullett,
Pesticide Control Branch,
British Columbia Ministry of
Environment, Victoria.

Dr. H.J. O'Reilly,
Entomology-Plant Pathology Branch,
British Columbia Ministry of
Agriculture, Victoria.

Dr. J. Sutherland,
Pacific Forest Research Centre,
Canadian Forestry Service,
Victoria.

B.F. Vance,
Pesticide Control Branch,
British Columbia Ministry of
Environment, Surrey.

A.L. Vaudry,
Entomology-Plant Pathology Branch,
British Columbia Ministry of
Agriculture, Surrey

Dr. N.S. Wright,
Research Branch,
Agriculture Canada, Vancouver.

Dr. J.M. Yorston,
Entomology-Plant Pathology Branch,
British Columbia Ministry of
Agriculture, Summerland.

Note: Agency affiliations are those at completion of Fourth Edition in 1979.

APPENDIX II: CONVERSIONS FROM IMPERIAL AND U.S. TO METRIC MEASURES

Imperial or U.S. Units	× Conversion Factor	= Metric Units
Length		
inches	× 2.54	= centimetres (cm)
feet	× 30.5	= centimetres (cm)
yards	× 0.91	= metres (m)
miles	× 1609	= metres (m)
miles	× 1.61	= kilometres (km)
Area		
square inches	× 6.45	= square centimetres (cm^2)
square feet (ft^2)	× 0.093	= square metres (m^2)
square yards (yd^2)	× 0.84	= square metres (m^2)
acres	× 4,047	= square metres (m^2)
acres	× 0.405	= hectares (ha)
Volume		
teaspoons (Imp.)	× 4.74	= millilitres (mL)
tablespoons (Imp.)	× 14.2	= millilitres (mL)
fluid ounces (Imp.)	× 28.41	= millilitres (mL)
fluid ounces (U.S.)	× 29.57	= millilitres (mL)
pints (Imp.)	× 0.57	= litres (L)
quarts (Imp.)	× 1.14	= litres (L)
gallons (Imp.)	× 4.55	= litres (L)
gallons (U.S.)	× 3.79	= litres (L)
cubic feet	× 28.32	= litres (L)
cubic inches	× 16.39	= cm^3, mL, cc
cubic feet	× 0.028	= m^3
cubic yards	× 0.77	= m^3
bushels	× 36.4	= litres (L)
Weight		
ounces	× 28.35	= grams
pounds	× 0.45	= kilograms
short tons (2,000 lb.)	× 0.91	= tonnes (1,000 kg.)
Speed		
miles per hour (mph)	× 1.609	= kilometres/hour (km/h)
feet per second	× 30.48	= metres/second (m/sec)
Pressure		
pounds per square inch (psi)	× 6.895	= kilopascals (kPa)
Proportions		
ounces/acre	× 70.05	= grams/hectare (g/ha)
pounds/acre	× 1.12	= kilograms/hectare (kg/ha)
fluid ounces/acre (Imp.)	× 70.21	= millilitres/hectare (mL/ha)
pints/acre (Imp.)	× 1.40	= litres/hectare (L/ha)
gallons/acre (Imp.)	× 11.23	= litres/hectare (L/ha)
gallons/acre (U.S.)	× 9.35	= litres/hectare (L/ha)
bushels/acre	× 90	= litres/hectare (L/ha)

.....continues

Imperial or U.S. Units	× Conversion Factor	= Metric Units
Proportions (continued)		
plants/acre	× 2.47	= plants/hectare (plants/ha)
teaspoons/gallon (Imp.)	× 1.04	= millilitres/litre (mL/L)
tablespoons/gallon (Imp.)	× 3.12	= millilitres/litre (mL/L)
fluid ounces/gallon (Imp.)	× 6.25	= millilitres/litre (mL/L)
pounds/gallon (Imp.)	× 0.10	= kilograms/litre (kg/L)
ounces/square foot	× 305	= grams/square metre (g/m²)
pounds/square foot	× 4.88	= kilograms/square metre (kg/m²)
ounces/foot row	× 93.01	= grams/metre row
pounds/foot row	× 1.49	= kilograms/metre row

APPENDIX III: CROSS REFERENCE LIST OF PESTICIDE TRADE NAMES, ACTIVE INGREDIENTS AND LD_{50} VALUES

In the following table, most pesticides used by commercial applicators, or of historic interest in British Columbia are listed alphabetically by active ingredient and trade name. The use category (e.g., insecticide, herbicide etc.) is indicated for each pesticide and pesticide trade names (capital first letter) are cross-referenced with their active ingredients (small first letter, except where abbreviated, such as MCP).

LD_{50} values (mg/kg body weight) are listed, where available, for each **active ingredient** (whether listed alone or in a trade named product). Note that each LD_{50} is for pure active ingredient and does not represent the toxicity of the trade named product. The lowest LD_{50} value is listed for an active ingredient where several are given in the literature reviewed. LD_{50} values are from tests with rats or rabbits (dermal).

Some pesticides may not be included in the list because the editors were unaware of their use in British Columbia, or were unfamiliar with a specific trade name, or because the pesticide came into use since publication of this text. No endorsement of any products is implied by the inclusion of selected trade names in the table.

Pesticides with numbers, such as 2,4-D, are listed alphabetically according to the lettered portion of their name, e.g. 2,4-D is listed with pesticides beginning with the letter D.

For more information on a particular pesticide, determine the category of use, then see the reference list of active ingredients at the end of the appropriate chapter (8-17).

Key to the Abbreviations for Pesticide Use Categories and Chapters with Information on each Category

Abbreviation	Use Categories	Chapters
AH	Aquatic Herbicide and Algicide	17
AR	Animal Repellent	17
Av	Avicide	15
F	Fungicide	10
Fum	Fumigant	11, 13
H	Herbicide	12
I	Insecticide	8
M	Miticide	9
Mo	Molluscicide	17
N	Nematicide	11
P	Piscicide	17
Pr	Predacide	17
PG	Plant Growth Regulator	12
R	Rodenticide	16
WP	Wood Preservative	14

Active Ingredients and Trade Names	Use Categories	Active Ingredients in Trade Name Products	LD_{50} for Pure Active Ingredient: Oral	Dermal
Aatrex	H	atrazine	1,780	7,500
Abate	I	temephos	1,000	> 4,000
ACA	WP	ammoniacal copper arsenate	8	
acephate	I		866	2,000
acrolein	AH		46	562
Acti-dione	F	cycloheximide	1.8	
Activol	PG	gibberellic acid	6,300	
Afesin	H	monolinuron	2,200	
Afolan	H	linuron	1,500	
Agricultural Weedkiller No 1	H	mineral oils		
Agrimycin	F	streptomycin sulphate	9,000	
Agristrep	F	streptomycin sulphate	9,000	
Agritox	H	MCPA	700	
Agrox Flowable	F	maneb	1,000	
Aqrox D-L Plus	F, I	captan & diazinon & lindane		
Agroxone	H	MCPA	700	
Alanap	H	naptalam	1,700	> 8,500
Alar	PG	daminozide	8,400	> 1,600
Alchem	WP	sodium pentachlorophenate	210	250
aldicarb	I, M		0.8	3

Active Ingredients and Trade Names	Use Categories	Active Ingredients in Trade Name Products	LD_{50} for Pure Active Ingredient Oral	Dermal
aldrin	I		39	98
Algimycin Pill	AH	copper present as chelates of copper citrate and copper gluconate		
allethrin	I		680	
allidochlor	H		700	
Allizol	H	amitrole	1,100	
alpha-chlorohydrin	R		127	
Altosid	I	methoprene	> 34,000	> 3,000
aluminum phosphide	Fum, I, R			
Amaze	I	isofenphos	28	162
Ambush 500	I	permethrin	> 4,000	> 2,000
Amiben	H	chloramben	3,500	3,200
Amid Thin	PG	naphthaleneacetamide	1,000	
aminocarb	I		21	275
4-aminopyridine	Av			
amitrole	H, AH		1,100	
Amitrol-T	H, AH	amitrole	1,100	
Amizine	H	amitrole & simazine		
Amizol	H	amitrole	1,100	
Amkil	H	2,4-D	300	
ammonia	AR			
ammoniacal copper arsenate	WP		8	
ancymidol	PG		> 2,000	> 2,000
anilazine	F		2,700	> 9,400
Apex	I	methoprene	> 34,000	> 3,000
APM	I	azinphos-methyl	7	220
Apron	F	metalaxyl	670	
Aqua	I	parathion	3	7
Aqua-Kleen	AH	2,4-D	620	
Arasan	F	thiram	375	> 2,000
Arborgard	AR	thiram	375	> 2,000
A-Rest	PG	ancymidol	> 2,000	> 2,000
Arrest	F	carbathiin	3,200	> 8,000
asulam	H		2,000	> 1,200
Asulox F	H	asulam	2,000	> 1,200
Atlacide	H	sodium chlorate	1,200	>20,000
atrazine	H		1,780	7,500
Atra-Mix	H	atrazine	1,780	7,500
Avadex BW	H	triallate	675	
Avenge	H	difenzoquat	270	3,500
Avitrol	Av	4-aminopyridine	28	327
azacosterol hydrochloride	Av		470	7,800
azinphos-methyl	I		7	220
Bacillus thuringiensis	I			
Bacillus thuringiensis israeliensis	I			
Bactospeine F	I	*Bacillus thuringiensis*		
Banisect	I	chlorpyrifos	82	202
Banvel	H	dicamba	1,000	> 2,000
barban	H		600	> 1,600
Basagran	H	bentazon	1,100	2,500
Basamid	Fum, N, F, H	dazomet	320	
Basfapon	H, AH	dalapon	3,900	
Basico	F	coppers (fixed)		
Basudin	I, M	diazinon	300	2,150
Baygon	I	propoxur	80	>2,400
Bayluscide	Mo	niclosamide	500	
Baytex	I	fenthion	190	320
Belmark	I	fenvalerate	451	2,500
benazolin	H		> 3,000	
bendiocarb	I		179	1,000

Active Ingredients and Trade Names	Use Categories	Active Ingredients in Trade Name Products	LD_{50} for Pure Active Ingredient Oral	Dermal
Benlate	F	benomyl	> 9,600	
benomyl	F		> 9,600	
bensulide	H		770	3,950
bentazon	H		1,100	2,500
Benolin	F, I	benomyl & thiram & lindane		
Betanal	H	phenmedipham	> 8,000	> 4,000
Betanex	H	desmedipham	8,000	> 4,000
Betasan	H	bensulide	770	3,950
Bird Tanglefoot	Av	polymerized butenes		
Birlane	I	chlorfenvinphos	10	30
bis(tri-n-butyltin)oxide	WP		87	1,170
Bladex	H	cyanazine	150	> 2,000
Blightox	F	zineb	1,000	> 2,500
B-Nine	PG	daminozide	8,400	> 1,600
bone oil	AR			
boracic acid	I	boric acid	3,000	
borate	H	sodium metaborate tetrahydrate	> 2,000	
borax	H, I, WP	sodium tetraborate decahydrate	2,660	
borax anhydrous	WP			
Bordeaux mixture	F			
boric acid	I		3,000	
Botran	F	dichloran	1,500	
Bravo	F	chlorothalonil	10,000	
brodifacoum	R		0.27	50
bromacil	H		5,200	
bromadiolone	R		1.1	> 400
Bromex	I, M	naled	250	800
Brom-O-Gas	I, R	methyl bromide & chloropicrin		
Brominal	H	bromoxynil	190	
Bromone	R	bromadiolone	1.1	> 400
Bromox	H	bromoxynil & MCPA		
bromoxynil	H		190	
Buctril	H	bromoxynil & MCPA		
Busan	WP	TCMTB	1,590	> 10,000
Butoxone SB	H	2,4-DB	500	
butylate	H		4,000	> 2,000
Butyrac	H	2,4-DB	500	
Caddy	F	cadmium compounds	88-660	
Cadminate	F	cadmium compounds	88-660	
cadmium compounds	F		88-660	
calciferol	R		4	
calcium cyanide	Fum, I	hydrogen cyanide	4	
calcium polysulfide	F, M, I	lime sulphur		
Calmix	H	bromacil & 2,4-D		
Cantrol	H	MCPB	680	
capsaicin	AR			
captafol	F		2,500	
captan	F		8,400	
carbaryl	I, PG		400	> 2,000
carbathiln	F		3,200	> 8,000
carbendazim-phosphate	F		1,500	
carbofuran	I		5	1,000
carbophenothion	I, M		7	27
Carbyne	H	barban	600	> 1,600
Carzol	M	formetanate hydrochloride	15	> 10,200
Casoron	H	dichlobenil	2,700	> 1,350
CCA	WP	chromated copper arsenic	8	
CDAA	H	allidochlor	700	
chinomethionat	I, M, F		1,100	2,000

Active Ingredients and Trade Names	Use Categories	Active Ingredients in Trade Name Products	LD$_{50}$ for Pure Active Ingredient Oral	Dermal
chloramben	H		3,500	3,200
chlordane	I		283	530
chlordecone	I		95	345
chlorfenvinphos	I		10	30
chlorflurenol	PG	chloroflurecol-methyl	400	> 2,000
chlormequat	PG	670	440	
Chloro IPC	H	chlorpropham	3,800	
chlorflurecol-methyl	PG		>3,100	
chloroneb	F		>5,000	>5,000
chlorophacinone	R		20	200
4-chlorophenoxyacetic acid	PG			
chloropicrin	Fum, I, M, F, H, R, WP		0.8	
chlorothalonil	F		10,000	
Chloroxone	H	2,4-D	300	
chloroxuron	H		3,000	> 10,000
chlorpropham	H, PG		3,800	
chlorpyrifos	I		82	202
chlorsulfuron	H		5,500	
chlorthal	H		3,000	> 10,000
chromated copper arsenic	WP		8	
Ciodrin	I	crotoxyphos	74	202
CIPC	H	chlorpropham	3,800	
Clear Cuprinol	WP	zinc naphthenate	4,920	
clopyralid	H		5,000	> 2,000
CMPP	H	mecoprop	800	
coal tar creosote	WP	creosote	725	
Cobutox	H	2,4-DB	500	
Co-op DP	F, I	maneb & lindane		
Compitox	H	mecoprop	800	
Compound 1080	Pr	sodium monofluoroacetate	0.22	
Contrax-P	R	pindone	50	
copper (fixed)	F			
copper hydroxide	F	copper (fixed)		
copper naphthenate	WP		450	
copper oxychloride	F	coppers (fixed)		
copper present as triethanolamine complex	AH			
copper present as chelates of copper citrate and copper gluconate	AH			
copper-8-quinolinolate	WP		> 10,000	
copper sulphate	AH, Mo			
Coprantol	F	coppers (fixed)		
Co-Ral	I, M	coumaphos	13,860	
Cornox	H	dichlorprop	375	
coumafuryl	R	fumarin	25	
coumaphos	I, M		13	860
Counter	I	terbufos	1.6	1.1
4-CPA	PG	4-chlorophenoxyacetic acid		
creosote	WP		725	
crotoxyphos	I		74	202
Cutrine-Plus	AH	Copper present as triethanolamine complex		
cyanazine	H		150	> 2,000
cycloate	H		3,200	> 4,600
cycloheximide	F		1.8	
Cycocel	PG	chlormequat	670	440
Cygon	I, M	dimethoate	215	400
cyhexatin	M		540	> 2,000

Active Ingredients and Trade Names	Use Categories	Active Ingredients in Trade Name Products	LD50 for Pure Active Ingredient Oral	Dermal
cypermethrin	I		251	1,600
Cyprex	F	dodine	566	
Cythion	I, M	malathion	1,000	4,100
Cytrole	H, AH	amitrole	1,100	
2,4-D	H		300	
2,4-D amine	H	2,4-D	300	
2,4-D ester	H	2,4-D	620	
2,4-D butoxyethanol ester	H	2,4-D	620	
2,4-D butyric	H	2,4-DB	500	
Dacamine	H	2,4-D	300	
Daconil 2787	F	chlorothalonil	10,000	
Dacthal	H	chlorthal	3,000	> 10,000
dalapon	H, AH		3,900	
daminozide	PG		8,400	> 1,600
Dasanit	I	fensulfothion	2	4
Dawgone	AR	bone oil& oil of lemongrass & mustard oil		
dazomet	Fum, N, F, H		320	
2,4-DB	H		500	
DDT	I		113	2,150
DDVP	I	dichlorvos	25	75
Decis	I	deltamethrin	128	
Deer-Away	AR	putrescent whole egg solids		
deet	I		1,950	
deltamethrin	I		128	
demeton	I		1.7	8.2
Demosan	F	chloroneb		
Deritox	I	rotenone	132	
Des-i-cate	H	endothall	38	
desmedipham	H		8,000	> 4,000
Desormone 7	H	dichlorprop & 2,4-D		
De-Sprout V	PG	maleic hydrazide	1,400	
Detia Gas	Fum, I	aluminum phosphide	8.7	77
Detia Tablets	Fum, I	aluminum phosphide		
Detour	AR	methyl nonyl ketone	10,000	
Dexon	F	fenaminosulf	60	100
Diatox	WP	sodium pentachlorophenate	210	250
diazinon	I, M		300	2,150
20, 25 diazocholesterol	Av	azocosterol hydrochloride	470	7,800
Dibrom	I, M	naled	250	800
dicamba	H		1,000	> 2,000
dichlobenil	H		2,700	> 1,350
dichlofluanid	WP		500	
dichlone	F		1,300	
dichloran	F		1,500	
2,4-dichlorophenoxyacetic acid	H	2,4-D	300	
dichloropropenes	Fum, N, F, I, H		100	2,000
dichlorprop	H		375	
dichlorvos	I		25	75
diclofop-methyl	H		563	> 2,000
dicofol	M		575	1,000
dieldrin	I		40	60
dienochlor	M		3,160	> 3,160
difenzoquat	H		270	3,500
diflubenzuron	I		4,640	
Difolatan	F	captafol	2,500	
dimethoate	I, M		215	400
dimetilan	I		25	4,000

Active Ingredients and Trade Names	Use Categories	Active Ingredients in Trade Name Products	LD_{50} for Pure Active Ingredient Oral	Dermal
Dimilin	I	diflubenzuron	4,640	
Dinitro Amine	H	dinoseb amine	37	200
Dinitro General	H	dinoseb general	58	200
dinitrocresol	I, M, F, H	DNOC	24	200
dinocap	F		980	> 9,400
dinoseb amine	H		37	200
dinoseb general	H		58	200
Dipel	I	*Bacillus thuringiensis*		
Diphacin	R	diphacinone	2	
diphacinone	R		2	
Dipha-Tox	R	diphacinone	2	
diphenamid	H		700	
Dipterex	I	trichlorfon	450	> 2,000
diquat	H, AH		215	> 3,000
disulfoton	I		2.3	6
Di-Syston	I	disulfoton	2.3	6
Dithane Z-78	F	zineb	1,000	2,500
Dithane M-22	F	maneb	1,000	
Dithane M-45	F	mancozeb	7,500	
diuron	H		3,400	
DNOC	I, M, F, H		24	200
DNPB	H	dinoseb	37	200
dodemorph-acetate	F		2,500	
dodine	F		566	
dormant oil	I, M	mineraloils		
Dowicide	WP	pentachlorophenol	125	320
Dowpon	H, AH	dalapon	3,900	
Driamine	H	2,4-D granular	300	
2,4-DP	H	dichlorprop	375	
Drione	I	silica aerogel	3,160	
Dual	H	metolachlor	2,800	> 10,000
Dursban	I	chlorpyrifos	82	202
Durtox	I	trichlorfon	450	> 2,000
Du-ter	F	fentin hydroxide	108	5,000
Dyfonate	I	fonofos	3.4	134
Dylox	I	trichlorfon	450	> 2,000
Dyrene	F	anilazine	2,700	> 9,400
Dyvel	H	dicamba	1,000	> 2,000
Easout	F	thiophanate-methyl	7,500	> 10,000
Ectiban	I	permethrin	> 4,000	> 2,000
Elgetol	I, F	DNOC	24	200
Embutox	H	2,4-DB	500	
endosulfan	I, M		18	74
endothall	H		38	
endrin	I		3	12
Enide	H	diphenamid	700	
Enstar	I	kinoprene	5,000	9,000
Entex	I	fenthion	190	320
Envirobac	I	*Bacillus thuringiensis*		
Epibloc	R	alpha-chlorohydrin	127	
Eptam	H	EPTC	1,400	2,600
EPTC	H		1,400	2,600
Equal	F	dodine	566	
Eradicane	H	EPTC	1,400	2,600
Eramox 80W	H	atrazine	1,780	7,500
Eraze	R	warfarin& sulfaquinoxaline		
ergocalciferol	R	(see) calciferol	4	
Estakil	H	2,4-D	300	
Estakil MCPA	H	MCPA	700	
Estaprop	H	dichlorprop & 2,4-D		

Active Ingredients and Trade Names	Use Categories	Active Ingredients in Trade Name Products	LD₅₀ for Pure Active Ingredient Oral	Dermal
Estasol	H	2,4-D	300	
Estemine 500	H	2,4-D	300	
Estemine MCPA	H	MCPA	700	
Esteron	H	2,4-D	620	
ethephon	PG		4,229	5,730
ethion	I, M		13	62
ethirimol	F		4,000	
ethofumesate	H		5,650	
Ethrel	PG	ethephon	4,229	5,730
etridiazole	F		1,077	
Exotherm Termil	F	chlorothalonil	10,000	
famphur	I		36	2,730
fenaminosulf	F		100	100
fenbutatin oxide	M		2,630	> 2,000
fenitrothion	I		130	300
fenoprop	H		375	
fensulfothion	I		2	4
fenthion	I, Av		190	320
fentin hydroxide	F		108	5,000
fenvalerate	I		451	2,500
ferbam	F		1,000	
Fermate	F	ferbam	1,000	
ferrous sulfate	H			
Ficam	I	bendiocarb	179	1,000
fixed coppers	F	copper (fixed)		
flamprop-methyl	H		1,210	
Flortox	F, M, I	sulphur		
fluazifop-butyl	H		3,328	
flurecol-methyl	PG	chloroflurecol-methyl	3,100	
Folithion	I	fenitrothion	130	300
folpet	F		10,000	
fonofos	I		3.4	134
Forestamine	H	2,4-D amine	300	
For-ester	H	2,4-D ester	620	
formaldehyde	F		800	
Formalin	F	formaldehyde	800	
formetanate hydrochloride	M		15	> 10,200
Formula 40-F	H	2,4-D amine	300	
fosamine ammonium	H		10,200	> 1,680
fumarin	R		25	
Funginex	F	triforine	6,000	
Furadan	I	carbofuran	5	1,000
Fusilade	H	fluazifop-butyl	3,328	
Futura	I	*Bacillus thuringiensis*		
gamma BHC	I	lindane	88	900
Gammasan	F,H	benomyl & captan & lindane		
Gardona	I	tetrachlorvinphos	1,100	>4,000
Garlon	H	triclopyr	713	
Gastoxin	Fum, I	aluminum phosphide	8.7	77
Gesagard	H	prometryne	2,500	3,100
Giant Destroyer	R	sulphur, gaseous oxides		
gibberellic acid	PG		6,300	
Glean	H	chlorsulfuron	5,500	
Glowon	H	MSMA	700	
glyodin	F		3,200	
Glyodine	F	glyodin	3,200	
glyphosate	H		4,300	>7,900
Gopher-Cop	R	strychnine	30	
Gopher Gasser	R	sulphur, gasous oxides		
Gopher Getter	R	strychnine	30	
Gopher-Kill	R	strychnine	30	

Active Ingredients and Trade Names	Use Categories	Active Ingredients in Trade Name Products	LD$_{50}$ for Pure Active Ingredient Oral	Dermal
Gopher Poison	R	strychnine	30	
Gramoxone	H, AH	paraquat	150	236
Green Cuprinol	WP	copper naphthenate	450	
Gro-tard	PG	maleic hydrazide	1,400	
Guthion	I	azinphos-methyl	7	220
Halt	AR	capsaicin		
HCN	Fum, I	hydrogen cyanide	4	
heptachlor	I		40	195
Herbate 2,4-D	H	2,4-D	300	
Herbec 20P	H	tebuthiuron	640	
hexazinone	H		1,700	5,300
Hinder	AR	soap & ammonia		
Hoe Grass	H	diclofop-methyl	563	> 2,000
Hopper Spray	I	dimethoate	215	400
Hot Foot	Av	polymerized butenes		
Hybor D	H	borate & bromacil		
hydrogen cyanide	Fum, I		4	
Hyvar	H	bromacil	5,200	
Igran	H	terbutryn	2,500	>2,000
Imidan	I, M	phosmet	113	1,550
Insecticidal Soap	I, M	soap		
ioxynil	H		110	210
iprodione	F		3,700	
iron sulfate	H	ferrous sulphate		
isofenphos	I		28	162
Karathane	F	dinocap	980	>9,400
Karmex	H	diuron	3,400	
Kelthane	M	dicofol	575	1,000
Kepone	I	chlordecone	95	345
Kerb	H	propyzamide	5,600	
Kil-Mor	H	dicamba & mecoprop & 2,4-D		
kinoprene	I		5,000	9,000
Krenite	H	fosamine ammonium	10,200	>1,680
Krovar I	H	bromacil & diuron		
KsC5	R	chlorophacinone	20	200
KsC7	R	chlorophacinone	20	200
KsD5	R	diphacinone	2	
KsGs	R	chlorophacinone	20	200
Laddok	H	atrazine & bentazon		
Lagon	I, M	dimethoate	215	400
Lannate	I	methomyl	17	> 15,000
Lesan	F	fenaminosulf	60	100
Lexone	H	metribuzin	1,100	> 20,000
Lignosan-P	F	carbendazim-phosphate	1,500	
lime sulphur	F, M, I			
lindane	I		88	900
linuron	H		1,500	
Lontrel	H	clopyralid	5,000	> 2,000
Lorox	H	linuron	1,500	
Lorsban	I	chlorpyrifos	82	202
Magnacide	AH	acrolein	46	562
Magnetic 6	F, M, I	sulphur		
Maki	R	bromadiolone	1.1	> 400
malathion	I, M		1,000	4,100
Malazide	PG	maleic hydrazide	1,400	
maleic hydrazide	PG		1,400	
mancozeb	F		7,500	
maneb	F		1,000	
Mantox	F	maneb	1,000	
Manzate	F	maneb	1,000	
Manzate 200	F	mancozeb	7,500	

Active Ingredients and Trade Names	Use Categories	Active Ingredients in Trade Name Products	LD_{50} for Pure Active Ingredient Oral	Dermal
Marlate	I	methoxychlor	5,000	6,000
Marzone	H	atrazine	1,780	7,500
Matacil	I	aminocarb	21	275
Mataven	H	flamprop-methyl	1,210	
MB-C2	Fum, I, R	methyl bromide & chloropicrin		
MBC-phosphate	F	carbendazim-phosphate	1,500	
MCP	H	MCPA	700	
MCPA	H		700	
MCPB	H		680	
MCPB Butyric	H	MCPB	680	
MCPP	H	mecoprop	800	
MC-2	Fum, I, N, F, H, R	methyl bromide		
Mecopar	H	mecoprop	800	
Mecopex	H	mecoprop	800	
mecoprop	H		800	
Mecoturf	H	mecoprop	800	
Meltatox	F	dodemorph-acetate	2,500	
Mephanac	H	MCPA	700	
Mergamma	F,I	maneb & lindane		
Mertect	F	thiabendazole	3,100	
Mesurol	Mo	methiocarb	100	>2,000
META	Mo	metaldehyde	600	
metalaxyl	F		870	
metaldehyde	Mo		600	
metam-sodium	Fum, N, F, H, WP		820	2,000
Metasystox R	I, M	oxydemeton-methyl	47	158
methamidophos	I		19	118
methidathion	I		25	150
methiocarb	Mo		100	>2,000
methomyl	I		17	>1,500
methoprene	I		>34,000	>3,000
Meth-O-Gas	Fum, I, R	methyl bromide		
Methoxone Amine 500	H	MCPA	700	
methoxychlor	I		5,000	6,000
methyl bromide	Fum, I, N, F, H, R		21	
methyl nonyl ketone	AR		10,000	
metiram	F		6,200	
metobromuron	H		2,000	>10,200
metolachlor	H		2,800	>10,000
metribuzin	H		1,100	>20,000
mevinphos	I		3	4.2
MGK-BGR	AR	putrescent whole egg solids		
Mildex	F	dinocap	980	9,400
Milgo-E	F	ethirimol	4,000	
mineral oils	I, H			
Monitor	I	methamidophos	19	118
Monobor-Chlorate	H	sodium chlorate & borate		
monolinuron	H		2,200	
Morestan	I, M, F	chinomethionat	1,100	2,000
Mouse Bait 2	R	zinc phosphide	46	
MSMA	H		700	
mustard oil	AR			
Mylone	H	dazomet	320	
NAA	PG	naphthaleneacetic acid	5,900	
naled	I, M		250	800
naphthalene	I, AR		2,200	>2,500
naphthaleneacetamide	PG		1,000	
naphthaleneacetic acid	PG		5,900	
naptalam	H		1,700	>8,500
NaTA	H	TCA	3,200	

Active Ingredients and Trade Names	Use Categories	Active Ingredients in Trade Name Products	LD_{50} for Pure Active Ingredient Oral	Dermal
Neguvon	I	trichlorfon	450	> 2,000
Neutro-Cop	F	coppers (fixed)		
niclosamide	Mo		500	
nicotine	I		50	50
Nicotine Sulfate	I	nicotine	50	50
No	AR	methyl nonyl ketone	10,000	
No Damp	F	oxine benzoate		
Nortron	H	ethofumesate	5,650	
Novabac-3	I	*Bacillus thuringiensis*		
Novathion	I	fenitrothion	130	300
No Weed	H	MCPA	700	
Noxfish Fish Toxicant	P	rotenone	132	
nuclear polyhedrosis virus	I			
Nuodex Copper	WP	copper naphthenate	450	
Nuodex Zinc	WP	zinc naphthenate	4,920	
Off	I	deet	1,950	
oil of citronella	AR		900	
oil of lemongrass	AR			
oils	H, I	mineral oils		
Omite	M	propargite	1,350	5,000
Ornitrol	Av	azacosterol hydrochloride	470	7,800
Orthene	I	acephate	866	2,000
Orthocide	F	captan	8,400	
Orthorix	F, M, I	lime sulphur		
oxamyl	N, I		5.4	
oxine benzoate	F			
Oxine-Copper	WP	copper 8-quinolinolate	> 10,000	
oxycarboxin	F		2,000	
oxydemeton-methyl	I, M		47	158
paradichlorobenzene	I, AR		500	
paraquat	H, AH		150	236
parathion	I		3	7
Pardner	H	bromoxynil	190	
Patoran	H	metobromuron	2,000	>10,200
PCNB	F	quintozene	1,650	
PCP	WP	pentachlorophenol	125	320
pebulate	H		920	> 2,900
Penta	WP, I	pentachlorophenol	125	320
Pentac	M	dienochlor	3,160	> 3,160
pentachlorophenol	WP, I		125	320
permethrin	I		> 4,000	> 2,000
Pes-San	R	fumarin	25	
Petroleum Oils	H	mineral oils		
Petroleum Solvents	H	mineral oils		
Phaltan	F	folpet	10,000	
phenmedipham	H		> 8,000	> 4,000
phorate	I		1.1	2.5
phosalone	I, M		82	> 2,000
Phosdrin	I	mevinphos	3	4.2
phosmet	I, M		113	1,550
Phostoxin	Fum, I	aluminum phosphide		
Phygon	F	dichlone	1,300	
picloram	H		8,200	
pindone	R		50	
piperonyl butoxide	I		6,150	> 7,950
pirimicarb	I		147	> 500
Pirimor	I	pirimicarb	147	> 500
Pival	R	pindone	50	
Pivalyn	R	pindone	50	
Plantfume	I	sulfotep	5	20

Active Ingredients and Trade Names	Use Categories	Active Ingredients in Trade Name Products	LD$_{50}$ for Pure Active Ingredient	
			Oral	Dermal
Plantvax	F	oxycarboxin	2,000	
Plictran	M	cyhexatin	540	>2,000
Poast	H	sethoxydim	2,700	>5,000
Pole-Fume	WP	metam-sodium	820	2,000
Pole-Preg	WP	borax & creosote & pentachlorophenol		
polymerized butenes	Av			
Polyram	F	metiram	6,200	
Pool NM Dual	F,I	maneb & lindane		
PQ-8	WP	copper 8-quinolinolate	>10,000	
Premerge	H	dinoseb amine	37	200
Primatol A	H	atrazine	1,780	7,500
Primextra	H	atrazine & metolachlor		
Princep	H, AH	simazine	>5,000	>3,100
Prolate	I, M	phosmet	113	1,550
Prolin	R	sulfaquinoxaline & warfarin		
prometryne	H		2,500	3,100
propanil	H		1,380	>1,000
propargite	M		1,350	5,000
propoxur	I		80	>2,400
propyzamide	H		5,600	
putrescent whole egg solids	AR			
Pyramin	H	pyrazon	2,500	
pyrazon	H		2,500	
pyrethrins	I, M		200	>1,800
Quindex	WP	copper 8-quinolinolate	>10,000	
quintozene	F		1,650	
Rabon	I	tetrachlorvinphos	1,100	>4,000
Ramik Brown	R	diphacinone	2	
Ramik Green	R	diphacinone	2	
Randox	H	allidochlor	700	
Ratak	R	brodifacoum	0.27	50
Ratkil	R	diphacinone	2	
red squill	R		200	
Reglone	H, AH	diquat	215	>3,000
Repell	AR	methyl nonyl ketone	10,000	
resmethrin	I		1,100	2,400
Retard	PG	maleic hydrazide	1,400	
Rid-A-Bird	Av	fenthion	190	320
Ridomil	F	metalaxyl	670	
Ripcord	I	cypermethrin	251	1,600
Rival	H	trifluralin	3,700	>2,000
Rodent Cake	R	diphacinone	2	
Rodentkil	R	warfarin	185	
Rogor	I, M	dimethoate	215	400
Ro-Neet	H	cycloate	3,000	>4,600
Roost-no-more	Av	polymerized butenes		
rotenone	I, P		132	
Rotenone Fish Poison	P	rotenone	132	
Roundup	H	glyphosate	4,300	>7,900
Rovral	F	iprodione	3,700	
Rozol	R	chlorophacinone	20	200
Rustler	H	2,4-D amine & glyphosate		
Sabre	H	bromoxynil & MCPA		
salts of higher fatty acids	AR			
Salvo	H	2,4-D	300	
Santobrite	WP	pentachlorophenol	125	320
Scat's Off	AR	oil of lemongrass		
Scent-Off	AR	oil of lemongrass & oil of citronella		

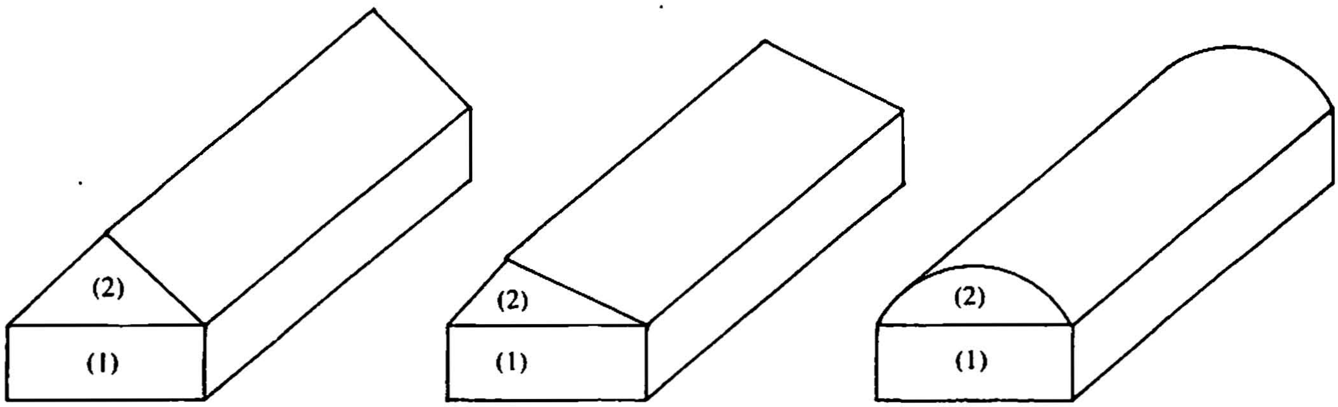
Active Ingredients and Trade Names	Use Categories	Active Ingredients in Trade Name Products	LD$_{50}$ for Pure Active Ingredient Oral	Dermal
Seedless Set	PG	4-chlorophenoxyacetic acid		
Sencor	H	metribuzin	1,100	>20,000
sethoxydim	H		2,700	>5,000
Sevin	I, PG	carbaryl	400	>2,000
Side-Kick	H	glyphosate	4,300	>7,900
siduron	H		7,500	5,500
silica aerogel	I		3,160	
Silvaprop	H	dichlorprop & 2,4-D		
Simadex	H, AH	simazine	> 5,000	> 3,100
simazine	H, AH		> 5,000	> 3,100
Sinbar	H	terbacil	> 5,000	> 5,000
Sinox	H	dinoseb	37	200
Skoot	AR	thiram	375	> 2,000
Slo-Gro	PG	maleic hydrazide		
Slug-Bait	Mo	metaldehyde	1,400	
SMDC	Fum, H	metam-sodium	820	2,000
Snip	I	dimetilan	25	4,000
soap	I, M, AR			
Sodinoc	I, M	DNOC	24	200
sodium chlorate	H		1,200	> 20,000
sodium fluoride	I, WP		75	
sodium fluoroacetate	Pr		0.22	
sodium fluorosilicate	I		125	
sodium metaborate tetrahydrate	H	borax	2,660	
sodium monofluoroacetate	Pr	sodium fluoroacetate	0.22	
sodium pentachlorophenate	WP		210	250
sodium tetraborate anhydrous	WP	borax anhydrous		
sodium tetraborate decahydrate	WP	borax	2,660	
Sorexa	R	warfarin & calciferol		
Spike	H	tebuthiuron	640	
Sprout-Nip	PG	chlorpropham	3,800	
Sprout-Stop	PG	maleic hydrazide	1,400	
Stampede	H	propanil	1,380	> 1,000
Stoddard Solvents	H	mineral oils		
streptomycin sulphate	F		9,000	
strychnine	R, Av		30	
Subdue	F	metalaxyl	670	
sulfaquinoxaline	R		1,000	
Sulfarin	R	sulfaquinoxaline & warfarin		
sulfotep	I		5	20
sulphur	F, M, I			
sulphur, gaseous oxides	R			
Sumithion	I	fenitrothion	130	30
Summer oil	I	mineral oils		
Superior oil	I	mineral oils		
Supracide	I	methidathion	25	150
Supreme oil	I, H	mineral oils		
Sure-Shot Forest amine	H	2,4-D amine	300	
Surpass	H	vernolate	1,400	4,600
Sutan	H	butylate	4,000	> 2,000
Sweep	H	paraquat	150	236
Sys-Tem	I, M	dimethoate	215	400
Systox	I	demeton	1.7	8.2
Tacky-toes	Av	polymerized butenes		
Talon	R	brodifacoum	0.27	50
Target	H	dicamba & mecoprop & 2,4-D		
TCA	H		3,200	
TCMTB	WP		1,590	> 10,000
tebuthiuron	H		640	
Tedion	M	tetradifon	566	10,000
Telone	Fum, N, F, I H	dichloropropenes	100	2,000

Active Ingredients and Trade Names	Use Categories	Active Ingredients in Trade Name Products	LD₅₀ for Pure Active Ingredient Oral	LD₅₀ for Pure Active Ingredient Dermal
temephos	I		1,000	>4,000
Temik	I, M	aldicarb	0.8	3
Tenoran	H	chloroxuron	3,000	>10,000
Ten-Ten	H	2,4-D	300	
terbacil	H		> 5,000	>5,000
terbufos	I		1.6	1.1
terbutryn	H		2,500	> 2,000
Termil	F	chlorothalonil	10,000	
Terraclor	F	quintozene	1,650	
Terraklene	H, AH	paraquat	150	236
Terr-O-Gas	Fum, I, R	methyl bromide	1	
Tersan	F	benomyl & thiram		
Tersan LSRF	F	maneb	1,000	
tetrachlorvinphos	I		1,100	> 4,000
tetradifon	M		566	10,000
tetramethrin	I		1,010	
thiabendazole	F		3,100	
Thimet	I	phorate	1.1	2.5
Thiodan	I, M	endosulfan	18	74
Thiogreen	F	zineb	1,000	> 2,500
thiophanate-methyl	F		7,500	> 10,000
Thiralin	F,I	benomyl & thiram & lindane		
thiram	F, AR, R		375	> 2,000
Thitrol	H	MCPB	680	
Thuricide	I	*Bacillus thuringiensis*		
Tiguvon	I	fenthion	190	320
Tillam	H	pebulate	920	> 2,900
Timber Fume	Fum, I, WP	chloropicrin	0.8	
Torch	H	bromoxynil	190	
Tordon	H	picloram	8,200	
Torque	M	fenbutatin oxide	2,630	> 2,000
Totril	H	ioxynil	110	210
Treflan	H	trifluralin	3,700	> 2,000
Tre-Hold	PG	naphthaleneacetic acid	5,900	
triallate	H		675	
tribasic copper sulfate	F	coppers (fixed)		
trichlorfon	I		450	>2,000
triclopyr	H	Garlon	713	
Tri-Cop	F	coppers (fixed)		
trifluralin	H		3,700	>2,000
triforine	F		6,000	
Trithion	I, M	carbophenothion	7	27
Tropotox	H	MCPB	680	
Truban	F	etridiazole	1,077	
Tupersan	H,	siduron	7,500	5,500
Ureabor	H	bromacil & sodium chlorate & sodium metaborate tetrahydrate		
Vapam	Fum, I, N, F, H	metam-sodium	870	2,000
Vapona	I	dichlorvos	25	75
Vectal Atrazine	H	atrazine	1,780	7,500
Vectobac	I	*Bacillus thuringiensis israeliensis*		
Vegiben	H	chloramben	3,500	3,200
Velpar	H	hexazinone	1,700	5,300
Vendex	M	fenbutatin oxide	2,630	>2,000
vernolate	H		1,400	
Verton	H	2,4-D	300	
Virtuss	I	nuclear polyhedrosis virus		
Vision	H	glyphosate	4,300	>7,900
Vitaflo 250	F	carbathiin	3,200	>8,000
Vitaflo DP	F,I	carbathiin & thiram & lindane		
Vitavax	F,I	carbathiin & thiram & lindane		

Active Ingredients and Trade Names	Use Categories	Active Ingredients in Trade Name Products	LD_{50} for Pure Active Ingredient Oral	Dermal
Volck oil	I	mineral oils		
Vorlex	Fum, N, F, I, H	dichloropropenes	100	2,000
Vydate	N, I	oxamyl	5.4	
Waco Bird Repellent	Av	polymerized butenes		
Warbex	I	famphur	36	2,730
warfarin	R		185	
Weedar	H	2,4-D	300	
Weedar MCPA	H	MCPA	700	
Weedaway	H	2,4-D	300	
Weedaway MCPA	H	MCPA	700	
Weed-B-Gone	H	2,4-D	300	
Weedex	H	2,4-D	300	
Weedone	H	2,4-D	300	
Weedone MCPA	H	MCPA	700	
Weed-Rhap	H	2,4-D	300	
Weedrite	H	paraquat & diquat		
Woodbrite	WP	sodium pentachlorophenate	210	250
Woodchuck Bombs	R	sulphur gaseous oxides		
Woodfume	WP	metam sodium	820	2,000
Woodsheath	WP	sodium pentachlorophenate	210	250
Wypout	H	barban	600	>1,600
zinc naphthenate	WP		4,920	
zinc phosphide	R		46	
zinc sulfate	H	(see) ferrous sulphate		
zineb	F		1,000	>2,500
ziram	F		1,400	
Zolone	I, M	phosalone	82	>2,000
Z-P	R	zinc phosphide	46	
Z-Phos	R	zinc phosphide	46	

APPENDIX IV: VOLUME CALCULATIONS FOR FUMIGATION WORK

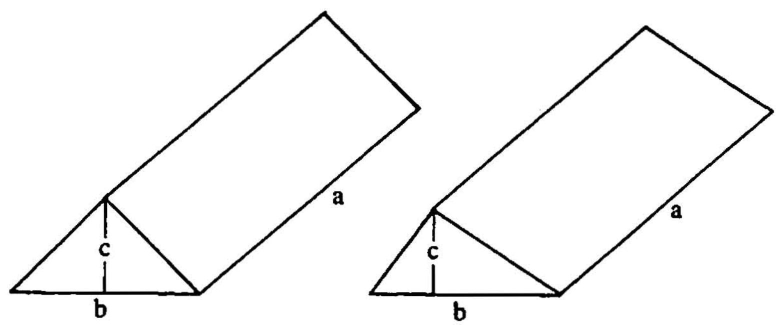
In practice, structures of various shapes and sizes must be calculated for cubic contents to establish the amount of fumigant needed. Usually one, two or more volume calculations must be made of several parts of the structure, due to the various shapes, and the cubic contents of the several parts are then added to establish the total cubic contents. For example: the total cubic contents of the following buildings is the sum of the cubic contents of part (1) and part (2).



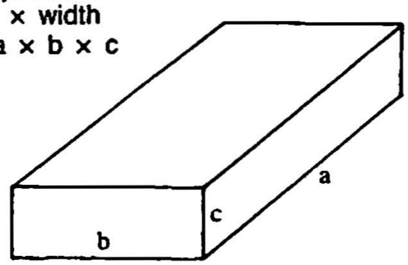
Even Span Uneven Span Quonset

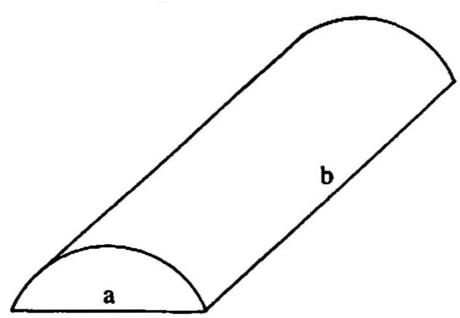
Measurements are made in metres to obtain m³. Calculate the cubic contents of the various parts as follows:

Even or Uneven Span
Multiply length × width × height and divide by 2, i.e. a × b × c/2 in illustration.



Rectangular Spaces
Multiply length × width × height, i.e. a × b × c in illustration.





Quonset Structures
Multiply $\pi \times (1/2 \text{ width})^2 \times 1/2 \times$ length,
i.e. $\frac{22}{7} \times \frac{a}{2} \times \frac{a}{2} \times \frac{1}{2} \times \frac{b}{1}$ in illustration

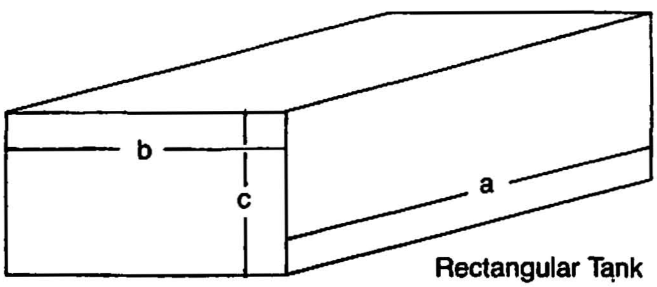
APPENDIX V: SPRAY TANK CAPACITY CALCULATIONS

Spray tanks come in many shapes and sizes. For proper mixing it is important to know the volume capacity of your spray tank.

TANK CAPACITY MAY BE CALCULATED AS FOLLOWS:

Rectangular Tanks: multiply length × width × height, i.e. a × b × c in illustration. Measure a, b and c in centimetres and use the following formula to obtain capacity in litres:

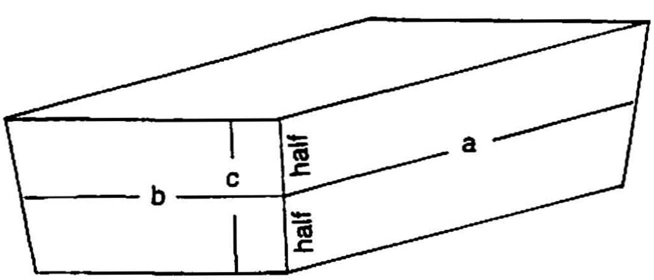
$$\frac{a \times b \times c}{1{,}000} = \text{litres}$$



Rectangular Tank

Tapered Tanks: multiply average length × average width × height, i.e. a × b × c in illustration. Measure a, b and c in centimetres and then use the same formula as used for rectangular tanks to obtain capacity in litres.

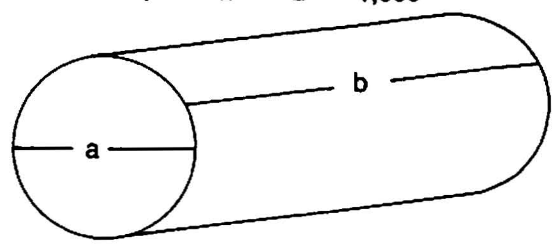
$$\frac{a \times b \times c}{1{,}000} = \text{litres}$$



Tapered Tank

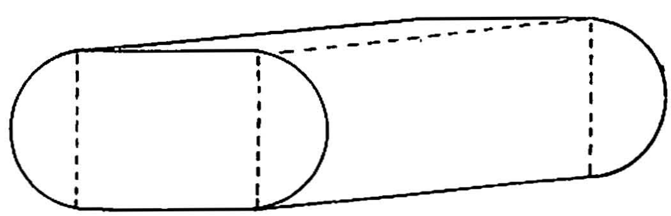
Cylindrical Tanks: multiply π × ½ diameter × ½ diameter × length, i.e. π × ½a × ½a × b in illustration. Measure a and b in centimetres and use the following formula to obtain capacity in litres:

$$\frac{22}{7} \times \frac{a}{2} \times \frac{a}{2} \times \frac{b}{1{,}000} = \text{litres}$$



Cylindrical Tank

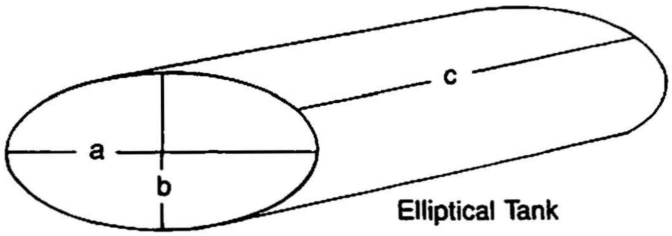
Flat Elliptical Tanks: treat the flat area the same as Rectangular Tanks and the rounded sides as a Cylindrical Tank as shown in the illustration.



Flat Elliptical Tank

Elliptical Tanks: multiply $\pi \times \frac{1}{2}$ long diameter $\times \frac{1}{2}$ short diameter $\times$ length, i.e. $\pi \times \frac{1}{2}a \times \frac{1}{2}b \times c$ in illustration. Measure a, b and c in centimetres and use the following formula to obtain capacity in litres:

$$\frac{22}{7} \times \frac{a}{2} \times \frac{b}{2} \times \frac{c}{1,000} = \text{litres}$$



Elliptical Tank

Volume of Partly Filled Spray Tanks

Once the volume capacity of the spray tank has been established, marking the tank for different volume levels is the next important step. Many smaller sprayers are already marked by the manufacturer. Unfortunately this is not the case with most spray tanks larger than about 100 L. Some pesticide application jobs do not require a full tank, other times left over spray mixtures pose a problem if the volume is not known. Marking the spray tank for different volume levels is a necessary step to accurately calculate mixing ratios for part tank mixes. Depending on the spray tank size, volume level-marks may be made for each litre, 5 litres, 10 litres, etc. A popular method is to attach a transparent plastic hose vertically on the side of the spray tank with the top and bottom connected to the inside of the spray tank. The fluid level will show in the hose and graduation marks may be put on the hose. The spray tank may now be filled with a measured container while marking the hose for each measured volume emptied in the spray tank. A MAJOR DRAWBACK OF THIS METHOD IS THE NEED FOR THE TANK TO BE IN GOOD LEVEL POSITION at the time the graduation marks are put on the hose, and each time a reading is taken in the future. A better and more accurate method is the use of a dipstick, marked in the same manner as the transparent hose and held vertically in the centre of the spray tank. The spray tank no longer needs to be dead level to obtain accurate readings. Filling holes on spray tanks should preferably be above the centre of the tank, as this is the best location to prevent pesticide spills. If a spray tank does not have the filling hole at the centre, a fitting can easily be installed to accommodate the dipstick.

GLOSSARY OF PEST CONTROL TERMS

abrasive — something that grinds down or wears away an object, e.g. wettable powders are abrasive to pumps and nozzles.

abscission — the formation of a layer of cells which causes the fruit, leaf or stem to fall off the plant.

absorption — movement of a pesticide from the surface into a body.

acaricide — a compound used to control mites and ticks, e.g. a miticide.

acetylcholine — a chemical conductor of a nervous impulse formed at the ends of nerves, to conduct the impulse over the microscopic gap between nerves or between nerve and muscle or gland. As soon as the response is given it is destroyed by an enzyme: cholinesterase.

acid equivalent (a.e.) — the amount of active ingredient in a formulation expressed in terms of the acid from which it was formulated.

activated charcoal — a finely-ground form of charcoal which absorbs most pesticide liquids and vapours.

active ingredient (a.i.) — the portion of a pesticide formulation which is the actual toxicant.

acute toxic effect — an adverse effect on a human or animal body which develops rapidly and quickly reaches a conclusion.

acute toxicity — the potential for an ingredient to cause ill health or death within a few hours to a few days after a single dose or exposure.

adhesive — a substance that will cause a pesticide spray to stick to the sprayed surface, e.g. a sticking agent.

adjuvant — a substance added to a pesticide to improve the pesticide's physical qualities, hence its effectiveness, e.g. wetting or spreading agents, stickers, penetrants, emulsifiers, and synergists.

adsorption — the adherence of a pesticide to the surface of a plant or soil particle.

adult — a fully grown, sexually mature, insect, mite, nematode or other animal. The adult stage is often related to dispersal and the beginning of a new colony or infestation.

adulticide — a pesticide directed at the adult stage of a species.

aerobic — living in air. The opposite of anaerobic.

aerosol (pressurized can) — a small amount of pesticide or combination of pesticides that is driven through a fine opening (orifice) by an inactive gas under pressure (propellant) when the nozzle is triggered, producing an extremely fine dispersion, spray, mist or fog of very tiny solid particles or droplets suspended in the air.

agitate — the movement of a liquid pesticide to keep the chemical contents mixed so as to prevent them from separating or settling in the spray tank.

air blast sprayer — a machine which can deliver high and low volumes of spray, propelled by air and used for orchards, shade trees, vegetables, and fly control.

air gap — the physical separation of a drinking water system from a contaminated system by a vertical air space.

algae — one-celled or multicelled photosynthetic nonvascular plants (without true roots, stems or leaves).

algicide — a pesticide used to control algae.

alkali — a substance which dissolves in water to form an alkaline solution, e.g. sodium hydroxide (lye).

alkaloids — natural organic bases found in plants, each having a specific physiological action. Most are crystalline solids, some are liquids, a few are gums. They are used in preparing the botanically-derived insecticides.

anaerobic — living where there is no air (or free oxygen). The opposite of aerobic.

annual — a plant that germinates from seed, produces seed, and dies in one year.

antibiotics — chemicals produced by microorganisms, or synthetically produced by man, which kill or inhibit growth of other competing microorganisms.

anticoagulants — a substance which prevents normal blood clotting. A poisoned animal bleeds internally, causing death, e.g. from ingestion of warfarin.

antidote — a substance used to counteract the effect of a poison.

apiary — collection of beehives kept for honey production and/or pollination.

application rate — the amount of pesticide product or active ingredient applied to a unit area.

aquatic plant — a plant that grows in water. There are three kinds: immersed, which grow beneath the surface; emergent, which root below but extend above the surface, e.g. cattails and water lilies; and floaters, e.g. water hyacinths.

aquatic weed — an aquatic plant growing where it is not wanted.

aqueous — a term used to indicate the presence of water in a solution.

aromatic solvents — derivatives of benzene having strong and rather pleasant odours. They penetrate the skin and may be dangerous to breathe, e.g. toluene, xylene, phenol and cresol.

attractant — a chemical that lures pests to a selected location where they may be destroyed, sterilized or trapped.

avicides — a pesticide or mixture of pesticides intended for bird control.

back siphonage — reversal of normal flow in a water supply system caused by negative pressure in the supply piping.

bacteria — one-celled microorganisms, some of which cause diseases in plants or animals. They can be seen with a microscope.

bactericide — a pesticide used to control bacteria.

bait — a food or other material which will attract a pest to a pesticide or to a trap where it may be killed or trapped.

bait shyness — the tendency of rodents, birds or other pests to avoid a poisoned bait.

band or row application — an application to separate bands such as to crop rows or between crop rows, rather than broadcast over the entire field area.

basal treatment — an application of a pesticide to the stems of plants above the groundline to a short distance up the stem.

beneficial — useful or helpful to people (as in 'a beneficial insect', e.g. an insect which feeds on aphids).

biennial — a plant that completes its life cycle in two years. The first year the seed germinates and the plant produces leaves and roots and stores food. The second year it produces flowers, fruit and seed, e.g. wild carrot, common mullein, bull thistle and burdock.

biological control — the use of living things such as predators, parasites, or disease organisms to control pests.

biomagnification — an increasing concentration of a chemical or substance through the trophic levels of a food chain.

bird repellent — a pesticide which repels birds, or discourages them from roosting or feeding.

blight — a general term used to describe symptoms of plant disease which may include spotting, sudden wilting or death of leaves, flowers, stems or the entire plant.

boom — a section of pipe (or tubing) which connects several nozzles so that a pesticide can be applied over a wider area.

botanical pesticide — naturally-occurring compounds which are derived from plant parts and are toxic to pests, e.g. pyrethrum. Synthetic botanical pesticides are man-made pesticides which are similar to those found in nature, e.g. allethrin.

broadcast application — an application of chemical over an entire area or field rather than only on rows, beds or individual plants.

broadleaved plants — most herbs, shrubs and trees having wide leaves. Not grasses or grasslike, nor coniferous plants.

broad spectrum pesticide — a pesticide that controls or is toxic to a wide range of pests when applied correctly. Same as nonselective.

brush control — control of woody plants.

bud spray — a pesticide applied to deciduous fruit trees between the time the first colour appears in the buds until the first blossoms begin to open. This is also known as a pink bud spray.

buffer zone — see pesticide buffer zone.

buildup — accumulation of a pesticide in soil, animals or in the food chain.

calibrate — (1) to determine the amount of pesticide being applied through a nozzle of a sprayer, duster or granular applicator over a given area; (2) to mark a container or tank to indicate the volume at certain levels.

calyx — the outer part of a flower which covers the buds. Fragments of the calyx may be seen on some fruits, e.g. on apples, opposite the stem end.

canister — a metal or plastic container filled with absorbent materials which filter fumes and vapours from the air before they are breathed in by an applicator.

carbamates — organic pesticides, esters of carbamic acids.

carcinogenic — capable of producing cancer.

carrier — an inert material mixed with active ingredients to make a pesticide formulation, e.g. finely ground clay, talc, volcanic ashes, water, oil, solvent, air and gas propellants.

cartridge — the part of the respirator which absorbs fumes and vapours from the air before the applicator breathes them in.

caterpillar — generally the larval (3rd) stage of moths and butterflies (Lepidoptera), also the larvae of some sawflies (Hymenoptera).

causal organism — the organism that produces a specific disease.

certified pesticide applicator — an individual who is certified by the Pesticide Control Branch through examination to use or supervise the use of pesticides in a specific category of pest control.

certified pesticide dispenser — an individual who is certified by the Pesticide Control Branch through examination to sell pesticides.

chemosterilant — a chemical that controls pests by destroying their ability to reproduce.

chlorinated hydrocarbon — see organochlorines.

chlorophyll — the green compound found in leaves and other green plant parts. It is the means by which the plant converts carbon dioxide in air and water into food through the energy of sunlight in a process called photosynthesis.

chlorosis — the yellowing of a plant's green tissue due to a breakdown of the chlorophyll or its failure to develop.

cholinesterase — a body enzyme (chemical catalyst) found in animals and humans that destroys acetylcholine after conducting a nerve impulse. Cholinesterase is necessary for the proper functioning of the nervous system. Organophosphorus compounds or carbamates, which enter the body by any path or in any fashion, are cholinesterase inhibitors. See acetylcholine.

chronic toxic effect — an adverse effect on a human or animal body which develops slowly or occurs a long time after exposure and lasts for a long time, i.e. years.

chronic toxicity — the potential for an ingredient to cause adverse effects which develop slowly or occur a long time after exposure and last for a long time, i.e. years.

compatible — materials in a spray or dust mixture are compatible if one does not reduce the effectiveness of the other and if crop injury does not result from the use of the combination.

complete metamorphosis — the process of insect development which includes the egg, larva, pupa and adult stages.

concentrate — opposite of dilute. Concentrated formulations are diluted with water or oil before use.

concentration — refers to the weight of active ingredient in a given weight or volume of a formulation.

conifer — a tree that bears its seeds in cones such as a pine tree.

conifer release — the removal of woody or brush species in a stand of coniferous trees to decrease competition for water, nutrients, light and space, and thus increase the growth rate of the conifers.

contact herbicide — a herbicide that kills plant tissue by direct contact rather than as a result of translocation.

contact insecticide — a compound that causes the death of an insect when it touches its external parts, it need not be swallowed to be effective.

contaminate — to alter or to render a material or food unfit for a specified use by the introduction of a chemical.

corrosive poison — a pesticide that contains a strong acid or base which will severely burn the skin, mouth, stomach, etc.

coverage — the degree of uniformity of a pesticide application over a surface.

crop — useful plants growing where desired.

crop tolerance — the ability of a crop to be treated by a pesticide but not be injured.

crown — the point where stem and root join in a seed plant.

crucifers (Cruciferae) — belonging to the mustard family, including cabbage, turnips, radish and broccoli.

cucurbits (Cucurbitaceae) — the plant family that includes cucumbers, melons, marrows and squash.

cumulative effect — the result of some pesticides which build up or are stored in the body so that small amounts eaten or contacted over a period of time can sicken or kill an animal or person, e.g.anticoagulant rodenticides, mercury compounds, thallium sulphate and DDT.

cutin — the fatty material that forms the cuticle, or waxy layer, covering the leaf of a plant.

days to harvest — the minimum number of days, established by law, between the final pesticide application and the harvest date, also called preharvest interval.

deciduous — plants which lose their leaves during the dormant winter season (leaf loss may also be induced by drought, etc.).

defoliant — a pesticide that causes plant leaves to drop off, the action may be herbicidal. Some defoliants are also used to assist in harvesting.

deflocculating agent — a substance that disperses a material so as to prevent rapid settling out of the spray solution in the spray tank.

degradation — the process by which a complex chemical is reduced into a less complex form. This process can be the result of the action of microbes, water, air, sunlight or other agents.

dermal toxicity — the degree of toxicity of a compound when it is absorbed through the skin of mammals.

desiccant — a chemical that hastens the drying of plant or animal tissues, i.e. plant desiccants used to make harvesting easier by causing defoliation, also insect desiccants which kill insects by dehydration.

desiccation — drying up of tissue, induced chemically or caused by natural phenomena.

detergent — any liquid normally used as a cleansing substance. Some may also be used as wetting agents due to their ability to reduce the surface tension of water droplets.

detoxify — to make harmless; to take out, take away or neutralize a poison; to remove a poisonous effect.

dicot (Dicotyledon) — a plant that has two seed leaves or cotyledons. Generally includes the broadleaved plants.

diluent — any liquid or solid material used to weaken (dilute) or carry an active ingredient.

dilute — to make a pesticide concentration thinner or weaker by adding water, oil or solids (dusts).

dinitrophenols — substituted phenol compounds containing NO_2.Highly toxic pesticides.

directed application — of a spray or dust to a restricted area such as rows or beds or the base of plants and spot spraying. Such an aplication is useful where weeds can be contacted without getting the spray or dust onto the crop plant.

disease — an abnormal condition of an organism resulting from an infectious (parasitic) or noninfectious (nonparasitic) agent.

dispersing agent — a substance that reduces the attraction between like particles: to break up.

dissolve — usually refers to getting solids into solutions.

dormancy — associated with the temporary suspension of visible plant growth, usually during the winter. Dormancy may be triggered by cold temperatures and/or short daylight hours.

dormant spray — a pesticide spray applied when plants are inactive, during the winter and early spring.

dose — the amount of active ingredient (not formulated product) which is applied to an area or other target.

drift — the movement of pesticide droplets or dust, by wind or air currents, away from the target area onto areas not being treated. Drift constitutes one of the major hazards of pesticide application.

dust — a finely divided carrier (diluent) containing an active ingredient, usually of low concentration, to be used without dilution.

ecology — the science that deals with the relationships of organisms with each other and their environment.

ectoparasite — an external parasite, e.g. bedbug, flea.

ecosystem — a community of organisms interacting with one another and the specific habitat (environment) in which they live.

efficacy — a term used in pest control to mean the degree to which a pesticide or procedure will control a specified target pest.

emergence — the action of a young plant breaking through the surface of the ground or of an insect coming out of an egg or pupa.

emulsifiable concentrate — a liquid pesticide consisting of an active ingredient, a solvent, and an emulsifier that mixes with water to form an emulsion.

emulsifying agent — a material which helps to suspend one liquid in another, such as oil in water. Emulsifier is synonymous.

emulsion — a mixture of two or more immiscible liquids, such as oil and water, where one is suspended or dispersed in the other in the form of very minute droplets and remains suspended or dispersed for a period of time through the use (addition) of an emulsifier.

encephalitis — inflammation of the brain. Virus-caused encephalitis, transmitted by mosquitoes, can affect man and horses.

endemic — a disease or organism which is always present but never increasing.

entomology — the science of the study of insects.

environment — the surroundings, including water, air, soil, plants and animals.

enzyme — an organic substance that regulates the rate of a reaction but which itself remains chemically unchanged.

epidemic — a sudden widespread increase in the incidence of a disease or organism, opposite of endemic.

epidermis — the outer cellular tissue of a plant or animal.

epinasty — twisting or curling of leaves and stems caused by uneven growth of cells. This reaction results from treatment with 2,4-D and other plant-growth regulators.

eradication — complete elimination of a living organism from a specific area.

ester — a hydrocarbon substance derived from the action of an alcohol and an acid; usually a liquid with a pleasant odour.

evaporation — the process of a solid or liquid turning to a gas and disappearing into the air.

exoskeleton — the segmented exterior skeleton of an insect; the insect's "skin".

exposure — when contact occurs with a pesticide orally, dermally, or through inhalation.

face shield — a transparent piece of protective equipment used by a pesticide applicator to protect the face from exposure.

flashpoint — the lowest temperature at which a liquid or solid material gives off vapour which, if combined with air, produces a flammable gas.

flowable or sprayable suspension — pesticide formulation which consists of a thick suspension of finely ground particles. The formulation is diluted with water and the spray mix should be kept well agitated.

foaming agent — a material which causes the pesticide mixture to form a thick foam, it is used to reduce drift.

fogger — an aerosol generator; pesticide applicator that breaks special pesticides into very fine droplets, and blows or allows the resulting "fog" to drift onto the target area.

foliage — the leaves, needles and blades of plants and grasses.

foliar application — spraying a pesticide onto the leaves, needles and blades of grasses, plants, shrubs or trees.

Food and Drugs Act — a Federal Act which ensures that food sold in Canada does not contain a harmful amount of any contaminant, pesticidal or otherwise.

formulation — a mixture of active ingredient with carriers, diluents or other materials, to make it safe and easy to store, transport, dilute and/or apply.

formulator — one who combines active ingredient with solvents, diluents, or other suitable substances to produce pesticides packaged, labelled, and ready for use or further dilution prior to application.

fry — young, recently hatched fish.

fume — a smoke, gas or vapour.

fumigant — chemicals used in the form of volatile liquids or gases to kill inscts, nematodes, fungi, bacteria, seeds, roots, rhizomes or entire plants. Usually applied in an enclosure of some kind or restricted to a zone below the soil surface by covering with a tarp or plastic sheet, or layer of water.

fumigation — the use of chemicals in gaseous form to destroy pests. Fumigation may be carried out in storage areas, under tents in the field, or by direct application to the soil and covering with a tarpaulin.

fungi — groups of small, often microscopic, plant organisms which cause rots, moulds and plant diseases; they lack chlorophyll (green colouring). Fungi grow from microscopic-size spores and produce tiny threadlike growths. Some fungi can cause the deterioration of structures (singular: fungus).

fungicide — a pesticide used to control fungi and other parasitic plant diseases.

gas mask — a type of respirator which covers the entire face and protects the eyes as well as the nose and mouth. It filters and cleans the air better than cartridge respirators, and is less likely to leak around the edges. A gas mask is effective against air which contains concentrations of sprays, dusts or gases not immediately dangerous to human health.

germination — the beginning of vegetative growth, usually refers to the beginning of growth from seed.

granular — a pesticide formulation in the form of relatively coarse particles which are applied dry with a spreader, seeder or special applicator.

growth regulator — a chemical which when applied in small amounts to plant leaves, stems, roots, or to an insect, alters the growth and behavior of the plant or insect.

grub — the larval stage of some beetles.

habitat — a particular environment in which organisms live.

hack and squirt — a method of applying a herbicide selectively to a cut made with an axe. This may be done with an axe which injects a measured amount of herbicide with each cut (hypohatchet).

halide detector — a device for detecting the presence of certain odourless, or nearly odourless, gases such as methyl bromide. The usual type has a propane flame that changes colour in the presence of the gas.

hard water — water which contains certain minerals, usually calcium and magnesium sulfate, chlorides, or carbonates in the solution so that a curd or precipitate occurs rather than a lather when soap is added. Very hard water may cause objectionable precipitates in some herbicidal sprays.

herbaceous — a plant that remains soft or succulent and does not develop woody tissue.

herbicide — a pesticide used to control or manage weeds.

hormone — a growth regulating substance occurring naturally in plants or animals. Also used with reference to certain man-made or synthetic chemicals which regulate growth activity.

host — the living plant or animal a pest depends on for survival.

humidity — refers to moisture or dampness in the air. Herbicides are often comparatively more effective under moderately warm, humid conditions. In areas or at times when humidity is very low, high herbicidal rates or high volumes of diluent may be required because sprays dry more quickly and absorption is poor.

hydraulic agitator — a device which keeps the pesticide formulation in the tank well mixed by returning some of the spray from the pump back to the spray tank.

hydraulic sprayer — a machine which delivers high volumes of pesticide spray in a range of pressures to the target. Used for crops, fruit trees, shade trees and ornamentals.

hydrocarbon — a chemical compound composed of carbon and hydrogen.

hydrogen-ion concentration — a measure of acidity or alkalinity, expressed in terms of the pH of the solution. For example, a pH of 7 is neutral, from 1 to 6 is acid, and from 8 to 14 is alkaline.

hydrolyze — to decompose or break down by the addition of the elements of water.

hygroscopic — readily absorbing and retaining moisture, usually from the air.

hypohatchet — a specially designed axe which injects a measured amount of herbicide into a tree with each cut.

incompatible — cannot be mixed or used together. When two or more pesticides that are not compatible are mixed together, one or more may precipitate from the mixture, or the effectiveness of one or more may be reduced, or injury to plants or animals may result.

inert ingredient — any ingredient in a formulation which does not produce a toxic effect when a pesticide is applied.

infection — the establishment and development of a pathogen (e.g.a bacterium) in its host, which will produce a parasitic or infectious disease.

infestation — pests that are found in an area or location where they are not wanted.

ingestion — to swallow into the digestive system.

inhalation — to breathe air into the lungs.

inhibit — to hold in check or stop, e.g.to inhibit or check seed germination or plant growth with herbicides.

inorganic chemical — a chemical that does not contain carbon.

insect — adults are characterized by having the body divided into three regions: head, thorax and abdomen; and the thorax divided into three segments, each bearing a pair of segmented legs.

insecticide — a pesticide used to control or manage insects.

instar — one step or stage in the development of nymphal or larval insects.

integrated control — the use of more than one approach to or method of pest control, including cultural practices, natural enemies and selective pesticides.

invertebrate — any animal without a bony spinal column, e.g.insects, molluscs.

invert emulsion — one in which the water is dispersed in oil rather than oil in water. Oil forms the continuous phase with the water dispersed therein, usually a thick mayonnaise-like mixture results.

larva — the growing, wormlike stage of insects which go through complete metamorphosis. Many insects cause most or all of their damage as larvae (plural of larva), e.g. caterpillars.

larvicide — a pesticide used to kill the larval stage of insects.

lateral movement — chemical movement in a plant or a soil to the side, or horizontal movement in the roots or soil layers.

LC_{50} (lethal concentration to 50% of a population, median lethal concentration) — a statistic used to indicate degree of toxicity. It is normally expressed in weight per volume as the ppm (parts per million) of a pesticide in the air or water sufficient to kill half of the test animals exposed for a predetermined period of time, usually 96 hours. The lower the LC_{50} value, the more toxic is the pesticide.

LD_{50} (lethal dose to 50%) — a statistic used to indicate degree of toxicity. It is expressed as the number of milligrams of a toxicant per kilogram or body weight of an animal, sufficient to kill 50 per cent of such animals.

leaching — refers to the movement of chemicals through a soil by water.

lethal — fatal or deadly.

life-cycle — the progression of stages in the life development of an organism.

looper — larval (3rd) stage of some Lepidoptera, usually Geometrids, which have some of their abdominal legs missing causing the back to arch in a loop when moving. Loopers are further characterized by fast backward movement when touched.

low volume air sprayer — a machine similar to an air blast sprayer, but with somewhat lower water volume and higher air velocity, which produces extremely fine droplets. Same as a mist blower.

maggot — larval stage of many flies and midges (Diptera), 3rd stage of complete metamorphosis. Maggots are legless.

mammals — warm-blooded animals that nourish their young with milk; their skin is more or less covered with hair.

maximum dosage — the largest amount of a pesticide that can be used safely, without excess residues or damage occurring to the host organism to be protected or cured.

mechanical agitation — the stirring, paddling, or swirling action of a device which keeps a pesticide and any additives thoroughly mixed in a spray tank.

median lethal concentration — LC_{50}. The concentration of a pesticide in air or water which is lethal to 50% of the population of a species. It is expressed in mg/L.

metabolism — the sum total of life processes in living organisms.

metabolite — a compound inside a plant resulting from the breakdown of a pesticide by the plant itself, sometimes more toxic than the parent pesticide.

metamorphosis — any change in form or structure of an insect during the growing period. Complete metamorphosis: four stage development of an insect consisting of an egg, larva, pupa, and adult.

methyl — a basic building block of most organic compounds consisting of three hydrogen atoms attached to one carbon atom, e.g.

  H
H-C-OH = methyl alcohol, a blinding poison.
  H

microbe — an organism of extremely small size, e.g. bacteria, fungi, and viruses.

microbial pesticide — a pesticide whose "active ingredient" is a bacteria, virus, or other microscopic plant or animal, e.g. *Bacillus thuringiensis* (a bacterium).

miscible — capable of being mixed. Usually refers to liquids, e.g. water with alcohol.

mites — small to minute animals having eight legs in the adult stage. There are harmful and beneficial species. Closely related to spiders.

miticide — a pesticide used to control or manage mites.

mitotic poison - a poison which interferes with cell division.

mode of action — the ways in which a pesticide affects a living organism, e.g. disrupts the nervous system, inhibits cell division, etc.

mould — a fungus-caused growth, often found in damp or decaying areas or on living things.

molecule — the smallest unit of matter that has the chemical characteristics of the mass.

molluscicide — a pesticide used to control snails and slugs (molluscs).

monocot (Monocotyledon) — a seed plant having a single cotyledon or seed leaf, includes corn, grasses, lilies, orchids, and palms. Leaves are mostly parallel veined.

mutagenic — capable of inducing genetic changes which produce offspring that have different characteristics from their parents.

mycoplasmas — organisms recently discovered to be the cause of many plant diseases formerly attributed to viruses; organisms smaller than bacteria and larger than viruses, e.g. aster yellows.

narrowleaved plants — those plants having narrow leaves and parallel veins.

natural enemies — the predators and parasites in the environment which attack pest species.

necrosis — death of plant tissue.

nematicide — a pesticide used to control nematodes.

nematodes — miscroscopic roundworms (thread worms, eelworms) which may do considerable crop damage. Nematodes may be animal or plant parasites, some are free living. Generally found in the soil feeding on plant root systems. Not all nematodes are harmful.

nocturnal — active at night or in the dark.

nonparasitic plant disease — plant disease which is not caused by a parasite. May be caused by nutrient deficiencies, lack of water, poor climate, etc. Subsequent parasitic plant disease and insect attack often results. Synonymous: noninfectious plant disease.

nonpersistent pesticide — a pesticide that breaks down almost immediately, or only lasts for a few weeks or less, and turns into nontoxic breakdown products.

nonselective pesticide — a pesticide that is toxic to a wide range of pests, or toxic to more than one plant or animal, e.g. a nonselective herbicide is one which kills all plant species.

nontarget organism — any plant or animal organism which is not the object of a pesticide application.

nonvolatile — a liquid or solid that does not turn into a gas or vapour.

noxious weed — a weed defined by law as being particularly undesirable, troublesome, or difficult to control. Control is mandatory under the provincial Weed Control Act, administered by the Ministry of Agriculture and Fisheries.

nozzles — devices which control droplet size, application rate and uniformity of a pesticide application. The nozzle type determines the ground pattern of coverage, e.g. tapered flat spray, even flat spray, flooding, off centre, atomizing, broadcast, solid stream, full cone and hollow cone nozzles.

nutrient (plant) — a chemical element taken into the plant that is essential to its development.

nymph — the immature stages of insects such as plant bugs, aphids, and grasshoppers which undergo incomplete metamorphosis.

oral toxicity — the degree of toxicity of a compound when it is ingested or swallowed.

organic chemical — a chemical compound containing carbon. Many organic compounds occur in nature while others are produced by man through chemical synthesis.

organochlorines — organic chemicals containing chlorine, e.g. DDT or dieldrin.

organomercury compounds — organic compounds which contain mercury. Highly toxic and cumulative poisons. No longer used in B.C. as pesticides. Environmental pollutants.

organophosphorous pesticides — synthetic organic pesticides which contain carbon, hydrogen, and phosphorus. Act by inhibiting a chemical in the body called cholinesterase. As a rule, organophosphorous compounds are less persistent than the organochlorines.

orifice — the opening or hole in a nozzle through which a liquid is forced out and broken up into a spray. The size of the orifice controls the volume, while the shape of the orifice controls the spray pattern.

ornamentals — plants which are used to beautify homes, gardens and lawns; included are trees, shrubs and flowers.

ovicide — a pesticide used to control eggs, particularly insect, mite or nematode eggs.

parasite — an organism that lives in or on the body of another organism and obtains nourishment from it.

particulating agent — a thickening agent used as an adjuvant in pesticide formulations to increase droplet size and thus reduce drift.

pathogen — any disease producing organism.

percent by weight — a percentage which express the weight of active ingredients as a part of the total weight of the formulation, e.g. 1 kg of active ingredient added to and mixed with 3 kg of other materials results in a formulation which is 25% pesticide by weight.

percent concentration — the weight of an active ingredient expressed as a percentage of the formulation in weight per volume (liquid formulations) or weight per weight (dry formulations). In liquid volume concentration calculations it is assumed that one litre weighs one kilogram.

perennial — a plant that continues to live from year to year. The tops may die back in winter or in severe drought, but the roots or rhizomes persist, e.g. field bindweed, Canada thistle, quack grass and Russian knapweed.

persistence — the time during which a pesticide retains its toxic properties.

pest — an undesirable organism.

Pest Control Products Act — a Federal Act administered by Agriculture Canada. The Act provides that, in order to be registered for sale or use in Canada, a pesticide must be accompanied with evidence of effectiveness for the purposes claimed. The pesticide must be accurately labelled as to composition and hazards. The seller must also provide adequate directions for use.

Pest Control Product Registration Number — the number which is assigned to a specific pesticide when registration is approved. It must be displayed on every pesticide container label sold or used in Canada.

pest control service — a person (company, firm, proprietorship, agency, etc) who by himself or by the employees provides a service involving the use or application of pesticides. A certified pesticide applicator must be in attendance at each pesticide application.

pesticide — under the B.C. Pesticide Control Act, any substance or mixture of substances, other than a device, intended for killing, controlling or managing insects, rodents, fungi, weeds and other forms of plant or animal life that are considered to be pests.

pesticide buffer zone — A strip of land between the 10 m pesticide free zone and the pesticide treatment area. Pesticides are not applied directly in the pesticide buffer zone to prevent entry of pesticides or pesticide residues by drift, runoff, or leachate into the pesticide free zone. The width of the pesticide buffer zone is up to the discretion of the pesticide applicator, who must take the type of pesticide application equipment, speed of travel, terrain topography, soil conditions and weather conditions into account.

Pesticide Control Act — a Provincial Act, which replaced sections of the Pharmacy Act. It is administered by the Ministry of Environment and Parks, Pesticide Control Branch. The Act and Regulation provide for the certification of pesticide applicators and dispensers, as well as the licensing of pest control services and pesticide vendors in the Province of British Columbia.

pesticide free zone — A strip of land, usually 10 m in width, adjacent to water bodies. Pesticides may not be directly applied to, or allowed to reach the pesticide free zone via drift, runoff or leachate. Specific authorization is needed if the pesticide free zone is to be less than 10 m.

pesticide residue — a deposit that remains in or on a product following the application of a pesticide.

pH — an expression of the degree of acidity or alkalinity. The pH scale of numbers 0 to 14 expresses the intensity of acidity or alkalinity. Materials with a pH of 7 are neutral. Those below 7 are acid. Those above 7 are caustic (alkaline).

phenoxys — hormone type herbicides belonging to the carboxylic-aromatic compounds, e.g. 2,4-D and mecoprop.

pheromones — chemicals produced by insects and other animals to communicate with other members of the same species. Some synthetic pheromones are used to monitor or control insect populations.

photodecomposition — the degradation of a complex substance such as a pesticide into more simple compounds from the action of sunlight.

photosynthesis — the manufacture of simple sugars by green plants utilizing light as the energy source. Also called carbon-assimilation.

phytophagous — feeding on plants, e.g. phytophagous mites.

phytoplankton — microscopic plant life living suspended in water.

phytotoxic — poisonous or injurious to plants.

piscicide — a pesticide used to control fish, e.g. rotenone.

plant disease — disease resulting from fungus, bacteria or virus infection of plants, or from deficiencies in essential nutrients, the presence of materials toxic to the plants, genetic abnormalities, or unfavourable environmental factors.

plant pathology — the science dealing with diseases of plants.

Poison Control Centre — located at all major hospitals in British Columbia. They provide first aid information for poisoning victims. Antidotes and treatment procedures are available to doctors.

pollen — male microspores of seed plants needed to fertilize female parts of flower to produce seed.

pollination — fertilization of female parts of flower with pollen.

postemergence treatment — treatments made after crop plants or weeds emerge through soil surfaces.

potentiation — the joint action of two pesticides to bring about an effect greater than the sum of their individual effects.

pour-on — a pesticide which is poured along the midline of the backs of livestock.

ppb — parts per billion.

ppm — parts per million.

pre-baiting — feeding bait without pesticide to target species, e.g. rodents or birds, to allow them to become accustomed to the bait or feeding location before applying the pesticide-bait mixture.

precipitation — refers to rainfall or snowfall. A precipitation in a spray mixture refers to the separation and settling out of one or more pesticide ingredients.

predator — an organism, often an insect or mite, that preys upon another animal. A predator feeds on and kills its prey.

preemergence treatment — treatment made after a crop is seeded but before it emerges. May also refer to treatment before weeds emerge.

preharvest interval — see days-to-harvest.

preplanting treatment — treatment made before the crop is planted.

product — the pesticide as it is packaged and sold.

prolonged exposure — more than a brief (or one-time) contact with a pesticide or its residue. Chronic exposure is synonymous.

propellant — the liquified gas used in pesticide aerosols to disperse the pesticide.

protectant — a pesticide, usually a fungicide, that is applied where pests are expected to prevent them becoming established. Sometimes called a preventative pesticide.

protective equipment or gear — any clothes, materials or devices that offer protection from pesticides; especially important when handling or applying toxic pesticies, e.g. gloves, apron, boots, coveralls, hat, respirator and face shield.

pubescent — hairy. Pubescence affects ease of wetting of foliage and absorption of spray on foliage.

pupa — the stage between the larva and the adult in insects with complete metamorphosis, a nonfeeding and usually an inactive stage.

registered pesticide — a pesticide accepted under the Pest Control Products Act for the uses and purposes claimed. The P.C.P. registration number must be displayed on the label of each pesticide container sold or used in Canada.

repellant — a chemical that drives pests away from a treated object, area or individual.

residual — to continue to have a killing effect over a period of time after application.

residue — the amount of pesticide that is on or in the crop at the time an analysis is made.

residue tolerance — the maximum amount of pesticide residue that may lawfully be present in or on a food product offered for sale. It is expressed in parts per million. Tolerances are established by the Federal Health Protection Branch of Health and Welfare Canada.

resistance — the ability of an organism to resist or suppress the injurious effects of a pesticide.

respiration — the act of breathing. Also, the physical and chemical processes by which an organism supplies its cells and tissues with oxygen, and the use of oxygen in the production of energy to sustain the living organism.

rhizome — underground root-like stem that produces roots and leafy shoots, e.g. the white underground parts of quack grass and Canada thistle, the black underground parts of Russian knapweed.

rodent — small mammals of the order Rodentia. Includes such pest species as rats, mice and pocket gophers.

rodenticide — a pesticide used to control rodents.

saprophyte — living and feeding on dead or decaying organic matter.

seedling stage — usually refers to the early stages of growth of crop plants or weeds, technically; a plant prior to the development of a root system other than the seed or seminal roots.

seed protectant — a pesticide applied to seed before planting to protect seeds and new seedlings from diseases and insects.

selective pesticide — a pesticide which is more toxic to some types of organisms than others. Usually used to describe a particular type of pesticide, such as a selective herbicide, e.g. a selective herbicide may kill crab grass in a cornfield without injury to the corn.

selective herbicide — a herbicide that is more toxic to some species of plants than others.

slugs — molluscs, belonging to the class Gastropoda, which do not have a shell. Larvae of some sawflies and certain Coleoptera are also referred to as slugs.

slurry — a mixture of a liquid and a wettable powder to the consistency of a slow-running paste. It is good practice to prepare a slurry of wettable powder prior to incorporation in the final mixture.

snail — a mollusc, belonging to the class Gastropoda, which may be easily recognized by its shell.

soft water — water which does not contain those minerals that prevent free lathering when soap is added.

soil fumigant — a pesticide used to control pests in the soil. When added to the soil, it takes the form of a gas or vapour. Since it can evaporate quickly, it is often used with some kind of cover, e.g. a tarpaulin which traps the gas in the soil until the pest is controlled.

soil sterilant — a nonselective chemical with the ability to persist for varying periods in the soil, thus preventing germination and growth of plants and other organisms.

soluble — will dissolve in a liquid.

solubility — the amount of a substance which will dissolve in a given amount of another substance.

soluble powder (SP) — a dry (powder) formulation which contains an active ingredient that dissolves in water (or another liquid), and forms a solution so that it can be applied.

solvent — a liquid which will dissolve one or more substances to form a solution.

space spray — a pesticide which is applied in the form of tiny droplets which float in the air and destroy insects and other pests in a localized space, either indoors or outdoors.

species — a group of individuals which are similar in structure and physiology and are capable of producing fertile offspring.

species diversity — the number of different animal or plant species comprising the community structure of a given habitat.

spiders — tiny animals closely related to insects; they have eight jointed legs, two body regions, no antennae, and no wings. Spiders are often grouped with mites and ticks.

split application — applying a portion of the pesticide at one time and the remainder later.

spore — an inactive form of microorganism that is capable of becoming active again when conditions are favourable.

spot treatment — an application of spray to localized or restricted areas as differentiated from broadcast or complete coverage.

spray — a pesticidal formulation dissolved or suspended in a liquid (usually water or oil) so that it can be applied in fine droplets.

spreading agent — a substance used to improve the wetting and spreading properties of a spray mixture.

spreader sticker — a substance used to improve the wetting, spreading and sticking properties of a spray mixture, e.g. facilitates the spreading of a liquid over leaf surfaces, and enhances adherence.

stem — those parts of a plant above the ground which support branches, twigs or flowers.

sterile male technique — a method to control insects by sterilization of males, usually accomplished by radiation or a chemosterilant, e.g. sterile male codling moths.

stolon — above-ground runners or slender stems that develop roots and shoots and new plants at the tips or at nodes, e.g. strawberries and creeping buttercups.

stomach poison — compounds that kill organisms when they are eaten and absorbed.

stratification — layering. Referring to horizontal temperature and/or moisture zones. Stratification plays a role in air inversions (fog and smog) and night frosts. Also used to induce germination of seeds, by layering seeds between moist materials and/or exposing to cold temperatures.

structural pests — any organism that can damage houses, storage buildings, furniture or other man-made structures, e.g. termites, carpenter ants, rodents and decay fungi.

stunting — in relation to weeds or crop plants, usually refers to a retarding effect on growth and development. Often stunting or suppressing of weeds or grasses, even without kill, may give effective control (management).

sublethal — insufficient dose of a pesticide to be the direct cause of death for an oganism.

summer annuals — plants which germinate in the spring, do most of their growing in the summer, produce flowers or seeds, and then die in the fall.

surface tension — the force which tends to cause a liquid drop to retain its shape rather than spreading as a film.

surfactant — a chemical or agent used in a pesticide to make mixing easier and to assist in the spreading of a chemical and the wetting of and adherence to the surface to be treated, e.g. emulsifiers, soaps, wetting agents, detergents and spreader stickers.

susceptibility — the degree to which an organism can be injured or affected by a pesticide at a known dose or exposure.

suspension — a liquid or gas in which very fine solid particles are dispersed but not dissolved, e.g. diuron or simazine in water. Constant agitation is essential.

swath — the width covered by a sprayer when it moves across a field or other area to be treated.

synergist — a chemical added to a pesticide to increase the level of activity of the active ingredient.

synthetic — a term derived from the Greek "Synthetikos", meaning "that which is put together". Man-made chemicals may be identical to those found in nature, but are generally purer and more uniform.

systemic pesticide — a pesticide which is absorbed by and flows through the plant or animal.

target pest — the pest at which a pesticide application or other control method is directed.

technical material — the pesticide (active ingredient) as it is manufactured by a chemical company before formulation.

teratogenic — capable of inducing deformities to unborn animals, as with thalidomide.

test animal — laboratory animals exposed to pesticides so that toxicity and hazards can be determined, e.g. rats, mice, rabbits, birds and fish.

threshold of toxicity — the lowest dose of a poison which causes one or more toxic effects examined for in animals or humans.

ticks — tiny animals closely related to insects. They have eight jointed legs, two body regions, no antennae and no wings. Ticks are blood sucking organisms and are often found on dogs, cows or other domestic and wild animals. They are closely related to mites and spiders.

tolerance — see residue tolerance.

tolerant — ability to withstand effect, e.g. grasses are tolerant to 2,4-D to a degree that it can be used selectively on lawns to control some broadleaved weeds.

topical application — a pesticide that is applied from above, usually to the top or upper surface of a plant.

toxicant — poison.

toxicity — the degree to which a substance is poisonous or injurious to a plant or animal. Toxicity is one consideration in assessing the hazard in handling a particular pesticide.

translocation — transfer of food or other materials, e.g. 2,4-D, from one part of a plant to another.

translocating herbicide — a herbicide that is capable of moving through the plant's system from one point to another.

trophic level — one of several successive levels of nourishment in a food web or food chain; plants consititute the first (lowest) trophic level, dominant carnivores constitute the highest trophic level.

ultra low volume (ULV) — a spray application of a pesticide that is almost pure active ingredient (technical material); it is sprayed in extremely small amounts over a large area, usually less than 5 to 6 L/ha.

unsulphonated residue — that part of an oil which is not acted upon by sulphuric acid.

vapour — the gas produced by a substance which is generally a solid or liquid at room temperature. A gas or vapour is not the same as an aerosol or mist which are composed of tiny droplets of liquid suspended in air.

vapour drift — the movement of vapours from the area of application to other areas.

vector — a carrier of a disease producing organism (pathogen); an insect or other animal that transmits a pathogen, e.g. aphids, leafhoppers and nematodes can transfer viruses from one host to another. The vector may or may not be affected by the pathogen.

vertebrate — an animal with a bony spinal column, e.g. mammals, fish, birds, snakes, man and frogs.

viroids — very small molecules of infectious (naked) RNA (Ribo Nucleic Acid), 50 times smaller than typical plant viruses. Viroids have been recognized only recently and so far only in plants. They lack the protein coating which is found in viruses. Control of viroids is the same as for viruses: sound cultural practices and control of vectors.

virus — infectious agent of plant or animal, too small to be seen except with an electron microscope. They are protein bodies capable of multiplying and acting like living organisms within the host organism.

viscosity — the ability of a liquid to resist flowing. The higher the viscosity, the slower it flows.

volitility — the degree to which a solid or liquid material evaporates (evolves a gas).

volatility injury — injuries from the vapour of a pesticide.

weed — any plant growing where it is not wanted.

wettable powder — a powder containing a wetting agent so that it will readily form a suspension in water.

winter annual — plants which germinate in the fall or early winter, do most of their growing in the spring, produce flowers and seeds and die within a year.

wood preservation — preserving the usefulness and structural strength of wood and wood products by chemical treatment to repel harmful parasitic organisms.

zooplankton — microscopic animal life living suspended in water.

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Emergency Phone Numbers

In most areas of BC, phone 9-1-1.

For emergency numbers in areas without 9-1-1 service, see the inside front cover of your telephone directory.

When seeking medical help if pesticide poisoning is suspected, take with you the pesticide label or at least:

- The name of the product;
- The active ingredient and % concentration; and
- The P.C.P. Act Registration Number.

Emergency Phone Numbers

Poison Control Centre........................(604) 682-5050 or 1-800-567-8911
(Lower Mainland) (other areas of BC)

Have the complete Trade Name and Pest control Products Act Registration Number (PCP Number) from the pesticide label when you go for medical help.

Doctor ____________________

Ambulance ____________________

Fire ____________________

Police ____________________

Spill Response (24hours)....................................**1-800-663-3456**
Call this number for cleanup advice or assistance and to report spills to the Ministry of Environment.

IPM Program offices:

Lower Mainland and Vancouver Island..604-582-5200
Kootenay, Okanagan and Thompson Regions...............................250-490-8200
Omineca, Peace, Cariboo and Skeena Regions.............................250-565-6135

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