Pesticides Manual
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# PESTICIDES MANUAL

*. . . Classification*
*. . . Toxicities*
*. . . Formulation*
*. . . Handling*
*. . . Application*



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Any chemical or mixture of chemicals used for preventing, destroying, repelling, or mitigating unwanted or harmful organisms, viruses, or air pollutants is a pesticide. Chemical substances for regulating plant growth or development, such as plant regulators, defoliants, or desiccants, are also considered pesticides.

There are several groups of pesticides which are named for the target organism they affect. The general name for the pesticide group is developed by adding the suffix "cide," meaning to kill or destroy, to the type of animal or plant life being attacked. Therefore, herbicides, insecticides, rodenticides, or bactericides are pesticides designed to kill weeds, insects, rodents (rats) or bacteria, respectively.

## Names of Pesticides

A pesticide, whether a fungicide, insecticide, herbicide, etc., usually has several names. These range from the technical name for the active ingredient to the trade names the manufacturers use to sell their formulated products.

Technical names, although they identify a specific pesticide beyond question, are usually long and often difficult to pronounce and remember. Therefore, a shorter, common, name is given to each chemical. The common name, once it is approved by the National Standards Institute, refers to a specific chemical compound. Common names are used by most federal and state agencies in their literature on pesticides. Common names are sometimes referred to as "generic" or "coined" names.

## How Pesticides Work

Plants may be protected from attack by pests in several different ways. By understanding how pesticides act, their application can be better timed to achieve the best results.

Protectant Pesticides—applied before the pest has a chance to enter (infect) or feed on the plant. They set up a chemical barrier between the susceptible tissue and the attacking organism. Protectants may be used as needed in any stage of plant growth. They may be applied to seeds or cuttings for protection from soil-borne pests, or to the foliage and fruit to ward off above-ground pests.

Eradicant Pesticides—"destroy" the pest within a few hours to days after the infestation is established. Only a limited number of pesticides have curative properties and most of these are used to control certain tree-fruit diseases.

Protectant-eradicant Pesticides — Guard against new attacks while eliminating recently established pests. They are similar to mixtures of protectant with eradicant compounds except only one chemical is involved. Normally, these kinds of materials do not require application as frequently as protectants.

Systemic Pesticides—absorbed into the plant's system and then translocated to new leaves, shoots, or roots where they guard against pest attack. Because the materials are in the plant, they are less subject to weathering, and therefore may provide control for a longer period of time than surface acting compounds. They hold particular promise for the control of problems like Dutch Elm disease that reside deep within the host.

Broad-spectrum Pesticides – chemical that reduce loss due to two or more pests of a particular crop. They are sometimes labeled multipurpose disease control chemicals. A material capable of controlling scab, powdery mildew, and mites on apples, for example, is broad-spectrum in its action. This category of pesticides is somewhat more general than the others since a broad-spectrum pesticide may be a protectant, eradicant, or systemic in its action.

Fumigants—gases or liquid chemicals that volatilize before acting. They have diffusion properties and can easily penetrate soil, certain seeds, and other materials to kill pests. Several types of compounds are available for use in either confined or unconfined areas.

## Types of Chemicals Used as Pesticides

Pesticides may be classified by their mode of activity (i.e. pre-emergence herbicides, protectant fungicides, contact insecticides, etc.) or the chemical group they belong to, or a combination of the two methods. Classification based upon chemical nature of the pesticide is often useful when trying to decide on the general properties of a new or unfamiliar compound. This is because related chemicals may have similar biological or physical characteristics.

### FUNGICIDES

Chemically, fungicides may be broken down into inorganic or organic types. The inorganic materials, such as sulfur, copper, and mercury compounds, were the first fungicides used in commercial agriculture. Many of these early compounds have been replaced in recent years by organic fungicides.

#### Inorganic Fungicides

Copper Compounds: Bordeaux mixture has been used for nearly 100 years for disease control. Consisting of soluble copper sulfate mixed with hydrated lime in water, it is used as a spray. The lime safens the mixture and improves control by sticking the copper onto the plant.

The "fixed" or "insoluble" copper compounds have generally replaced Bordeaux mixture for disease control. There are several fixed copper products available, containing either basic copper sulfate, basic copper chlorides, copper oxides, or various other formulations. They are used as sprays or dusts for the control of certain fungal and bacterial diseases.

Sulfur Compounds: Sulfur was the first known fungicide and is still used extensively today for the control of certain foliage and fruit diseases. Sulfurs are known particularly for their effectiveness in controlling powdery mildews. They are used as dusts or as sprays. Although several formulations of sulfur exist, they fall into three types, wettable sulfur, sulfur paste, and lime-sulfur. The wettable sulfurs are the most common types used today. Lime-sulfur, a special mixture of hydrated lime and sulfur, was used extensively for insect and disease control at one time, but today, like sulfur paste, is decreasing in importance.

Mercury Compounds: Mercury, both inorganic and organic forms, was used extensively as a fungicide for seed treatment and to a lesser extent as a foliar spray until recent years. Due to their possible contribution to mercury contamination of the environment and their toxicity to humans and animals, mercury compounds have been suspended for use as fungicides. Organic fungicides have essentially replaced the mercuries.

#### Organic Fungicides

Carbamates: Development of the carbamate fungicides was a major breakthrough in fungicide chemistry. Because of their value to mankind in preserving food and fiber, the discovery of the carbamate fungicides is comparable to the discovery of DDT as an insecticide. These compounds are still used throughout the world to control a variety of diseases on many crops.

The carbamate fungicides are all derivatives of dithiocarbamic acid, an organic acid used in vulcanizing rubber. They are classified into three groups: 1) *The thiuram disulfides.* These are sold under many trade names such as Thiram, Arasan, Tersan, Thylate, etc. and are known by the common name of thiram. They are used for seed and bulb treatments, against certain foliage disease, particularly the rusts, and as soil-drenches for damping-off and seedling blight.

2) *The dithiocarbamates.* Ferbam and ziram are the important members of this class. Although they are not used as much today as previously, they are still used to some extent for the control of certain foliage diseases on vegetables, ornamentals and fruit trees.

3) *The ethylene bisdithiocarbamates.* Nabam, zineb, and maneb are important members of this class. They are used extensively on vegetables for the control of several diseases and also on flowers, turf and fruit crops. Like the dithiocarbamates, each of these chemicals contain a metal such as sodium, zinc, iron, or manganese.

QUINONES: Several quinones have been tested as fungicides but only two, chloranil and dichlone, have been developed for use commercially. Chloranil, the first of the organic fungicides, is used primarily as a seed protectant and is sold under the trade name Spergon. It has limited use as a spray or dip treatment. Dichlone is used as a foliar and fruit protectant on fruit and certain other crops. It also has some use as a seed protectant. Dichlone is sold as Phygon, Phygon XL, etc.

BENZENE COMPOUNDS: There are several fungicides in this chemical class but most of them are relatively specific in the pest they control or in how they may be used. Dexon and pentachloronitrobenzene (PCNB or Terrachlor) are used primarily for the control of soil-borne diseases. Dinocap is specific for powdery mildew and is sold under the trade name of Karathane or Mildex. Dichloran or Botran prevents decay of fruit crops caused by *Rhizopus*, a common bread mold. It is used as a foliar spray or soil fungicide on vegetable, flowers, and fruit or as a postharvest treatment on certain fruit and vegetables. Daconil is a relatively new compound for use on vegetables and certain other crops. It differs from the other benzene compounds in being effective against a spectrum of foliage and fruit pathogens.

HETEROCYCLIC COMPOUNDS: 1) *Benzimidazoles:* The benzimidazoles are systemic fungicides and include thiabendazole (TBZ) and benomyl. These compounds are in the early stages of development commercially, having been registered to date on only a few crops. They are particularly effective against the ascomycete fungi, a group that includes a large number of plant pathogens. Benomyl appears to be active at slightly lower rates than thiabendazole. Because they are systemic, there is great hope that they will be effective against internal pathogens and less subject to weathering. Since they are translocated to the new growth, new leaves or shoots should be protected.

*2) Trichloromethylmercapto compounds:* This group includes three closely related fungicides – captan, folpet, and difolatan. Captan was the first to be developed. It is used for the control of a large number of fungus diseases of fruits, vegetables, and ornamentals in foliage, seed, and soil applications. Folpet and difolatan have similar properties and are used where they are more effective than captan. Difolatan is known particularly for its ability to resist weathering and provide extended control.

OTHER ORGANIC FUNGICIDES: *Guanidines:* The main fungicide in this class is dodine. Sold under the trade name of Cyprex, it is used for the control of foliage diseases of apples, cherries, strawberries and roses. It is used primarily as a protection but is also a good eradicant against apple scab.

**Antibiotics**

Antibiotics are chemical substances produced by micro-organisms which are toxic to other micro-organisms. Penicillin, produced by the fungus *Penicillium notatum,* is an example of an antibiotic widely used in human medicine. Certain others are used for control of plant diseases.

STREPTOMYCIN: Streptomycin, an antibiotic produced by a soil micro-organism, is used for the control of certain bacterial diseases. It is applied as a spray or dust for control of certain bacterial blights and bacterial leaf spots of several crops. It has some use as a disinfectant in treating seeds and seed pieces.

TETRACYCLINES: Tetracycline antibiotics, similiar to those used in veterinary medicine, are active against several bacterial plant pathogens. Since their spectrum of activity resembles the spectrum of streptomycin, the tetracyclines have not gained wide usage. Today, there is renewed interest in the tetracyclines because of their activity against mycoplasma, the cause of aster yellows and related "yellows" diseases.

CYCLOHEXIMIDE: Cycloheximide is an antibiotic active against fungi. It has been used for the control of turf diseases, cherry leaf spot, and powdery mildews. Although it was used extensively at one time, it has generally been replaced by synthetic organic fungicides.

## HERBICIDES

A large number of chemical weed-killers are now available. Selective control of weeds in crops may be obtained by either foliage sprays (post emergence) or application of the chemicals to the soil either as pre-planting or pre-emergence sprays.

Factors such as rainfall, soil type and method of application influence herbicide effectiveness. Use herbicides on only those crops for which they are specifically approved and recommended.

Chemicals may be used for selective control of weeds in tolerant crops and nonselectively for control of annual and perennial species in non-crop areas.

**Important Terms Used in Weed Control**

• A weed is a plant *growing where it is not desired;* or a *plant out of place.*

• Herbicides are weed-killing chemicals. There are *three types of herbicides* defined by their effects on plants: *contact, growth regulators, and soil sterilants.*

• Contact herbicides kill plant parts covered by the chemical. Contact herbicides may be (1) selective or (2) non-selective; usually non-selective.

- A *selective herbicide* kills or stunts some plants with little or no injury to others.
- A *non-selective herbicide* is toxic to all plants.
- Growth regulators are also called *growth modifiers, growth substances, translocated herbicides,* and *systemic herbicides.* They can be absorbed by the leaves, stems or roots and are translocated through the plant system affecting the physiological system of the plant.
- A soil sterilant is any chemical which prevents the growth of green plants when present in the soil. Length of time of residual toxicity is an important factor in their use.
- Preplanting treatment is any treatment made before the crop is planted.
- Pre-emergence treatment is any treatment made prior to emergence of crops.
- Post-emergence treatment is any treatment made after emergence of a crop.
- Broadcast treatment or blanket application is uniform application to an entire area.
- Spot treatment is treatment of a restricted area, usually to control an infestation of a weed species requiring special treatment.
- Surface active agents include wetting agents, emulsifiers, detergents, spreaders, sticking agents, and dispersing agents. Water is not compatible with many chemicals used as herbicides, or with many plants surfaces. Surface active agents produce more uniform mixing of herbicides and water in the sprayer and better coverage of the weeds.
- Active ingredient is that part of a chemical formulation directly responsible for the herbicidal effect.

**Characteristics of Herbicides**

This table has been prepared as a guide for those who advise in the use of herbicides in Michigan. The aim of the authors is to integrate as much specific information as possible into one handy reference. In order to help readers interpret this table correctly, the following descriptions of terms are provided:

*1. **Common Name.*** The common names for herbicides which are provided here are those which are approved by the Terminology Committee of the Weed Science Society of America.

*2. **Trade Name.*** Where possible, all trade names are provided. In some instances where there are numerous suppliers, they are not listed singly.

*3. **Type of activity.*** The major sites of action of the herbicide. (a) Soil—acts on germinating weed seeds. (b) Contact—burns off foliage of emerged weeds. (c) Systemic—translocated throughout the plant after foliar application.

*4. **Solubilities.*** These figures are expressed as parts per million (ppm) water at room temperature.

*5. **Weeds Most Effectively Controlled.*** For each herbicide, a general description of the susceptible weeds and best growth stage for herbicide application is provided. Weak or strong areas, that we are aware of are also emphasized.

*6. **Residual Life in the Soil.*** The residual life of a herbicide in the soil varies from year to year, and depends on the rate of application, environmental factors, soil organic matter, and clay content. The figures provided are estimates based on our observations with recommended rates in Michigan. The chemicals have been grouped into five broad categories—those which remain biologically active for 0 - 10 days, 10 - 30 days, 30 - 60 days, 60 - 120 days, and over 120 days.

**Factors Affecting Soil-Applied Herbicides**

Many factors may have an effect on how well soil applied herbicides move to the site of action. A knowledge of these factors involved in the transfer of a herbicide from applicator, through the soil, and to the plant is helpful in obtaining more consistent responses or to help explain some of the variability.

Proper Application. The use of the specific rate of application is essential. Very small amounts are necessary to inhibit plant growth. However, sufficiently high rates must be used to compensate for the amount bound to the soil or that otherwise made unavailable for uptake by the plants. Rates must not be of the magnitude to cause crop injury or soil residues.

## Table 1

CHARACTERISTICS OF HERBICIDES RECOMMENDED

IN THE PRODUCTION OF HORTICULTURAL AND FIELD CROPS

| Common Name | Trade Names and Manufacturers | Type of Activity | Solubility In Water (ppm) | Weeds Most Effectively Controlled | Residual Life In Soil (Days) |
|---|---|---|---|---|---|
| Alachlor | LASSO (Monsanto) | Soil | 148 | Germinating annual grasses and some broadleaved weeds. | 60 - 120 |
| Amitrole | AMINO TRIAZOLE (Am. Cyanamid) WEEDAZOL (Amchem) | Systemic | 280,000 | Actively growing perennials | 10 - 30 |
| Amitrole-T | AMITROLE-T (Amchem) CYTROL (Am. Cyanmid) | Systemic | 280,000 | Actively growing perennial grasses, quackgrass. | 10 - 30 |
| AMS | AMMATE-X (Dupont) | Contact Systemic Soil | 60% | Woody perennials | 10 - 30 |
| Atrazine | AATREX (Ciba-Geigy) | Soil Contact | 70 | Germinating annual weeds except late germinating grasses, quackgrass. | Over 120 |
| Azak | AZAK (Hercules) | Soil | 6 | Crabgrass. | Over 120 |
| Benefin | BALAN (Eli Lilly) | Soil | 70 | Germinating annuals, particularly grasses. | 60 - 120 |
| Bensulide | PREFAR, BETASAN (Stauffer) | Soil | 25 | Germinating annual grasses. | Over 120 |
| Bromoxynil | BROMINAL (Amchem) BUCTRIL (Chipman) | Systemic | 130 | Seedling broadleaf weeds. | 30 - 60 |
| Butylate | SUTAN (Stauffer) | Soil | 300 | Germinating annual grasses, nutsedge. | 60 - 120 |
| Calcium arsenate | CHIP-CAL (Chipman) KLEEN-UP (Cevron) | Soil | 5,000 | Annual grasses. | Over 120 |
| CDAA | RANDOX (Monsanto) | Soil | 19,700 | Germinating annual grasses, purslane & pigweed on muck soils. | 30 - 60 |

| Common Name | Trade Names and Manufacturers | Type of Activity | Solubility In Water (ppm) | Weeds Most Effectively Controlled | Residual Life In Soil (Days) |
|---|---|---|---|---|---|
| CDEC | VEGADEX (Monsanto) | Soil | 100 | Germinating annual weeds. | 10 - 30 |
| Chloramben | AMIBEN VEGIBEN (Amchem) | Soil | 700 | Germinating annuals, more effective on broadleaved weeds. | 60 - 120 |
| Chloramben (Methyl ester) | VEGIBEN-ZE (Amchem) | Soil | 120 | Germinating annuals, more effective on broadleaved weeds. | 60 - 120 |
| Chloroxuron | TENORAN (CIBA-Geigy) | Contact Soil | 3.7 | Germinating and seedling broadleaved annuals. | 30 - 60 |
| Chlorpropham | CHLORO IPC (PPG) | Soil | 80 | Germinating annual weeds. Particularly good on chick-weed, smartweed and field dodder. | 30 - 60 |
| Cyanazine | BLADEX (Shell) | Soil Contact | 160 | Germinating annual weeds. | 60 - 120 |
| Cycloate | RO-NEET (Stauffer) | Soil | 100 | Germinating annuals. | 60 - 120 |
| Cyprazine | OutFox (Gulf) | Soil | 6.9 | Germinating annual weeds. | Over 120 |
| 2,4-D | ACID FORMU-LATION (Several suppliers) | Systemic | 725 | Actively grow-ing broadleaved annuals and perennials. | 10 - 30 |
| | AMINE FORMU-LATIONS (Several suppliers) | Systemic | | Same as Above. | |
| | ESTER FORMU-LATIONS (Several suppliers) | Systemic | | Broadleaved annuals and woody peren-nials. | |
| | OIL SOLUBLE AMINE-DACAMINE 4-D (4 lb/gal) | Systemic | | Broadleaved annuals and perennials. | |
| | SODIUM SALT (95%) | Systemic | | Same as Above. | |
| Dalapon | DOWPON (Dow) BASFAPON (BASF) | Systemic Soil | 900,000 | Emerging and actively grow-ing annual and perennial grasses. | 30 - 60 |

| Common Name | Trade Names and Manufacturers | Types of Activity | Solubility In Water (ppm) | Weeds Most Effectively Controlled | Residual Life In Soil (Days) |
|---|---|---|---|---|---|
| 4-(2,4-DB) | BUTOXONE (Chipman) BUTYRAC 118 (Amchem) | Systemic | 53 | Broadleaved annuals. | 10 - 30 |
| DCPA | DACTHAL (Diamond Shamroack) | Soil | <.5 | Germinating annual grasses. | 60 - 120 |
| Dicamba | RANVEL-D (Velsicol) | Systemic | Very Slight | Broadleaved perennials. | 60 - 120 |
| Dichlobenil | CASORON (Thompson-Hayward) | Soil | 20 | Germinating annual weeds. Some perennial weeds including quackgrass. | 60 - 120 |
| Dinoseb | PREMERGE (Dow) SINOX PE (Uniroyal) | Contact Soil | 50 | Germinating annuals, especially broadleaves. | 10 - 30 |
| Diphenamid | ENIDE (Upjohn) DYMID (Elanco) | Soil | 260 | Germinating annual weeds, especially grasses. Winter annuals. | 60 - 120 |
| Diuron | KARMEX (Dupont) | Soil | 42 | Germinating annual weeds. | Over 120 |
| DSMA | Several | Contact | 256,000 | Annual grasses. | 10 - 30 |
| Endothall | ENDOTHALL | Soil Contact | 21 | Germinating annuals esp-pecially broadleaves. | 10 - 30 |
| EPTC | EPTAM (6 lb/gal) | Soil | 375 | Germinating annual weeds, nutsedge. | 30 - 90 |
| EXD | HERBISAN 5 | Contact | | Emerged annuals. | 0 - 10 |
| Fenuron | DYBAR (Dupont) | Soil | 3850 | Woody perennials. | Over 120 |
| Fluorodifen | PPEFORAN (CIBA-Geigy) | Soil | <2 | Germinating annuals. | 60 - 120 |
| Isopropalin | PAARLAN (Elanco) | Soil | <0.5 | Germinating annuals, especially grasses. | 60 - 120 |
| Linuron | LOROX (Dupont) | Soil Contact | 75 | Germinating and emerged annuals. | 60 - 120 |
| MAA | ANSAR 157 (Ansul) | | 256,000 | Annual grasses. | 10 - 30 |
| MCPA | Several suppliers. | Systemic | 640 | Broadleaved annual weeds. | 10 - 30 |
| MCPP | MECOPEX MECOPROP (Nor-Am) | Systemic | 600 | Broadleaved annuals and perennials. | 10 - 30 |
| Metham | VAPAM (Stauffer) VPM (Dupont) | Soil | | Annuals. | 10 - 30 |

| Common Name | Trade Names and Manufacturers | Type of Activity | Solubility In Water (ppm) | Weeds Most Effectively Controlled | Residual Life In Soil (Days) |
|---|---|---|---|---|---|
| Methyl bromide | Several suppliers. | Soil | 15,000 | Annual weeds. | 10 - 30 |
| Metobremuron | PATORAN (CIBA-Geigy) | Soil Contact | 320 | Annual weeds. | 60 - 120 |
| Monuron | TELVAR (Dupont) | Soil | 230 | Annual weeds. | Over 120 |
| Naptalam | ALANAP (Uniroyal) | Soil | 200 | Annuals, particularly broadleaved weeds. | 10 - 30 |
| Nitrofen | TOK (Rohm and Haas) | Contact Soil | 1 | Annuals, particularly broadleaved weeds. | 30 - 60 |
| Paraquat | PARAQUAT CL DUAL PARAQUAT (Chevron) | Contact | Soluble | Annuals and top kill of perennials. | 0 - 10 |
| Pebulate | TILLAM (Stauffer) | Soil | <30 | Annuals. | 30 - 60 |
| Phermedipham | BETANOL (Nor-am) | Contact | <10 | Emerged broadleaved annuals. | 0 - 10 |
| Prometryne | CAPAROL (Geigy) | Soil Contact | 48 | Annuals. | 60 - 120 |
| Propachlor | RAMROD (Monsanto) | Soil | 70 | Germinating annual grasses. | 60 - 120 |
| Pyrazon | PYRAMIN (BASF) | Soil Contact | 300 | Germinating annual weeds, especially broadleaves. | 30 - 90 |
| Siduron | TUPERSAN (Dupont) | Soil | 18 | Seedling grasses. | 60 - 120 |
| Silvex | KURON (Dow) WEEDONE 2,4,5-TP (Amchem) | Systemic | 140 | Broadleaved perennials, woody perennials. | 10 - 30 |
| Simazine | PRINCEP (CIBA-Geigy) | Soil | 5 | Germinating annual weeds. | Over 120 |
| TCA | SODIUM TCA | Soil Systemic | Completely | Germinating annuals, especially grasses. | 30 - 90 |
| Terbacil | SINBAR (Dupont) | Soil Contact | 710 | Germinating annuals and selected perennials. | Over 120 |
| Trifluralin | TREFLAN (Elanco) | Soil | 4 | Germinating annuals, particularly grasses. | Over 120 |

Uniformity of distribution over the sprayed surface is important. Nozzles must have a uniform delivery, a uniform spray pattern, even spacing and proper height to give uniform coverage. Water volume is not important if there is a constant concentration and uniform distribution. Constant pressure and speed are necessary. Granulars present a greater problem in obtaining uniformity.

Soil Interception. An even, uniform surface, free of clods, manure, plant litter and other debris will provide a good distribution pattern. Spray droplets cover the upper surfaces of clods, but not beneath while granulars fall in depressions. Granular formulations again present a greater problem on uneven surfaces.

Physical Movement. Wind and water (excessive rainfall) cause run-off or movement from treated area. Movement is to depressions, causing increased concentrations in these areas. Some leaching into the soil is necessary for effective control. Incorporation properly carried out will benefit some herbicides but may cause variable concentration or placement too deep. Band applications are lost when untreated soil is moved in by the cultivator.

Volatility. This is a major form of loss for certain herbicides. High soil temperatures and air movement increases volatility losses. Damp or wet soil at time of application can cause additional losses through water vapor distillation or by keeping the herbicide concentrated in the exposed surface layer as water moves to the surface. Incorporation reduces volatility losses.

Photo-decomposition. Many herbicides are broken down by exposure to sunlight. Losses occur when herbicides remain on the soil surface for extended periods.

Solubility. Movement into the soil is related to solubility, therefore, salts will move more readily than wettable powders. Additional rainfall is needed to get wettable powders into the upper ¼ to ½ inch of soil.

Movement in Soil. Water transport provides for the greatest amount of herbicide movement in the soil. This occurs primarily when there is sufficient water to exceed field capacity. Diffusion in soil water is important only in the vicinity of roots. Diffusion in soil gases plays a part if the herbicide is quite volatile. Greatest movement is downward, however, some lateral and some upward movement occurs. Movement varies greatly in different soil types.

Degradation. Breakdown of the chemical is by chemical and biological processes. Temperature, aeration, pH and other soil factors will affect chemical processes such as hydrolysis and oxidation. The degradation by micro-organisms is one of the major means of herbicide loss from soil. Organisms may be specific for a particular herbicide and their numbers will increase when repeated applications are made. Conditions that favor growth of micro-organisms will speed breakdown.

Adsorption. A great deal of variability exists in the amount of herbicide adsorbed by soil since soils vary in organic matter and inorganic soil colloids. Organic matter adsorbs more strongly and thereby greatly reduces the amount of chemical available and also retards movement in soil. Randox (CDAA) is an exception in that it is more effective in high organic matter soils.

Absorption. This is the means of entry into the plant and it is favored by conditions that favor high transpiration rates. The amount of root system exposed is important since amount of herbicide absorbed is generally proportional. A heavy plant population may reduce amount absorbed by any one plant as well as concentration of herbicide in soil.

Translocation. Upward movement is primarily in the xylem (non-living tissue) and concentration is in areas of most rapid water loss. Rather high concentrations of herbicide can be moved since living tissue is not involved once the chemical reaches the vascular system.

Activation and Deactivation. Some herbicides (2, 4-DB, Sesone) require activation either in the soil or plant. Other herbicides may be deactivated in the plant by metabolism or modification. Active and inactive metabolites or complexes may be formed. Selectivity may be obtained by these processes.

Accumulation. There is a threshold concentration for phytotoxicity. Amount taken in must be greater than the amount degraded or eliminated. Conditions that affect absorption, translocation or degradation will reduce the accumulation of toxic concentrations.

Cellular Sensitivity. Plant response is due to sensitivity to a certain concentration of chemical. Species vary greatly in tissues within a plant. Environmental conditions and tissues maturity play an important role. Mature tissue generally shows less activity and older plants are less likely to be killed.

### Factors Affecting Foliar-Applied Herbicides

Applying herbicides to plant foliage is a direct means of getting the chemical to the plant. Many factors influence the movement into the plant and responses vary. More consistent results are obtained and variability may be explained if these factors are known.

Proper Application. Rate and concentration of herbicide is important and therefore uniform application and choice of gallonage is necessary. Although uniform distribution of systemic-type herbicides is not as critical as for soil applications, too high a rate can cause decreased long term kill. Uniformity of concentration and delivery rate is essential, therefore correct nozzles, sprayer speed, agitation, pressure and dilution are important.

Interception by Leaves. Leaf angle, degree of hairiness, expansion, and leaf area-dry weight ratio influence response. In annuals, greatest concentration per unit area of dry weight is obtained in seedling stage. In perennials, the greatest ratio occurs later so treatment should be delayed until considerable growth has developed. A canopy of leaves can be a deterrent to effective control or a safeguard against injury. Wetting conditions will affect interception by changing leaf orientation and reducing leaf area.

Retention. Keeping spray droplets on the leaf is an important consideration once contact with the leaf has been made. Type of leaf surface such as waxy coating, pubescence, and roughness affect retention. Retention can be increased by use of wetting agents and other materials that lower surface tension, nonpolar formulations (esters) and low spray volumes.

Rainfall will cause run-off if it occurs shortly after or during application. With many herbicides, 1 to 2 hours after application without rain will allow for penetration. Herbicides also volatilize from leaf surfaces when exposed to high temperatures.

Absorption. This phenomena varies with each herbicide, formulation, plant species, and environmental factor. Thickness of the cuticle (waxy coating) has a direct relationship. Uniform leaf coverage is essential for maximum penetration. Penetration may be both an active and a passive process. High humidity, high soil moisture and conditions that favor rapid growth increase absorption. Stomata that are open may be an avenue of entry for volatile herbicides and those of low surface tension.

Translocation. Downward movement is through the phloem (living tissue) and is favored by production of assimilatory material and growth processes. Herbicides tend to move to regions of activity such as buds, young leaves, seed, storage organs and meristematic areas. Excessive application rates or contact injury reduce translocation and is a factor to consider in herbicide combination. In a few cases, herbicides have recycled in a plant. Movement out of the plant roots or excretion of herbicides have been shown under certain conditions. This will reduce the amount available to the plant and plant responses will be altered accordingly.

Activation and Deactivation. Some herbicides (2, 4-DB) are activated by an enzyme system after entering the plant (B-oxidation) while others (atrazine in corn) are deactivated by being metabolized or complexed with cell constituents such that it is not available to exert phytoxicity. The rate or degree of degradation is influenced by conditions affecting plant growth, i.e. temperature, sunlight, soil moisture.

Accumulation. The rate of absorption and translocation affect accumulation. Accumulation at the sites of action generally meristematic regions varies with species and rate of degradation at these sites. Environmental factors that influence metabolism and other mechanisms at the site of action will influence plant response.

Cellular Sensitivity. Ultimate response of a plant to a herbicide is at the cellular level. Susceptibility varies during the season and with the season. Maturing plants develop varying levels of tolerance. Mature tissues or those of low metabolic activity will show little response to a concentration that would have been injurious at an earlier stage of growth.

## INSECTICIDES AND NEMATICIDES

Insecticides had previously been classified on their mode of entry into the insects, such as stomach, fumigant, or contact poison. However, with the development of the present insecticides, classification is now based upon the chemical nature of the insecticide. These categories are: (1) organic chemicals of plant or animal origin; (2) inorganic chemicals; (3) synthetic organic chemicals; (4) attractants and repellents. Nematicides are included in fumigant and synthetic organic chemical groupings.

### *Organic chemicals of plant or animal origin*

These chemicals occur in nature in plants, animals, or as in the case of oils, as a result of the breakdown of plants and animals. Included in the plant organic group are nicotene, rotenone, and pyrethrin. They are rapidly broken down by sunlight leaving little toxic residue. Many of these compounds have contact, stomach and fumigant action and are commonly employed in aerosol sprays for rapid knockdown. Petroleum oils, upon refinement, are commonly used as contact insecticides, acaricides (against mites) and ovicides (against the egg) and are applied both during the dormant and growing period of plants. In general, oils suffocate the insect, mite or egg by covering it with a thin flm which prevents normal exchange of oxygen.

Biological insecticides, naturally occurring diseases of the insects, can also be used for insect control. The best known are the bacterial disease agents *Bacillus* *thurengiensis* and *B. popillae*. Such diseases are specific to a certain insect species, breakdown rapidly upon exposure to light and leave little or no harmful residues. These diseases are applied as a spore suspension to the plant part where the insect feeds to ensure the ingestion of the spores. Once ingested, the spores paralyze the gut of the insect preventing further feeding and eventually invade other parts of the insect's body.

There are other types of "biologicals," such as fungi, virus and nematodes, which are being studied for controlling insects.

### *Inorganic chemicals*

The inorganic chemicals are effective solely as stomach poisons. Lead arsenate, Paris green, sulfur and sodium fluoride are examples of stomach poisons previously receiving much use. Their potential for insect control is questionable when compared to the more efficient synthetic organic chemicals.

### *Synthetic organic chemicals*

This is by far the most important group of insecticides now available for pest control. They can be separated according to their chemical make-up into the following groups:

CHLORINATED HYDROCARBONS: These chemicals are characterized by their long residual properties important in long term insect control such as for termites, grubs and wood boring insects. Included in this group are DDT, dieldrin, chlordane, lindane, endrin, methoxychlor, BHC and others. Because of their persistence and a tendency to accumulate in fat and in "non-target" organisms, their use is being limited to essential uses where less persistent alternative chemicals are not available. Their toxicity to humans ranges from quite toxic (endrin) to relatively safe (methoxychlor), but in general are less toxic to man than the organic phosphates. The chlorinated hydrocarbons should be limited for those essential uses where a less persistent alternative is not available.

ORGANIC PHOSPHATES: Unlike many of the chlorinate-hydrocarbons, the organic phosphate insecticides and nematicides are generally more acutely toxic to man. They have a short residual life, being broken down by exposure to sunlight, heat and water. They affect the nervous systems of animals and kill insects by contact, fumigation and stomach poisoning. Examples of the organic phosphates include parathion, malathion, Guthion, diazinon, TEPP, ethion, Dasanit, Vapona and others. Certain organic phosphate insecticides exhibit systemic action in plants and animals. This ability to be absorbed and translocated into the plant sap or the blood stream of animals increases their efficacy for pest control. Some systemics presently available are dimethoate, Thimet, Di-Syston and Meta-Systox-R. The organic phosphates do not accumulate in body tissues like the chlorinated hydrocarbons but can reduce the levels of cholinesterase (an important chemical of the nervous system) upon repeated exposure.

Because of their short residual life and quick action against insects, the organic phosphates have been, and will continue to be, used extensively in all aspects of agriculture. These materials must be handled with extreme care because of their inherent toxicity to man.

CARBAMATES: The carbamates, like the organic phosphates, are nerve poisons. Many carbamates are of recent development and show a wide range of variability in toxicity and residual life. Some of the more commonly used carbamates include Sevin, Matacil, Baygon, Isolan, Furadan, and Temik. The carbamates show considerable range in toxicity from relatively safe (Sevin) to extremely toxic (Temik). They also exhibit variability in action including stomach, contact, and systemic properties. Residual properties of most carbamates exceed many of the organic phosphates, hence they are often used for residual treatments.

DINITROPHENOLS: The dinitrophenols are extremely toxic to man and harmful to many plants. Thus, they are most commonly employed as dormant sprays. They are especially effective against mites, scales and aphids when applied during the period of plant dormancy. Their action is primarily as a contact poison against insects but they are also used against mites, plant diseases, and weeds. They have also been used as a blossom thinning agent on certain fruit trees. Some of the more common dinitrophenols are Elgetol, Kremite, DNOC and DHC.

### *Fumigants*

Chemicals fumigants are most often defined as materials which exist as gases at ordinary pressures and temperatures and which are lethal to pests at proper concentrations. Fumigants are poisons and toxic to all warm blooded animals (including humans) as well as insects, nematodes and other pests. Most fumigants are vesicants which cause severe burns when in contact with skin or mucous membranes. Avoid direct contact and inhalation of these materials. Certain fumigants are used safely. These materials should be used only by trained and experienced applicators. Fumigants are grouped according to their usage, (i.e. space fumigants and soil fumigants) but a given fumigant might be used in either manner.

1. *Carbon bisulfide* (CB) is a colorless, highly flammable, explosive liquid with a very disagreeable odor. It is phytotoxic to plants and has a high chronic toxicity to humans. Repeated exposure to low concentra-

tions produces a variety of nervous disorders in man. This is used primarily as a space fumigant.

2. *Carbon tetrachloride* (CT) is a heavy, colorless, non-flammable, explosive liquid with a pungent odor. Mixed with other fumigants, it decreases fire hazards, increases volatilization and serves as a dilutent. Except where acute fire hazards exist, CT is seldom used alone due to its low toxicity to insects and slow reaction rate. At recommended dosages, it does not affect seed germination but is injurious to nursery stock, growing plants, vegetables and fruits. Carbon tetrachloride is toxic to humans. Breathing of the vapors or dermal contact with the liquid should be avoided. It is used as a space fumigant.

3. *Chloropicrin,* a yellowish, non-flammable, dense liquid is generally used as a warning agent when mixed with other fumigants such as methyl bromide. Humans can detect a concentration of one ppm, which incites tears and a burning of the eyes. It is very toxic to insects, nematodes, fungi and extremely phytotoxic. Chloropicrin volatilizes slowly and is difficult to remove from fumigated commodities. Chloropicrin is used with other space and soil fumigants.

4. *Dibromo-chloropropane* (DBCP) is a dense, yellow, non-flammable liquid fumigant that can be applied as a pre-plant, at-time-of planting, and post-plant treatment. It is highly toxic to most nematodes and has a low phytotoxicity, except to bromine sensitive plants. The material can be applied by soil injection or water drench. Never use on an organic soil. Bromide residues in food crops must be considered, although careful following of directions minimizes this problem. DBCP is never used as a space fumigant.

5. *Dichloropropene* and *Dichloropropene-Dichloropropane* mixtures are pungent, flammable liquids that are used widely in agricultural soils to control symphillids and nematodes. They are phytotoxic to plants and seeds. Therefore, soil treated with these materials require a waiting period prior to planting. These fumigants are especially irritating to eyes and mucous membranes and can be absorbed by the skin on contact. They are never used as a space fumigant.

6. *Ethylene dibromide* (EDB) is used as a soil fumigant as well as for space fumigation. The heavy liquid volatilizes to a heavy gas which diffuses slowly through the soil, killing most nematodes and insects. EDB is usually formulated with a light petroleum solvent to increase soil penetration and reduce weight and cost. EDB is phytotoxic to plants and seeds and should be used as only a pre-plant treatment. When in contact with skin, EDB can induce a serious chemical burn. As a space fumigant it is especially useful in the fumigation of fruits, vegetables and "spot" treatments of grains.

7. *Ethylene dichloride* (EDC) is an explosive flammable, colorless liquid with a sweetish odor used as a space fumigant. It is slow acting and only moderately toxic to insects. EDC is usually mixed with CT or EDB to reduce both cost and fire hazard. These mixtures do not adversely affect seed germination or milling qualities of grain.

8. *Hydrocyanic acid* (HCN), one of the most toxic insect fumigants, may be used safely on dry foodstuffs, grains or dormant nursery stock. Highly water soluble, it is unsafe on fruits, vegetables and other moist materials. HCN is strongly absorbed by most materials, but this reaction is reversible with time, leaving detectable residue. HCN is flammable and explosive at high concentrations and phytotoxic to most plants. It is never used as a soil fumigant.

9. *Methyl bromide* (MBR) is probably the most important insecticidal space fumigant in use today. It is easily volatilized and penetrates quickly and deeply into most materials at normal temperatures and pressures, and at the end of treatment, the heavier-than-air gas dissipates rapidly from bluk commodities allowing for safe handling. Methyl bromide is non-flammable, non-corrosive and easily applied to warehouses, box cars, bulk grain storage, residences and industrial buildings of all kinds. Food commodities, grains, animal feeds and nursery stock can be fumigated successfully with this material to control unwanted insects, rodents and other pests. Lacking any odor, a warning agent such as chloropicrin should be added as a protective measure. For maximum efficiency when fumigating, buildings and storage facilities must be tightly sealed to prevent excessive diffusion.

Circulation fans or recirculating ducts are needed to prevent stratification of methyl bromide in large facilities and bulk commodities. All flames or sources of heat should be extinguished to prevent the hydrolysis of methyl bromide to hydrobromic acid, a highly corrosive chemical. Methyl bromide also reacts with articles with a high sulfur content, producing off flavors and odors which cannot be corrected by aeration. Rubber or leather goods, furs, woolens, high protein foods and synthetic detergents must be removed before fumigation.

Methyl bromide is also an excellent soil fumigant, which is toxic to a wide range of soil pests. The highly volatile properties of MBR require the use of polyethylene covers. The material is either injected into the soil with a soil chisel and immediately covered by polyethylene tarps or the area is first covered and then the liquid is leleased underneath the cover. It is used primarily as a soil sterilant in green houses, nurseries, plant and seed beds. Soils treated with MBR can usually be planted within a week after treatment.

10. *Sodium methylisothiocyanate,* is used alone or in combination with dichloropropene-dichloropropane

mixtures as nematicides and general soil sterilants. SMDC is a water-soluble liquid that can be applied directly to the soil surface and watered in, or injected into the soil. SMDC & D-D mixtures are injected into the soil and sealed with a drag or water seal. The materials require a waiting period of at least 14 days from time of application to planting due to their phytoxic nature. They are not used as space fumigants.

### *Attractants and repellents*

The principal use of repellents has been against mosquitoes, biting flies, fleas, ticks, and chiggers that attack man and animals. Indalone, diethyl toluamide, ethyl hexanediol, dimethyl carbamate and others have been employed for use on man. Livestock repellents include dibutyl succinate, and butoxy polypropylene clycol.

Attractants are compounds used for sampling populations, luring insects to traps or poison bait, away from crops or for reducing the repellent properties of certain sprays. Compounds used in attractants include molasses, sugar, siglure, yeast extract, geraniol, sex pheromones and others. While the use of attractants has been employed sparingly in insect control they are often quite specific, thus providing a selective weapon against the target species.

## NEMATICIDES

CHEMICAL: Chemical soil treatment offers the most promising means of nematode control at this time. Nematode-toxic chemicals can be brought into contact with the nematodes by mechanical dispersal through the infested soil, percolation in water or a gaseous diffusion of a nematicidal fumigant through the pore spaces of the soil. To kill nematodes, chemicals must enter their bodies. This penetration may occur through the cuticle, through body openings or by infestion during nematode feeding. However, several of the new nematicides apparently reduce nematode activity by suppressing their feeding and/or reproduction rather than actively killing them.

Complete eradication of soil-borne plant parasitic nematodes through soil application of nematicides is impractical for field conditions. The objectives of such treatments is to reduce nematode populations to a level where serious crop damage will not result. Complete eradication is obtainable, however, on limited volumes of soils, such as in greenhouses and seedling production.

Nematicides are generally used as a preventive measure. By the time nematode damage becomes apparent, the infested crops are usually injured so severely that control measures are ineffective in increasing yields. Therefore, control procedures are normally based on pre-plant or time-of-planting application.

SOIL FUMIGANTS: Fumigants are used to reduce infestation of soil-borne nematodes, fungi, insects and weed seeds. Due to the cost of the chemicals and treatment, the use of soil fumigants has been restricted to high volume value crops (i.e. potatoes, fruit trees, strawberries, muck crops, ornamentals, nursery beds, greenhouse soils, and other speciality items. The cost and operation of fumigation equipment is another deterrent to the widespread use of soil fumigation. Most soil fumigants are injected as liquids into the soil where they volatilize to gas and diffuse through the soil mass. The soil must be sealed immediately following an application using a drag, roller, water or polyethylene tarp to maximize the effectiveness of the material. Such things as soil porosity, soil moisture, temperature and organic content of the soil influence control. (See general discussion of fumigants.)

NON-FUMIGANT NEMATICIDES: Contact nematicides are not fumigants, and will not give satisfactory results if applied by fumigant methods. Non-fumigant nematicides must be applied, mixed into, and/or carried by water into contact with the nematodes.

Non-fumigant nematicides may be applied either pre-plant and/or at time of planting. When such chemiclas are used, care must be taken to plant the seeds in the treated portion of the soil. Possibility of injury to germinating seeds and seedlings is ususally minimal when these materials are used correctly.

Chemically, non-fumigant nematicides are generally either organic phosphates or carbamates. As with chemically similar insecticides, these nematicides are nerve poisons which are acutely toxic to man and should be handled with care.

## Formulations of Pesticides

Most chemical compounds used as pesticides are hard, waxy, or oily materials that are unsatisfactory by themselves for application. These compounds (the "active ingredients" as they are called) are dissolved or mixed with other ingredients (the "active or inert ingredients" stated on the pesticide label) to make them miscible in water or otherwise suitable for application. These mixtures, called formulations, are made in different forms for use in different types of application equipment and different purposes. Some formulations generally used in the control of pests are:

DUSTS (d)—dry powders intended for use without mixing with water. Dusts are somewhat more expensive than wettable powders and emusifiable concentrates because greater quantities of dusts must be shipped to obtain the same amount of active pesticide as found in sprays. In general, dusts are more adversely affected by wind and may drift excessively when applied. To be effective, dusts must be applied to wet foliage. Dusts can generally be applied more quickly than sprays and are often used against certain diseases where timing has become critical. The content of active pesticide in the dust is stated as the percentage, by weight, in the formulation.

Granules (G)—coarse, dry particles intended for use without mixing with water. Granular pesticides are especially well suited for applying pesticides for soil pest control by allowing the chemical to leach from the granule into the soil. Pesticides formulated as granules cost more than the same chemical formulated as a wettable powder. The content of active pesticide in a granular formulation is stated as the percentage, by weight, in the formulation.

Wettable Powders (WP)—fine, dry powders that are intended to be mixed with water for use as soil and foliage sprays on many crops. The content of active pesticide in a wettable powder is stated as the percentage, by weight, in the formulation. Wettable powders are generally not completely soluble in water and must be kept in the suspension by constant agitation. Wettable powders have a tendency to produce more wear on pumps and nozzles than emulsifiable concentrates but are safer to use.

Flowables (F)—concentrates of fine particles of pesticide suspended in a liquid intended to be mixed with water for use in ground or aerial foliage sprays. The content of active pesticide in a flowable formulation is stated as the percentage, by weight, in the formulation and also as pounds of active pesticide per gallon of formulation.

Emulsifiable Concentrates (EC) – solution of pesticide in a solvent with an emulsifier added so that that it will suspend in water; used in ground or aerial applications. The content of the active pesticide in an emulsifiable concentrate is stated as the percentage, by weight, and also as pounds of active pesticide per gallon of formulation. Pesticides formulated as emulsifiable concentrates are often somewhat more phytotoxic than wettable powder formulations of the same pesticide. Even though an emulsifiable concentrate is disbursed in water, agitation may be necessary to prevent the pesticide emulsion from separating from the water. Such separation is often referred to as partitioning or breaking. With some formulations, once breaking occurs it may be difficult to re-emulsify the pesticide.

Aerosols—contain the pesticide dissolved in a liquid and held under pressure in a container. When this mixture is released by the pressure valve a fine mist is expelled from the container. This mist contains fine droplets which remain suspended in air for a considerable length of time. Once the liquid carrier evaporates, minute pesticide deposits remain. Aerosols are most appropriate for use within buildings although there are types available for limited outdoor treatment. Insecticidal fogs generated by heating a mixture of an insecticide in a solvent such as kerosene are similar in principle to aerosols. They are employed outdoors for controlling certain flying insects such as mosquitoes and flies. Aerosols are seldom used commercially for foliar application because of drift problems.

Ultra-low-volume Concentrate (ULV)—concentrate liquid pesticide intended to be used undiluted. Both aircraft and ground equipment may be used to apply ULV sprays, but special nozzles such as spinning disks or spinning cages are usually required for their application. The content of active pesticide in an ultra-low-volume concentrate is stated as the percentage, by weight, in the formulation.

Fumigant—volatile pesticide that kills pests with its vapors. Fumigants can be used only where the gas can be confined such as in storage bins, in the soil, within buildings or under gas tight tarps. Fumigants are effective against nematodes, weeds, fungi, and insects. Commercial fumigants are proprietary mixtures that are sold for use variably by volume or by weight.

### Determining Amount Of Formulation To Use

#### *Row Crops*

The amount of pesticide to be applied per acre is usually given in the recommendations as the pounds or ounces of active pesticide to be applied. The amount of formulated pesticide needed to obtain the correct amount of active pesticide will have to be calculated for the formulation to be used. This calculation for dust, granular, and wettable powder formulations can be made using the equation:

$$\textit{ounces or pounds of formulations} = \frac{100R}{P}$$

. . . where R is the recommended amount of active pesticide in pounds or ounces and P is the percentage of active pesticide in the formulation. For example, if 1½ pounds of active pesticide is recommended ($R = 1.5$) and an 80 percent wettable powder is used ($P = 80$):

$$\textit{pounds formulation} = \frac{100 \times 1.5}{80} = 1.88 \textit{ pounds (1 lb. 14 oz.)}$$

The calculation for flowable or emulsifiable concentrate formulations can be made using the equation:

$$\textit{pints formulation} = \frac{8R}{P}$$

. . . where R is the recommended amount of active pesticide in pounds, and P is the pounds of active pesticide per gallon of formulation. For example, if one pound of active pesticide is needed ($R = 1$) and an emulsifiable concentrate containing five pounds of active insecticide per gallon is used ($P = 5$):

$$\text{pints formulation} = \frac{8 \times 1}{5} = 1.6 \text{ pints (about 26 liquid oz.)}$$

The dust and granular formulations are applied directly without water. The amount of formulation of a granule or dust needed to give the recommended amount of active pesticide should be determined first and the equipment then calibrated to deliver exactly that amount of formulation. Wettable powders, flowables, and emulsifiable concentrates are mixed with the spray water. The amount of these formulations needed to obtain the recommended amount of active pesticide per acre or per gallon should be calculated and added to the amount of spray delivered per acre by the sprayer.

Recommendations for the amount of pesticide to be applied per acre are sometimes given as pounds per acre even though the pesticide is applied only as narrow bands across the field. The amount applied per acre may be independent of the width of the rows. At times, the recommendation is given for a specified row width (such as band applications for rootworm control in corn), and adjustment in the amount of actual material must be made when a row width other than that specified is used. This adjustment is made using the equation:

$$\text{pounds per acre} = \frac{RW}{V}$$

. . . where R is the recommended amount of pesticide in pounds; W is the specified row width, in inches; and V is the row width, in inches, that will be used. For example, if 1 pound of active pesticide ($R = 1$) for a 40 inch row is recommended ($W = 40$) and a row width of 30 inches is to be used ($V = 30$):

$$\text{pounds per acre} = \frac{1 \times 40}{30} = 1.33 \text{ lb. (about 21 oz.)}$$

Some recommendations for pesticides are given as the amount of pesticide (as either active insecticide or as a formulation) to be mixed with a specified volume of water. The amount to be used in some volume of water other than the volume of water specified can be calculated using the equation:

$$\text{amount to be used} = \frac{RV}{W}$$

. . . where R is the recommended amount of pesticide, V is the volume of water to be used, and W is the volume of water specified. For example, if two pounds of a 15 percent wettable powder are recommended ($R = 2$) per 100 gallons of water ($W = 100$) and 250 gallons of water are to be used ($V = 250$):

$$\text{amount to be used} = \frac{2 \times 250}{100} = 5 \text{ lbs. of 15\% wettable powder}$$

### *Orchard Crops*

Spray schedules for tree fruit crops indicate the amount of pesticide formulation to mix in 100 gallons of water. If the same chemical comes in two formulations, each with different levels of active ingredients, then the rate for each formulation will be specified. The amount of chemical formulation per 100 gallons is referred to as the standard or dilute rate.

The gallons of dilute spray mix used per acre varies with tree size and spacing. For mature trees, the followings gallons per acre are generally suggested: 400 on apples and sweet cherries; 350 on pears; and 300 on tart cherries, peaches, prunes, and apricots. This is the amount of liquid required to wet trees to the point of drip.

Often, greater efficiency can be achieved by using less water per acre but maintaining the amount of chemical applied to that acre at the same level. This is concentrate spraying and is accomplished by adding 2, 3, 6, 10, or 30 times the amount of pesticide used in dilute application, but applying correspondingly less (i.e. ½, ⅓, ⅙, etc.) spray per acre. Thus, an acre of trees requiring 400 gallons of spray mixture at dilute concentartion for complete coverage will require only 66.6 gallons at 6X concentration or 13.3 gallons at 30X concentration.

## Pesticide Compatibilities

Frequently, it is desirable to combine chemicals designed for different purposes and apply them as a single spray application. Multiple combinations of fungicides, plus various combinations of fungicides, insecticides, miticides, herbicides, growth regulators, liquid nutrients, etc. are often used to save time and labor. This short cut may be profitable or disastrous, depending on the compatibility of the materials to be mixed.

When pesticides are used in combination without impairing the efficiency of the component chemicals, or resulting in injury to the plants to which they are applied, the combination is "compatible." If the combination results in reduced efficiency, causes plant damage, or has undesirable physical properties, the mixture is "incompatible."

Incompatibility may be due to the alteration of either the chemical or the physical properties of one or more products in the spray mixture. It is frequently the cause of poor performance of multiple pesticide combinations.

Chemical incompatibility is the breakdown or loss in effectiveness of one or all of the components. The mixture, therefore, may not be as effective in controlling unwanted pests or may cause injury to the plant (phytotoxicity). For example many organic pesticides break down when used with alkaline materials (lime, lime-sulfur, and bordeaux mixture).

Physical incompatibility occurs when the mixture becomes unstable and results in the formation of a heavy precipitate or buttery mass, excess foaming, or poor distribution of the chemical. Often, this type of incompatibility causes settling-out of the chemicals in the spray tank and leads to clogging of sprayer nozzles and screens. Solubilization of captan and oil or sulfur and oil are examples of physical incompatibility.

## Types of Application Equipment

There are several standard types and a large number of improvised or special types of pesticide application equipment used in crops. Some of the standard types are:

Dusters—blow fine particles of pesticide dusts onto the crop. Dusters have advantages over sprays in that the dusters are faster, lighter, and cheaper to purchase and operate. The fine dusts do not penetrate well into tight places and may give excessive chemical drift into adjacent fields and waters under windy conditions. To be effective, dusts must be applied to wet foliage.

Granular Applicators—apply coarse particles to the soil or foliage of plants. They may be adapted to apply the pesticide granules into a furrow in the row, into a band over the row, or to broadcast the granules over the whole field. A granular applicator is like a duster in that granular applicators do not require water and are light and relatively simple. It has advantages over a duster as the granules will penetrate into heavy foliage and tight places and the granules will not be carried out of the field by the wind. When applying granules to foliage, the leaves should be wet so the chemical will adhere to the surface of the leaf and spread the material for better coverage.

Weed-type Sprayers—apply pesticides mixed with water onto the soil or foliage of plants at relatively low pressure. The weed-type sprayer is the type of pesticide equipment that is most commonly used in field crops in Michigan. They are adequate for the control of most pests of field crops when properly calibrated and used. They usually do not have sufficient capacity to adequately penetrate and cover heavy vegetation. The capability of some weed-type sprayers can be increased by adding a higher capacity pump and by using drop nozzles to apply the pesticide to the sides as well as the tops of the plants. They must be used under still or calm conditions to avoid drift and achieve good coverage.

Row-type Sprayers—apply pesticides mixed with water onto the foliage of plants at relatively high pressure. Row-type sprayers can be adapted to use in all field crops by adopting special booms or by using different nozzles for the different crops.

"Hi-Boy" Sprayers—weed-type or row-type sprayers mounted on high clearance tractors. They are especially suited for treating crops such as sweet corn, blueberries or nursery stock. The "Hi-Boy" sprayer can be adapted to the same uses in other crops as are the regular tractor-mounted sprayers.

Hydraulic Sprayers—designed to apply dilute pesticidal sprays mixed with water up into trees, shrubs, and the walls of buildings, or onto livestock. The spray is delivered at high pressure through a single nozzle in a pray gun. The spray gun can usually be adjusted to give from a driving stream to a fine mist of the pesticide. The hydraulic sprayer may vary in size from the small unit used in gardens to very large machines used to spray large orchards. Their greatest advantage is that they can apply pesticides into the tops of trees and exactly where needed. The orchard sprayer is lower and requires more water and more work for orchard spraying than an air blast sprayer. Generally, plants are treated to the point of chemical run-off and the concentration in the tank determines the deposit on the plant or soil surface.

Air-blast Sprayers—use a high velocity wind to blow droplets of a pesticide in water onto trees or vegetable crops. A large fan directs a blast of air over nozzles that are delivering small droplets of water with pesticides—and the blast carries the droplets out to the surface to be treated. These machines are faster than hydraulic sprayers and usually result in more even spray coverage. Air blast sprayers are complex and must be very carefully adjusted to achieve maximum effectiveness. The air blast sprayer may also use less water than an orchard type hydraulic sprayer. The amount of pesticide mixed with the water must be carefully adjusted to correspond to the reduced rate (called "concentrate") of water. This adjustment is made by multiplying the amount of pesticide recommended per 100 gallons of dilute spray (R in the equation below) by the concentrate rating of the air blast sprayer to be used (C in the equation below):

$$\textit{amount to be used} = RC$$

For example, if one quart of pesticide per 100 gallons of water of a dilute spray is recommended ($R = 1$) and a "4X" concentrate air blast sprayer is to be used ($C = 4$):

$$\textit{amount to be used} = 1 \times 4 = 4 \textit{ quarts per 100 gallons of water}$$

Ultra-low Volume (ULV) sprayers and aerosol generators—used to apply very fine droplets of highly concentrate pesticides. They are used extensively for fly and mosquito control in ground applications and for the same use as well as pest control in crops in aerial applications. Their use is limited to pesticide formulations with the proper physical characteristics to ensure fine droplets. The drift from these machines is great because of the fine droplets that they form. Insecticides that are highly toxic or that may persist as undesirable residues on crops are not suitable for ULV or generators because of the danger of drift.

**Fumigants**

Soil fumigants are often applied under pressure through a pump powered by the power take-off shaft of the tractor, by an independent gasoline engine, or by a ground wheel. Pumps used for nematicides are specially constructed for resistance to the corrosive action of these materials. With a constant pressure on the fumigant and a constant forward speed, the application rate can be regulated by placing discs of noncorrosive metal with accurately bored orifices in unions in the lines between the pump and the outlets in the soil. Good screen strainers must be placed in the suction line running to the pump as well as in front of each of the orifice discs.

For simplicity and accuracy, the ground-wheel drive pump has much to offer. This pump is set according to calibration charts for any desired rate; thus, regardless of the tractor speed, the appldication rate will be uniform. With a good flow divider, no discs are needed to regulate the delivery rate.

There are several types of gravity flow equipment available which are simple, economical, and reasonably accurate. With these units, tractor speed must be accurately regulated.

A heavy drag, roller, or cultipacker must be pulled behind the applicator or by a second tractor to seal the openings made by the machine and thus retard the escape of the gas.

## Pesticide Application Techniques

Pesticides can be applied in a variety of ways. Some common types of applications used in Michigan are outlined below:

Seed Treatment—coverage of seeds, tubers, bulbs, and roots with protectant chemical prior to planting. Treating seed is best done by the seed dealer who has specialized seed treating equipment. Special formulations of pesticides for use by the grower to treat his own seed are available as are relatively simple home made treaters. These chemicals should be used when a seed treatment is needed and ready-treated seed is not available. Tubers, bulbs, corms, and roots are treated in similar ways. Certain insects and diseases are commonly controlled using these methods.

Broadcast Soil Application—coverage of the soil of the entire field with a pesticide spray or granules prior to planting. Broadcast soil applications should be made just before final discing or dragging of the field. The final fitting operation will incorporate the chemical into the upper surface of the soil.

Furrow Application—placement of a pesticide in a narrow line in the soil below and to the side of the seed at planting time. Granular materials are usually used for this type of application and the pesticide is often dropped into the fertilizer furrow.

Soil-band Application – placement of sprays of granular pesticide in a band centering over the row of the crop leaving an area between the rows untreated. The material is usually placed above and out of contact with the seed and is covered with soil immediately after application. Soil band applications can be made at the time of planting or, if special equipment is available to apply and cover the pesticide, after the plants have emerged.

Foliage Sprays, Granular Applications, or Dusts —applications of pesticides to the plant itself. This type of application can be made either as a broadcast type to cover the entire field or as a directed application to cover only the row of plants. Broadcast treatment is common in small grains and hay crops and directed application to concentrate the pesticide on the plants grown in rows.

Aerial Sprays—applications of pesticides made from aircraft. Aerial applications of granules or dust can also be made, but are seldom used in Michigan. Aerial applications are especially desirable for treating large plants or trees over an extensive area or when damage can be done to the crop by a tractor-drawn sprayer moving through the field. Most aerial sprays are applied at the rate of from 1 to 5 gallons of spray per acre. Ultra-low-volume (ULV) or concentrate aerial sprays can be used against some insect pests. The sprays are made at rates of about 4 to 16 liquid ounces of spray per acre.

Sanitary Sprays or disinfestation practices—applications of special pesticides used in the home or to kill stored grain pests in cracks and corners of storage bins and grain handling equipment, before new grain is stored in the area. Sanitary sprays are especially recommended in wooden bins, the boots of the grain handling equipment, or other places that cannot be swept clean of the debris that harbors the pests.

Space Fumigation—application of insecticides as gases or as liquids that will vaporize—in buildings, stored grain or soil. The fumigants will penetrate and kill the insects within the building, grain or soil. Fumigation is a hazard by nature and should be done only by someone experienced in the use of fumigants. Two men should always work together on all fumigation operations.

Broadcast Soil Treatment of Fumigants—applying nematicides evenly to the entire filed. Fumigants are injected from chisels or shanks spaced 8 to 12 inches apart and 6 to 10 inches deep. Most chemicals diffuse at least five to ten inches from the point of injection, giving complete coverage. Chisels work best when the shanks are staggered on the tool bar so that adjacent chisels are several inches apart from the front to back. Staggering the chisels helps prevent clogging. A pressure-type applicator provides an even distribution of chemicals using this system.

The moldboard plow is also used for broadcast application. Delivery tubes attached to the rear of the plows discharge chemicals into the bottom of the open furrow where they are covered immediately.

Blade applicators have been used to insure an even more effective injection pattern than can be obtained by the plow-sole or injector applicators. With these applicators, the fumigant is sprayed as a continuous "sheet," avoiding some of the difficulties encountered in obtaining lateral diffusion. The injection boom, adapted with fan type nozzle, is mounted in a protected recess beneath the blade and sprays the entire width of the soil as it flows over the rear edge of the blade. The soil must be in excellent tilth and free of trash for proper operation. Pressure equipment should be used.

Row Application—most commonly used control in row crop production, is less expensive than broadcast. Either pressure or gravity-flow equipment can be used. In row application, the chemical is placed six to eight inches deeps, then covered with a listed bed of soil formed by two disc plows mounted behind the fumigation shanks. Listed bed rows are used to seal volatile fumigants in the soil, except when the chemical is applied during planting.

## Pesticide Registration and Tolerance

All pesticide uses must be approved (registered) by the Environmental Protection Agency. This includes uses for mixtures of chemicals either as formulated materials or those to be used together in the spray tank. Registration is based on several years of supporting data to show that the chemical is effective and safe to the crop and that it poses minimal hazard to the environment. Any pesticide sold in Michigan must be registered with the Michigan Department of Agriculture.

To keep the level of pesticide residues on food crops within safe limits, the Environmental Protection Agency establishes "tolerances" for each pesticide. If a food crop has residues of a pesticide higher than that prescribed by law, the crop cannot be sold for human consumption. If the crop is sold, it can be confiscated and destroyed. High residues on food crops can be avoided by stopping chemical application a specified number of days before harvest. The "days before harvest" allowed differs for each chemical and depends on how fast it will break down, the rate that is used, and its relative toxicity. Follow the directions on the label or in spray recommendations to avoid problems.

## Restricted Use Pesticide Dealers

Persons who wish to sell restricted use pesticides to the ultimate user in Michigan shall be licensed with the Michigan Department of Agriculture as provided by a recent amendment to the Michigan Economic Poison Law, Act No. 297, Public Acts of 1949, and Regulation No. 633 effective March 22, 1972.

Applicants shall apply for a license on a form provided by the Michigan Department of Agriculture and shall qualify by passing a written examination on the laws and regulations and the dealer's responsibility in carrying on the business of a restricted use pesticide dealer. The forms and information necessary to study for the examination are available from the Plant Industry Division of the department at the main office (5th Floor Lewis Cass Building, Lansing, 48913, phone 517-373-1087) or at the following district office locations:

- ***Traverse City, 49684, 124 N. Division St., phone (616) 947-3171***
- ***Grand Rapids, 49507, 2757 Eastern, S.E., phone (616) 245-8735***
- ***Frankenmuth, 48734, Frankenmuth Professional Bldg., Room 101, 140 Tuscola Avenue, phone (517) 652-9166***
- ***Benton Harbor, 49022, 2189 M-139, phone (616) 925-1941***
- ***Detroit, 48203, 1120 W. State Fair, phone (313) 368-2230***
- ***Escanaba, 49829, State Office Bldg., Room 126, phone (906) 786-5462***

No appointment is necessary for examination given at 10:00 a.m. and 3:00 p.m. on the first Monday of every month at each office. However, an examination taken at other times must be by a special appointment. The applicant may call the selected office for such an arrangement. The $50.00 license fee must be paid at the time of the examination.

## Safe Use of Pesticides

Pesticides are poisons that kill. Many of them are also highly toxic to man and other animals and some of them retain their potency long after they have been applied in a field. They should be stored, handled, and applied with respect to their dangerous nature. The label of the pesticide container, by law, clearly lists the precautions needed for the safe use of that pesticide. *READ THE LABEL* to be sure that these precautions are understood and that they can be followed before buying a pesticide. Many pesticides used on food and forage crops have limitations on the length of time that they can be applied before harvest. Such information is stated in all recommendations where applicable. Almost all cases of direct poisoning from pesticides result from carelessness in storing and handling the concentrate pesticide. Store all pesticides where they cannot possibly be contacted accidentally by children, livestock, or feed. A sturdy, locked cabinet in a machine shed is a good place to store them. Handle all pesticides with care; *READ THE LABEL* on the container for special equipment that may be needed for handling or aplying the pesticide. Wash and change clothes after using a pesticide and wash immediately if concentrate pesticide is spilled on the skin.

Use care in applying the pesticide to avoid drift into adjacent fields or waters and exposure of bees, livestock, and wildlife to pesticides. Apply sprays only when winds are negligible (generally less than five miles per hour) and cover soil pesticides immediately after application. Advise neighboring beekeepers that pesticides are to be applied so that they can move their hives if necessary. Honey bees are very important to Michigan agriculture and beekeepers deserve accommodations to protect the bees from unnecessary kill.

Pesticides, such as DDT and dieldrin, can persist as pollutants in our soils, streams, and even in our bodies long after they have been applied. The actual threat that these residues pose is disputed, but the fact that they do exist is not. Their use should be minimal and only when a less persistent alternative is unknown. All pesticide recommendations are made with this point in mind. Pesticides can also kill organisms other than the pests for which they are applied. Use the pesticides only when they are needed to protect the crop and then use only the recommended amount of pesticide in the safest way possible. Research on other, non-chemical means of control is underway. Presently, in the near future, chemicals provide the only reliable means of control. They must be used safely and with discretion.

**Some Precautions**

1. Read the label—ensure that label is current. Read completely, understand fully, and follow explicitly all directions on chemical containers, and in pertinent brochures.

2. Wear proper clothing and equipment, such as masks, goggles, respirator, and rubber gloves, if directions call for them. Never stir any chemical solution with your hands. Treat all pesticides with respect. Be sure to wash clothing and equipment thoroughly after each use.

3. Do not eat, drink, or smoke while mixing or applying pesticides. Wash hands and face immediately after spraying.

4. Rinse and drain the empty pesticide containers with water or other diluting agent being used in the spray program. Each container should be rinsed 3 times allowing 30 seconds for draining. Drain each rinse into the spray tank before filling it to the desired level.

5. Destroy empty pesticide containers by burning, or crushing and deep burial where water supply will not be contaminated. If you burn the containers, stay out of the smoke. Do not burn contaniers that contained 2,4-D and other growth regulating type materials.

6. Mix only the quantity of pesticides you need, then use it all. Avoid storage if possible. Protect labels so they won't become lost or illegible. Never use unlabeled chemicals.

7. Avoid contamination of wells, ponds, streams and other water supplies by tank overflow, by-pass, recycling through suction hose at time of filling sprayers.

Never leave the filling hose immersed in liquid in the spray tank, nor leave the sprayer unattended while it's being filled. If the filling hose is immersed in the spray liquid in the tank, shutting off the water supply at a level lower than the sprayer, a siphoning action may be created which draws liquid from the tank into the well. In cases of extremely poisonous chemicals, a new well may have to be constructed following accidental siphoning.

8. Dispose of left-over spray materials in a safe manner. Don't empty the spray tank into streams or areas where water run-off will carry it into ponds or other water sources. Avoid mixing greater quantities of pesticides than will be used. Spray small amounts of diluted pesticides on soil surface in a confined area away from livestock, and water suppiles so it can be broken down by microbial activity, sunlight, or chemical activity.

9. Store chemicals in a separate storage area. Keep it locked, with keys known only to responsible adults. Keep all chemicals out of reach of children, pets, and irresponsible persons. Label closed storage area.

10. Spray pesticides only on quiet days or when wind is at a minimum and blowing away from susceptible plants. Don't forget your neighbor—the wind may be blowing the material on his susceptible plants.

11. Calibrate sprayers at least once or twice a year. Orifice sizes change, due to corrosion. Know exactly how much spray material you're applying per acre.

Keep all equipment in good working condition. Be sure you know dosages, pressures, and tractor speeds recommended for the material you are using.

12. Never use a sprayer which has had *"hormone-type" weed killers* in it (2,4-D, 2, 4, 5-T; M. C. P.; "brush killers") on desirable plants. Traces of these chemicals are impossible to remove. Repeated rinsings and flushings will not suffice so that the application equipment may be used with confidence on such extremely susceptible plants as tomatoes, beans, (melons, cucumbers), zinnias, nasturtiums, grapes and roses. For small-area application, reserve a completely separate sprayer, sprinkling can or "gallon-jug" applicator for hormone-type weed killers. This is the safest procedure.

If it becomes absolutely necessary to use equipment which has had hormone-type weed killers in it, remember that the more quickly it is cleaned after use, the easier the job will be. Flush all contaminated tanks, hoses, nozzles and pumps immediately after use. Spread the contaminated flushing water out in the field away from buildings, where livestock cannot drink it, or where fumes or drift (or dust, after the material has dried) cannot injure garden ornamentals. If possible, use warm soapy water for the initial flushings.

After several thorough flushings with clean water, fill sprayer again, and then add a "neutralizing agent" to the water. Neutralizing materials, such as household ammonia (1 quart to 25 gallons of water), activated charcoal (1 pound to 25 gallons of water), baking soda (1 pound to 10 gallons of water), or trisodium phosphate (1 pound to 25 gallons of water), are satisfactory. Dissolve materials thoroughly, then pump solution through the entire system. Let stand in the sprayer overnight. Remove the contents in areas where soil injury can be tolerated.

After several such rinsings, equipment can be used on less sensitive crops, such as red clover, sweet clover, alfalfa and soybeans to apply insecticides and fungicides. More tolerant field crops, such as corn and small grain, can usually be sprayed with 2,4-D contaminated equipment if spraying is preceded by thorough rinsing.

## Toxicity Ratings of Representative Chemicals

There are several types of toxicological data used to evaluate the hazards of chemicals to humans. Acute toxicity is the short-term effect of chemical after oral (mouth), dermal (skin), eye contact or inhalation. These data are usually expressed as $LD_{50}$ (Lethal dose required to kill 50% of the test animals). The figures are a good index of the toxicity from an accidental exposure or ingestion. Long term (chronic) toxicity data is also obtained by feeding test animals for longer periods of time. Animals are checked to be sure that the chemical has no effect on reproduction over three generations. Tests are also run to ascertain that the chemical has no carcinogenic, mutagenic or teratogenic effects.

Toxicity values are a guide to the toxic effect of a chemical on humans or other animals. They do not constitute the only factor regarding the hazards associated with exposure to the chemicals. A compound may be extremely toxic but present very little hazard due to dilution, low volatility, or safe use. However, a chemical with low toxicity may be hazardous due to concentration, high volatility, or careless use. Pesticides are generally categorized according to acute oral toxicity, but the dermal toxicity is of equal or greater practical importance to the applicator. Ordinarily a user does not injest the chemical, although he may inadvertently do so while eating or smoking on the job. He may, however, absorb a quantity of the pesticide through his skin.

The oral values given in the tables were determined on rats. They cannot be directly extrapolated to humans, but do show relative toxicities between the chemicals. The range in acute oral or acute dermal LD 50s for a particular chemical is usually due to the sex of the test animal or to the use of different strains or species of animals.

In order to determine the general order of toxicity values into 4 classes, the lower the $LD_{50}$ value, the more *dangerous* the material is.

# Table 2 Oral and Dermal Toxicity Ratings for Selected Chemicals

| | | $LD_{50}$ - mg/kg Oral | Dermal |
|---|---|---|---|
| Class 1. | Highly toxic | 1-50 | 1-200 |
| Class 2. | Moderately toxic | 50-500 | 200-2000 |
| Class 3. | Low order of toxicity | 500-5,000 | 2,000-20,000 |
| Class 4. | Very low order of toxicity | over 5,000 | over 20,000 |

Classes 3 and 4 are generally considered of low hazard, even for the homeowner who usually does not have proper protective equipment.

Symbols Used in Tables

H = Herbicide
F = Fungicide
I = Insecticide

S = severe reaction
M = mild reaction
L = little or no reaction at dosages tested

Ø = persistent and accumulative pesticides
≠ = highly toxic pesticides

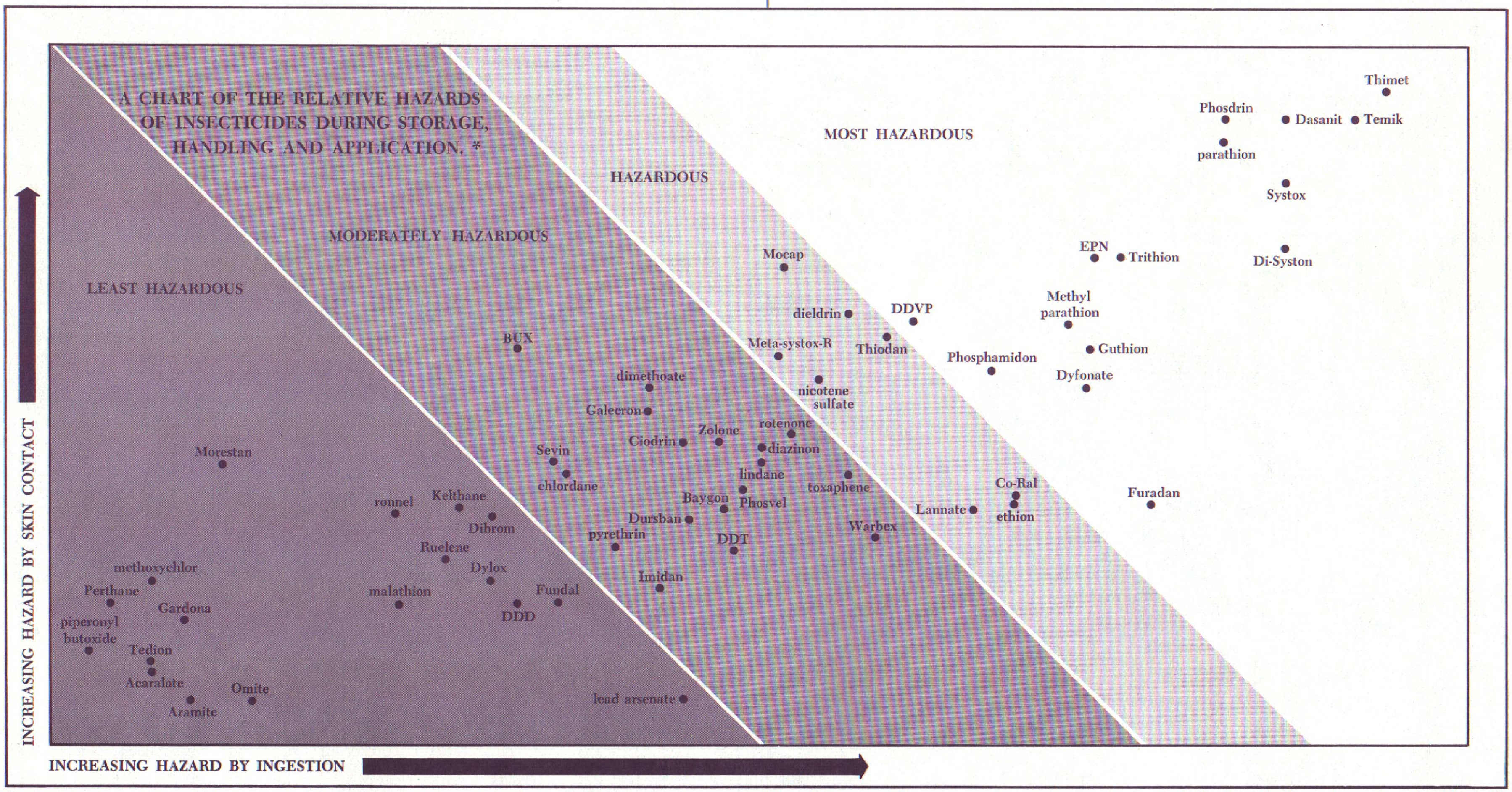
| Name | Oral $LD_{50}$ | Dermal $LD_{50}$ | Class |
|---|---|---|---|
| AAtrex | see atrazine-------------------- | | H |
| Acaraben | see chlorobenzilate------------- | | I |
| Acaralate | see chloropropylate------------- | | I |
| ≠Acti-dione PM | see cyclohexamide--------------- | | F |
| Agrox NM | see maneb----------------------- | | F |
| alachlor | 1200 | S | H |
| Alanap | 8200 | L | H |
| Øaldrin | 39-60 | 98 | I |
| allethrin | 680-1,000 | 11,200 | I |
| amiben | 3500-5620 | 3,136 | H |
| Amino-triazole | see amitrole------------------------ | | H |
| amitrole | 5000-15,000 | >10,000 | H |
| Amizol | see amitrole------------------------ | | H |
| Ammate X | 1600-3900 | L | H |
| Arasan | see thiram-------------------------- | | F |
| Aspon | 891-1700 | 3,830 | I |
| Aspirin | 750--------------------------------- | | Pain Reliever |
| atrazine | 3080 | 10,200 | H |
| Bacillus thuringiensis | L | L | I |
| Banvel D | see dicamba------------------------- | | H |
| Baygon | 95-104 | >1000 | I |
| ≠Baytex | see fenthion------------------------ | | I |
| Benlate | see benomyl------------------------- | | F |
| benomyl | 9590 | L | F |
| binapacryl | 161 | 1350 | I |
| Biotrol | see Bacillus thuringiensis--------- | | I |
| Bordeaux mixture | 300 | >1000 | F |
| boron | 2500 | L | H |
| Botran | 404->10,000 | M | F |
| Bravo | >3750 | >10,000 | F |
| bromacil | 5200 | >5000 | H |
| Brominal | see bromoxynil---------------------- | | H |
| bromoxynil | 190-270 | M | H |
| ≠Brozone | see methyl bromide------------------ | | F |
| Buctril | see bromoxynil---------------------- | | H |
| butylate | 4,660 | >4,640 | H |
| Bux | 87 | 400 | I |
| Caffein (coffe, tea) | 200--------------------------------- | | beverage |
| captan | 9000-15,000 | L | F |
| carbaryl | 500-850 | >4000 | I |
| ≠carbofuran | 5 | 885 | I |
| ≠carbophenothion | 10-30 | 27-54 | I |
| chlorbenside | 3000 | M | I |
| Øchlordane | 335-430 | 690-840 | I |
| chlorobenzilate | 1040-1220 | >5000 | I |
| Chloro-IPC (CIPC) | 5000-8000 | L | H |
| chloroneb | >11,000 | >5,000 | F |
| ≠Chloro-O-Pic | see chloropicrin-------------------- | | F |
| ≠chloropicrin | .8 mg/liter | S | F |
| chloropropylate | 34,600 | 10,200 | I |
| Ciodrin | 125 | 385 | I |
| Co-Ral | 15-41 | 860 | I |
| ≠cyclohexamide | 1.8-2.5 | S | F |
| Cygon | see dimethoate---------------------- | | I |
| 2,4-D | 375-800 | 800-1500 | H |
| Daconil | >3750 | >10,000 | F |
| Dacthal | >3000 | >10,000 | H |
| dalapon | 7570 | M | H |
| ≠Dasanit | 2-11 | 3-30 | H |
| 4-(2.4-DB) | 400-500 | 800 | H |
| D-D Mixture | 140 | 2,100 | F |
| DDVP | see Vapona-------------------------- | | I |
| ≠Delnav | see dioxathion---------------------- | | I |
| Demosan | see chloroneb----------------------- | | F |
| ≠demeton | 2-6 | 8-14 | I |
| Dexon | 60 | M | F |
| Diazinon | 76-108 | 455-900 | I |
| Dibrom | see naled--------------------------- | | I |
| dibromochloropropane | 172 | 1420 | F |
| dicamba | 1028 | M | H |
| dichlobenil | 3160 | 500 | H |
| dichlone | 1300-2250 | S | F |
| Ødieldrin | 46 | 60-90 | I |
| Difolatan | 4600-6200 | S | F |
| Dikar | see zinc ion maneb & Karathane----- | | F |
| dimethoate | 215 | 400-610 | I |
| ≠dioxathion | 23-43 | 63-235 | I |
| Dipel | see Bacillus thuringiensis--------- | | I |
| diphenamid | 970-1798 | >6320 | H |
| Dipterex | 560-630 | >2000 | I |
| ≠Di-Syston | 2-7 | 6-15 | I |
| Dithane D-14 | see nabam--------------------------- | | F |
| Dithane M-22 | see maneb--------------------------- | | F |
| Dithane M-45 | see zinc ion maneb------------------ | | F |
| Dithane Z-78 | see zineb--------------------------- | | F |
| ≠Dithio | 5 | 8 | I |
| diuron | 3400 | M | H |
| ≠DNBP | 40 | 500 | H |
| ≠DNOC | 30 | 150-600 | F,I,H |
| dodine | 750-1550 | >1500 | F |
| Dorlone | 250-500 | S | F |
| Dowpon | see dalapon------------------------- | | H |
| Sursban | 97-276 | 500-2000 | I |
| Du-Ter | 108 | 5000 | F |
| ≠Dyanap | see Alanap and DNBP---------------- | | H |
| ≠Dyfonate | 16 | 319 | I |
| Dylox | 560-630 | > 2000 | I |
| Dyrene | 2710 | M | F |
| ≠Edco MBX | see methyl bromide------------------ | | F |
| ≠Elgetol | see DNOC---------------------------- | | F,H |
| ≠endosulfan | 18-43 | 74-130 | I |
| ≠EPN | 8-36 | 25-230 | I |
| Eptam (EPTC) | 1630-3160 | 2641 | H |
| ≠ethion | 27-65 | 62-245 | I |
| Ethyl alcohol | 4500-------------------------------- | | beverage |

| Name | Oral $LD_{50}$ | Dermal $LD_{50}$ | Class |
|---|---|---|---|
| ethylene dibromide | 117-146 | 300 | F,I |
| ethylene dichloride | 770 | 3890 | I |
| ƒFamphur | 35-62 | 1460-5093 | I |
| fenthion | 215-245 | 330 | I |
| ferbam | 17,000 | >1000 | F |
| Ferradow | see ferbam------------------------ | | F |
| fixed copper | 3000-6000 | L | F |
| folpet | >10,000 | M | F |
| Fore | see zinc ion maneb----------------- | | F |
| formaldehyde | 800 | M | F |
| Formalin | see formaldehyde------------------- | | F |
| Fumazone | see dibromochloropropane----------- | | F |
| Fundal EC, SP | 162-170 | 225 | I |
| ƒFuradan | see carbofuran--------------------- | | I |
| Galecron EC, SP | 162-170 | 225 | I |
| Gasoline | 150-------------------------------- | | F |
| Gardona | 4000-5000 | >5000 | I |
| Glyodex | see glyodin and dodine------------- | | F |
| glyodin | 3,170-5,770 | M | F |
| Glyoxide | see glyodin------------------------ | | F |
| ƒGuthion | 11-13 | 220 | I |
| HCB | see hexachlorobenzene-------------- | | F |
| Øheptachlor | 100-162 | 195-250 | I |
| hexachlorobenzene | ? | M | F |
| Hyvar X-WS | see bromacil----------------------- | | H |
| Imidan | 147-216 | 3160 | I |
| Karathane | 980-1190 | 9400 | F,I |
| Karbam | see ferbam------------------------- | | F |
| Karmex | see diuron------------------------- | | H |
| Kelthane | 1000-1100 | 1000-1230 | I |
| Kocide | L | L | F |
| Korlan | see Ronnel------------------------- | | I |
| ƒLannate | see methomyl----------------------- | | I |
| Lasso | see alachlor----------------------- | | H |
| Ølead arsenate | 1050 | >2400 | I |
| lime | 7340 | M | F |
| Ølindane | 88-91 | 900-1000 | I |
| linuron | 1500 | M | H |
| Lorox | see linuron------------------------ | | H |
| malathion | 1000-1375 | >4444 | I |
| maneb | 6750-7500 | >1000 | F |
| Manzate | see maneb-------------------------- | | F |
| Manzate D | see maneb-------------------------- | | F |
| Manzate 200 | see zinc ion maneb----------------- | | F |
| MCPA | 650-700 | >1000 | H |
| Mertect 160F | see thiabendazole------------------ | | F |
| metaldehyde | 600-1000 | ? | I |
| Meta-Systox R | 65-75 | 250 | I |
| ƒmethomyl | 17-24 | 1500 | I |
| methoxychlor | 5000 | >6000 | I |
| ƒmethyl bromide | 1 mg/liter | S | F |
| ƒmethyl parathion | 14-24 | 67 | I |
| Methyl Trithion | 98-120 | 190-215 | I |
| Mildex | 980-1190 | 9400 | F |
| Mitox | see chlorobenside------------------ | | I |
| monuron | 3500-3600 | M | H |
| Morestan | 1100-1800 | >2000 | F,I |
| Morocide | see binapacryl--------------------- | | I |
| Mylone | 500-650 | M | F |
| nabam | 395 | >1000 | F |
| naled | 250 | 800 | I |
| napthalene | 2000-3000 | M | I |
| Nemagon | see dibromochloropropane----------- | | F |
| Neguvon | 560-630 | >2000 | I |

| Name | Oral $LD_{50}$ | Dermal $LD_{50}$ | Class |
|---|---|---|---|
| Niacide M | L | M | F |
| Nicofume | 83 | 285 | I |
| nicotine sulfate | 83 | 285 | I |
| No Bunt "40" | see hexachlorobenzene-------------- | | F |
| Nu Leaf | see ferbam------------------------- | | F |
| Omite | 2500 | ? | I |
| Orthocide | see captan------------------------- | | F |
| Ortho-nabam | see nabam-------------------------- | | F |
| Ortho-zineb | see zineb-------------------------- | | F |
| Panoram 75 | see thiram------------------------- | | F |
| paradichlorobenzene | >1000 | M | I |
| ƒParaquat | 157 | M | H |
| ƒparathion | 4-13 | 7-21 | I |
| PCNB | 1650-2000 | M | F |
| Pentac | 3160 | >3160 | I |
| Perthane | >4000 | L | I |
| Phaltan | see folpet------------------------- | | F |
| ƒphorate | 1-3 | 3-6 | I |
| phosalone | 135 | 390 | I |
| ƒPhosdrin | 4-6 | 4-5 | I |
| ƒphosphamidon | 24 | 107-143 | I |
| Phybam-S | see dichlone, ferbam, and sulfur--- | | F |
| Phygon XL | see diclone------------------------ | | F |
| ƒPicfume | see chloropicrin------------------- | | F |
| Pipron | 2529 | ? | F |
| Planavin | 2000 | 2000 | H |
| Plantvax | 3200-3820 | 8000 | F |
| Polyram | 6400 | >2000 | F |
| Prefar | 770 | 3950 | H |
| ƒPremerge | see DNBP--------------------------- | | H |
| Princep | see simazine----------------------- | | H |
| Pyramin | see pyrazon------------------------ | | H |
| pyrazon | 2500-4200 | M | H |
| pyrethrum | 820-1870 | >1880 | I |
| Rabon | 4000-5000 | >5000 | I |
| Radapon | see dalapon------------------------ | | H |
| Ramrod | 1200 | M | H |
| Randox | 700 | S | H |
| Res-Q | see captan, maneb & hexachlorobenzine | | F |
| Ro-Neet | 3160-4100 | ? | H |
| ronnel | 1250-2630 | >5000 | I |
| rotenone | 50-75 | >940 | I |
| Ruelene | 460-635 | 2000-4000 | I |
| Ryania | 750-1200 | >4000 | I |
| Sevin | see carbaryl----------------------- | | I |
| silvex | 650 | ? | H |
| simazine | >5000 | L | H |
| Sinbar | see terbacil----------------------- | | H |
| ƒSinox | see DNBP--------------------------- | | F,H |
| sodium borate | 2000 | M | H |
| sodium bypochlorite | M | M | F |
| Solubor | see sodium borate------------------ | | H |
| Stoddard solvent | M | M | H |
| streptomycin | 9000 | >600 | F |
| ƒSulfotepp | 5 | 8 | I |
| sulfur | >17,000 | M | F |
| Sutan | see butylate----------------------- | | H |
| ƒSystox | see demeton------------------------ | | I |
| ƒ2,4,5-T | 481-500 | M | H |
| Tandex | 3000 | >15,300 | H |
| Table salt | 3320------------------------------- | | Mineral food item |
| Tedion | see tetradifon--------------------- | | I |
| Telone | 250 | S | F |
| Telvar | see monuron------------------------ | | H |

| Name | Oral $LD_{50}$ | Dermal $LD_{50}$ | Class |
|---|---|---|---|
| Tenogran | 3700-5400 | >10,000 | H |
| ƒTEPP | 1.05 | 2.4 | I |
| terbacil | >5000 | >5000 | H |
| Termil | >3750 | >10,000 | F |
| Terraclor | see PCNB--------------------------- | | F |
| Terrazole | 2000 | ? | F |
| Tersan | see thiram------------------------- | | F |
| tetradifon | >14,700 | >10,000 | I |
| thiabendazole | 3100 | ? | F |
| ƒThimet | see phorate------------------------ | | I |
| ƒThiodan | see endosulfan--------------------- | | I |
| thiram | 780 | S | F |
| Thuricide | see Bacillus thuringiensis---------- | | I |
| Thylate | see thiram------------------------- | | F |
| Tillam | 1120 | >2936 | H |
| TOK E-25 | 1470 | M | H |
| Treflan | see trifluralin-------------------- | | H |
| trifluralin | 3700->10,000 | >5,000 | H |

| Name | Oral $LD_{50}$ | Dermal $LD_{50}$ | Class |
|---|---|---|---|
| ƒTrithion | see carbophenothion---------------- | | I |
| ƒTrizone | see methyl bromide & chloropicrin-- | | F |
| Vapam | 820 | 800 | F |
| ƒVapona | 56-80 | 75-107 | I |
| Vegedex | 850 | 2200-2800 | H |
| Vegiben | 3500-5620 | 3136 | H |
| Vernolate | 1780 | 4640 | H |
| Vitavax 75 | 3200-3820 | 8000 | F |
| Vorlex | 305 | M | F |
| Warbex | 35-62 | 1460-5093 | I |
| Weedazole | see amitrole----------------------- | | H |
| ƒZectran | 25-37 | 1500-2500 | I |
| zinc ion maneb | >8000 | >8000 | F |
| zineb | >5200 | >1000 | F |
| ƒZinophos | 9-16 | 8-15 | I |
| ziram | 1400 | >1000 | F |
| Zolone | see phosalone---------------------- | | I |




**Values are expressed in terms of $LD_{50}$ toxicities of technical chemicals to warm blooded animals. In most cases, the formulated chemical toxicity is significantly lower than that of the technical chemical.*