

## 9.2.2 Pesticide Application

### 9.2.2.1 General<sup>1-2</sup>

Pesticides are substances or mixtures used to control plant and animal life for the purposes of increasing and improving agricultural production, protecting public health from pest-borne disease and discomfort, reducing property damage caused by pests, and improving the aesthetic quality of outdoor or indoor surroundings. Pesticides are used widely in agriculture, by homeowners, by industry, and by government agencies. The largest usage of chemicals with pesticidal activity, by weight of "active ingredient" (AI), is in agriculture. Agricultural pesticides are used for cost-effective control of weeds, insects, mites, fungi, nematodes, and other threats to the yield, quality, or safety of food. The annual U. S. usage of pesticide AIs (i. e., insecticides, herbicides, and fungicides) is over 800 million pounds.

Air emissions from pesticide use arise because of the volatile nature of many AIs, solvents, and other additives used in formulations, and of the dusty nature of some formulations. Most modern pesticides are organic compounds. Emissions can result directly during application or as the AI or solvent volatilizes over time from soil and vegetation. This discussion will focus on emission factors for volatilization. There are insufficient data available on particulate emissions to permit emission factor development.

### 9.2.2.2 Process Description<sup>3-6</sup>

#### Application Methods -

Pesticide application methods vary according to the target pest and to the crop or other value to be protected. In some cases, the pesticide is applied directly to the pest, and in others to the host plant. In still others, it is used on the soil or in an enclosed air space. Pesticide manufacturers have developed various formulations of AIs to meet both the pest control needs and the preferred application methods (or available equipment) of users. The types of formulations are dry, liquid, and aerosol.

Dry formulations can be dusts, granules, wettable and soluble powders, water dispersible granules, or baits. Dusts contain small particles and are subject to wind drift. Dusts also may present an efficacy problem if they do not remain on the target plant surfaces. Granular formulations are larger, from about 100 to 2,500 micrometers ( $\mu\text{m}$ ), and are usually intended for soil application. Wettable powders and water-dispersible granules both form suspensions when mixed with water before application. Baits, which are about the same size as granules, contain the AI mixed with a food source for the target pest (e. g., bran or sawdust).

Liquid formulations may be solutions, emulsions (emulsifiable concentrates), aerosols, or fumigants. In a liquid solution, the AI is solubilized in either water or organic solvent. True solutions are formed when miscible liquids or soluble powders are dissolved in either water or organic liquids. Emulsifiable concentrates are made up of the AI, an organic solvent, and an emulsifier, which permits the pesticide to be mixed with water in the field. A flowable formulation contains an AI that is not amenable to the formation of a solution. Therefore, the AI is mixed with a liquid petroleum base and emulsifiers to make a creamy or powdery suspension that can be readily field-mixed with water.

Aerosols, which are liquids with an AI in solution with a solvent and a propellant, are used for fog or mist applications. The ranges of optimum droplet size, by target, are 10 to 50  $\mu\text{m}$  for flying

insects, 30 to 50 µm for foliage insects, 40 to 100 µm for foliage, and 250 to 500 µm for soil with drift avoidance.

Herbicides are usually applied as granules to the surface of the soil or are incorporated into the soil for field crops, but are applied directly to plant foliage to control brush and noxious weeds. Dusts or fine aerosols are often used for insecticides but not for herbicides. Fumigant use is limited to confined spaces. Some fumigants are soil-injected, and then sealed below the soil surface with a plastic sheeting cover to minimize vapor loss.

Several types of pesticide application equipment are used, including liquid pumps (manual and power operated), liquid atomizers (hydraulic energy, gaseous energy, and centrifugal energy), dry application, and soil application (liquid injection application).

### 9.2.2.3 Emissions And Controls<sup>1,7-14</sup>

Organic compounds and particulate matter are the principal air emissions from pesticide application. The active ingredients of most types of synthetic pesticides used in agriculture have some degree of volatility. Most are considered to be essentially nonvolatile or semivolatile organic compounds (SVOC) for analytical purposes, but a few are volatile (e. g., fumigants). Many widely used pesticide formulations are liquids and emulsifiable concentrates, which contain volatile organic solvents (e. g., xylene), emulsifiers, diluents, and other organics. In this discussion, all organics other than the AI that are liquid under ambient conditions, are considered to have the potential to volatilize from the formulation. Particulate matter emissions with adsorbed active ingredients can occur during application of dusts used as pesticide carriers, or from subsequent wind erosion. Emissions also may contain pesticide degradation products, which may or may not be volatile. Most pesticides, however, are sufficiently long lived to allow some volatilization before degradation occurs.

Processes affecting emissions through volatilization of agricultural pesticides applied to soils or plants have been studied in numerous laboratory and field research investigations. The 3 major parameters that influence the rate of volatilization are the nature of the AI, the meteorological conditions, and soil adsorption.

Of these 3 major parameters, the nature of the AI probably has the greatest effect. The nature of the AI encompasses physical properties, such as vapor pressure, Henry's law constant, and water solubility; and chemical properties, including soil particle adsorption and hydrolysis or other degradative mechanisms. At a given temperature, every AI has a characteristic Henry's law constant and vapor pressure. The evaporation rate of an AI is determined in large part by its vapor pressure, and the vapor pressure increases with temperature and decreases with adsorption of the AI to soil. The extent of volatilization depends in part on air and soil temperature. Temperature has a different effect on each component relative to its vapor pressure. An increase in temperature can increase or decrease volatilization because of its influence on other factors such as diffusion of the AI toward or away from the soil surface, and movement of the water in the soil. Usually, an increase in temperature enhances volatilization because the vapor pressure of the AI increases. Wind conditions also can affect the rate of AI volatilization. Increased wind and turbulence decrease the stagnant layers above a soil surface and increase the mixing of air components near the surface, thus increasing volatilization. The effects of the third major parameter, soil adsorption, depend not only on the chemical reactivity of the AI but to a great extent on the characteristics of the soil. Increased amounts of organic matter or clay in soils can increase adsorption and decrease the volatilization rate of many AIs, particularly the more volatile AIs that are nonionic, weakly polar molecules. The soil moisture content can also influence the rate of vaporization of the weakly polar AIs. When soil is very dry, the volatility of the AI is lowered significantly, resulting in a decrease in emissions. The presence of water in the soil can accelerate the

evaporation of pesticides because, as water evaporates from the soil surface, the AI present in the soil will be transported to the surface, either in solution or by codistillation or convection effects. This action is called the "wick effect" because the soil acts as a wick for movement of the AI.

Many materials used as inert ingredients in pesticide formulations are organic compounds that are volatile liquids or gases at ambient conditions. All of these compounds are considered to be volatile organic compounds (VOC). During the application of the pesticides and for a subsequent period of time, these organic compounds are volatilized into the atmosphere. Most of the liquid inert ingredients in agriculture pesticide formulations have higher vapor pressures than the AIs. However, not all inert ingredients are VOCs. Some liquid formulations may contain water, and solid formulations typically contain nonvolatile (solid) inert ingredients. Solid formulations contain small quantities of liquid organic compounds in their matrix. These compounds are often incorporated as carriers, stabilizers, surfactants, or emulsifiers, and after field application are susceptible to volatilization from the formulation. The VOC inert ingredients are the major contributors to emissions that occur within 30 days after application. It is assumed that 100 percent of these VOC inert ingredients volatilize within that time.

Two important mechanisms that increase emissions are diffusion and volatilization from plant surfaces. Pesticides in the soil diffuse upward to the surface as the pesticide at the soil surface volatilizes. A pesticide concentration gradient is thus formed between the depleted surface and the more concentrated subsurface. Temperature, pesticide concentration, and soil composition influence the rate of diffusion. The rate of volatilization from plant surfaces depends on the manner in which the pesticide covers the plant structure. Higher volatilization losses can occur from plant surfaces when the pesticide is present as droplets on the surface. Volatilization slows when the remaining pesticide is either left in the regions of the plant structure less exposed to air circulation or is adsorbed onto the plant material.

Alternative techniques for pesticide application or usage are not widely used, and those that are used are often intended to increase cost effectiveness. These techniques include (1) use of application equipment that increases the ratio of amount of pesticide on target plants or soil to that applied; (2) application using soil incorporation; (3) increased usage of water-soluble pesticides in place of solvent-based pesticides; (4) reformulation of pesticides to reduce volatility; and (5) use of integrated pest management (IPM) techniques to reduce the amount of pesticide needed. Microencapsulation is another technique in which the active ingredient is contained in various materials that slowly degrade to allow for timed release of pesticides.

#### 9.2.2.4 Emission Factors<sup>1,15-21</sup>

The variety in pesticide AIs, formulations, application methods, and field conditions, and the limited data base on these aspects combine to preclude the development of single-value emission factors. Modeling approaches have been, therefore, adopted to derive emission factors from readily available data, and algorithms have been developed to calculate emissions for surface application and soil incorporation from product-specific data, supplemented, as necessary, by default values. Emission factors for pesticide AIs, derived through modeling approaches, are given in Table 9.2.2-4. Factors are expressed in units of kilograms per megagram (kg/Mg) and pounds per ton (lb/ton). No emission factors are estimated beyond 30 days because after that time degradation processes (e. g., hydrolysis or microbial degradation) and surface runoff can have major effects on the loss of AIs, and volatilization after that time may not be the primary loss mechanism. The emission factors calculated using the model are rated "E" because the estimates are derived from mathematical equations using physical properties of the AIs. Because the factors were developed from a very limited data base, resulting emission estimates should be considered approximations. As additional data become

available, the algorithm and emission factors will be revised, when appropriate, to incorporate the new data.

This modeling approach estimates emissions from volatilized organic material. No emission estimates were developed for particulate because the available data were inadequate to establish reliable emission factors. The modeled emission factors also address only surface-applied and soil-incorporated pesticides. In aerial application, drift effects predominate over volatilization, and insufficient data are currently available to develop emission factors for this application method.

The model covers the 2 key types of volatilization emissions, (1) those of active (pesticidal) ingredients, and (2) those VOC constituents of the inert (nonpesticidal) ingredients. For some formulations (e. g., liquids and emulsifiable concentrates), emissions of inert VOCs may be an order of magnitude or more higher than those of the AIs, but for other formulations (e. g., granules) the VOC emissions are either relatively less important or unimportant. Thus, both parts of the model are essential, and both depend on the fact that volatilization rates depend in large measure on the vapor pressure of specific ingredients, whether AIs or inerts. Use of the model, therefore, requires the collection of certain information for each pesticide application.

Both the nature of the pesticide and the method by which it is applied must either be known or estimated. Pesticide formulations contain both an AI and inert ingredients, and the pesticide volatilization algorithm is used to estimate their emissions separately. Ideally, the information available for the algorithm calculation will match closely the actual conditions. The following information is necessary to use the algorithm.

- Total quantity of formulation applied;
- Method by which the formulation was applied (the algorithm cannot be used for aerially applied pesticide formulations);
- Name of the specific AI(s) in the formulation;
- Vapor pressure of the AI(s);
- Type of formulation (e. g., emulsifiable concentrate, granules, microcapsules, powder);
- Percentage of inert ingredients; and
- Quantity or percentage of VOC in the inerts.

#### 9.2.2.5 Use Of The Algorithm<sup>1,18,20</sup>

The algorithm for estimating volatilization emissions is applied in a 6-step procedure, as follows:

1. Determine both the application method and the quantity of pesticide product applied.
2. Determine the type of formulation used.
3. Determine the specific AI(s) in the formulation and its vapor pressure(s).
4. Determine the percentage of the AI (or each AI) present.

5. Determine the VOC content of the formulation.
6. Perform calculations of emissions.

Information for these steps can be found as follows:

- Item 1 — The quantity can be found either directly from the weight purchased or used for a given application or, alternately, by multiplying the application rate (e. g., kg/acre) times the number of units (acres) treated. The algorithm cannot be used for aerial application.
- Items 2, 3, and 4 — This information is presented on the labels of all pesticide containers. Alternatively, it can be obtained from either the manufacturer, end-use formulator, or local distributor. Table 9.2.2-1 provides vapor pressure data for selected AIs. If the trade name of the pesticide and the type of formulation are known, the specific AI in the formulation can be obtained from Reference 2 or similar sources. Table 9.2.2-2 presents the specific AIs found in several common trade name formulations. Assistance in determining the various formulations for specific AIs applied may be available from the National Agricultural Statistics Service, U. S. Department Of Agriculture, Washington, DC.
- Item 5 — The percent VOC content of the inert ingredient portion of the formulation can be requested from either the manufacturer or end-use formulator. Alternatively, the estimated average VOC content of the inert portions of several common types of formulations is given in Table 9.2.2-3.
- Item 6 — Emissions estimates are calculated separately for the AI using Table 9.2.2-4, and for the VOC inert ingredients as described below and illustrated in the example calculation.

#### Emissions Of Active Ingredients -

First, the total quantity of AI applied to the crop is calculated by multiplying the percent content of the AI in the formulation by the total quantity of applied formulation. Second, the vapor pressure of the specific AI(s) at 20 to 25°C is determined from Table 9.2.2-1, Reference 20, or other sources. Third, the vapor pressure range that corresponds to the vapor pressure of the specific AI is found in Table 9.2.2-4. Then the emission factor for the AI(s) is calculated. Finally, the total quantity of applied AI(s) is multiplied by the emission factor(s) to determine the total quantity of AI emissions within 30 days after application. Table 9.2.2-4 is not applicable to emissions from fumigant usage, because these gaseous or liquid products are highly volatile and would be rapidly discharged to the atmosphere.

#### Emissions Of VOC Inert Ingredients -

The total quantity of emissions because of VOCs in the inert ingredient portion of the formulation can be obtained by using the percent of the inert portion contained in the formulated product, the percent of the VOCs contained in the inert portion, and the total quantity of formulation applied to the crop. First, multiply the percentage of inerts in the formulation by the total quantity of applied formulation to obtain the total quantity of inert ingredients applied. Second, multiply the percentage of VOCs in the inert portion by the total quantity of inert ingredient applied to obtain the total quantity of VOC inert ingredients. If the VOC content is not known, use a default value from Table 9.2.2-3 appropriate to the formulation. Emissions of VOC inert ingredients are assumed to be 100 percent by 30 days after application.

#### Total Emissions -

Add the total quantity of VOC inert ingredients volatilized to the total quantity of emissions from the AI. The sum of these quantities represents the total emissions from the application of the pesticide formulation within 30 days after application.

Example Calculation -

3,629 kg, or 8,000 lb, of Spectracide® have been surface applied to cropland, and an estimate is desired of the total quantity of emissions within 30 days after application.

1. The active ingredient in Spectracide® is diazinon (Reference 2, or Table 9.2.2-2). The pesticide container states that the formulation is an emulsifiable concentrate containing 58 percent active ingredient and 42 percent inert ingredient.

2. Total quantity of AI applied:

$$0.58 * 3,629 \text{ kg} = 2,105 \text{ kg (4,640 lb) of diazinon applied}$$

$$= 2.105 \text{ Mg}$$

$$2.105 \text{ Mg} * 1.1 \text{ ton/Mg} = 2.32 \text{ tons of diazinon applied}$$

From Table 9.2.2-1, the vapor pressure of diazinon is  $6 \times 10^{-5}$  millimeters (mm) mercury at about 25°C. From Table 9.2.2-4, the emission factor for AIs with vapor pressures between  $1 \times 10^{-6}$  and  $1 \times 10^{-4}$  during a 30-day interval after application is 350 kg/Mg (700 lb/ton) applied. This corresponds to a total quantity of diazinon volatilized of 737 kg (1,624 lb) over the 30-day interval.

3. From the pesticide container label, it is determined that the inert ingredient content of the formulation is 42 percent and, from Table 9.2.2.3, it can be determined that the average VOC content of the inert portion of emulsifiable concentrates is 56 percent.

Total quantity of emissions from inert ingredients:

$$0.42 * 3,629 \text{ kg} * 0.56 = 854 \text{ kg (1,882 lb) of VOC inert ingredients}$$

One hundred percent of the VOC inert ingredients is assumed to volatilize within 30 days.

4. The total quantity of emissions during this 30-day interval is the sum of the emissions from inert ingredients and from the AI. In this example, the emissions are 854 kg (1,882 lb) of VOC plus 737 kg (1,624 lb) of AI, or 1,591 kg (3,506 lb).

Table 9.2.2-1. VAPOR PRESSURES OF SELECTED ACTIVE INGREDIENTS<sup>a</sup>

Active Ingredient	Vapor Pressure (mm Hg at 20 to 25°C)
1,3-Dichloropropene	29
2,4-D acid	$8.0 \times 10^{-6}$
Acephate	$1.7 \times 10^{-6}$
Alachlor	$1.4 \times 10^{-5}$
Aldicarb	$3.0 \times 10^{-5}$
Aldoxycarb	$9 \times 10^{-5}$
Amitraz	$2.6 \times 10^{-6}$
Amitrole (aminotriazole)	$4.4 \times 10^{-7}$
Atrazine	$2.9 \times 10^{-7}$
Azinphos-methyl	$2.0 \times 10^{-7}$
Benefin (benfluralin)	$6.6 \times 10^{-5}$
Benomyl	$< 1.0 \times 10^{-10}$
Bifenox	$2.4 \times 10^{-6}$
Bromacil acid	$3.1 \times 10^{-7}$
Bromoxynil butyrate ester	$1.0 \times 10^{-4}$
Butylate	$1.3 \times 10^{-2}$
Captan	$8.0 \times 10^{-8}$
Carbaryl	$1.2 \times 10^{-6}$
Carbofuran	$6.0 \times 10^{-7}$
Chlorobenzilate	$6.8 \times 10^{-6}$
Chloroneb	$3.0 \times 10^{-3}$
Chloropicrin	18
Chlorothalonil	$1.0 \times 10^{-3}$ (estimated)
Chlorpyrifos	$1.7 \times 10^{-5}$
Clomazone (dimethazone)	$1.4 \times 10^{-4}$
Cyanazine	$1.6 \times 10^{-9}$
Cyromazine	$3.4 \times 10^{-9}$
DCNA (dicloran)	$1.3 \times 10^{-6}$
DCPA (chlorthal-dimethyl; Dacthal®)	$2.5 \times 10^{-6}$
Diazinon	$6.0 \times 10^{-5}$
Dichlobenil	$1.0 \times 10^{-3}$
Dicofol	$4.0 \times 10^{-7}$
Dicrotofos	$1.6 \times 10^{-4}$
Dimethoate	$2.5 \times 10^{-5}$
Dinocap	$4.0 \times 10^{-8}$

Table 9.2.2-1 (cont.).

Active Ingredient	Vapor Pressure (mm Hg at 20 to 25°C)
Disulfoton	$1.5 \times 10^{-4}$
Diuron	$6.9 \times 10^{-8}$
Endosulfan	$1.7 \times 10^{-7}$
EPTC	$3.4 \times 10^{-2}$
Ethalfluralin	$8.8 \times 10^{-5}$
Ethion	$2.4 \times 10^{-6}$
Ethoprop (ethoprophos)	$3.8 \times 10^{-4}$
Fenamiphos	$1.0 \times 10^{-6}$
Fenthion	$2.8 \times 10^{-6}$
Fluometuron	$9.4 \times 10^{-7}$
Fonofos	$3.4 \times 10^{-4}$
Isofenphos	$3.0 \times 10^{-6}$
Lindane	$3.3 \times 10^{-5}$
Linuron	$1.7 \times 10^{-5}$
Malathion	$8.0 \times 10^{-6}$
Methamidophos	$8.0 \times 10^{-4}$
Methazole	$1.0 \times 10^{-6}$
Methiocarb (mercaptodimethur)	$1.2 \times 10^{-4}$
Methomyl	$5.0 \times 10^{-5}$
Methyl parathion	$1.5 \times 10^{-5}$
Metolachlor	$3.1 \times 10^{-5}$
Metribuzin	$< 1.0 \times 10^{-5}$
Mevinphos	$1.3 \times 10^{-4}$
Molinate	$5.6 \times 10^{-3}$
Naled	$2.0 \times 10^{-4}$
Norflurazon	$2.0 \times 10^{-8}$
Oxamyl	$2.3 \times 10^{-4}$
Oxyfluorfen	$2.0 \times 10^{-7}$
Parathion (ethyl parathion)	$5.0 \times 10^{-6}$
PCNB	$1.1 \times 10^{-4}$
Pendimethalin	$9.4 \times 10^{-6}$
Permethrin	$1.3 \times 10^{-8}$
Phorate	$6.4 \times 10^{-4}$
Phosmet	$4.9 \times 10^{-7}$
Profenofos	$9.0 \times 10^{-7}$



Table 9.2.2-1 (cont.).

Active Ingredient	Vapor Pressure (mm Hg at 20 to 25°C)
Prometon	$7.7 \times 10^{-6}$
Prometryn	$1.2 \times 10^{-6}$
Propachlor	$2.3 \times 10^{-4}$
Propanil	$4.0 \times 10^{-5}$
Propargite	$3.0 \times 10^{-3}$
Propazine	$1.3 \times 10^{-7}$
Propoxur	$9.7 \times 10^{-6}$
Siduron	$4.0 \times 10^{-9}$
Simazine	$2.2 \times 10^{-8}$
Tebuthiuron	$2.0 \times 10^{-6}$
Terbacil	$3.1 \times 10^{-7}$
Terbufos	$3.2 \times 10^{-4}$
Thiobencarb	$2.2 \times 10^{-5}$
Thiodicarb	$1.0 \times 10^{-7}$
Toxaphene	$4.0 \times 10^{-6}$
Triallate	$1.1 \times 10^{-4}$
Tribufos	$1.6 \times 10^{-6}$
Trichlorfon	$2.0 \times 10^{-6}$
Trifluralin	$1.1 \times 10^{-4}$
Triforine	$2.0 \times 10^{-7}$

<sup>a</sup> Reference 20. Vapor pressures of other pesticide active ingredients can also be found there.

Table 9.2.2-2. TRADE NAMES FOR SELECTED ACTIVE INGREDIENTS<sup>a</sup>

Trade Names <sup>b</sup>	Active Ingredient <sup>c</sup>
Insecticides	
AC 8911	Phorate
Acephate-met	Methamidophos
Alkron®	Ethyl Parathion
Alleron®	Ethyl Parathion
Aphamite®	Ethyl Parathion
Bay 17147	Azinphos-methyl
Bay 19639	Disulfoton
Bay 70143	Carbofuran

Table 9.2.2-2 (cont.).

Trade Names <sup>b</sup>	Active Ingredient <sup>c</sup>
Bay 71628	Methamidophos
Benzoepin	Endosulfan
Beosit®	Endosulfan
Brodan®	Chlorpyrifos
BugMaster®	Carbaryl
BW-21-Z	Permethryn
Carbamine®	Carbaryl
Carfene®	Azinphos-methyl
Cekubaryl®	Carbaryl
Cekudifol®	Dicofol
Cekuthoate®	Dimethoate
CGA-15324	Profenofos
Chlorpyrifos 99%	Chlorpyrifos
Chlorthiepin®	Endosulfan
Comite®	Propargite
Corothion®	Ethyl Parathion
Crisulfan®	Endosulfan
Crunch®	Carbaryl
Curacron	Profenofos
Curaterr®	Carbofuran
Cyclodan®	Endosulfan
Cygon 400®	Dimethoate
D1221	Carbofuran
Daphene®	Dimethoate
Dazzel®	Diazinon
Denapon®	Carbaryl
Devicarb®	Carbaryl
Devigon®	Dimethoate
Devisulphan®	Endosulfan
Devithion®	Methyl Parathion
Diagran®	Diazinon
Dianon®	Diazinon
Diaterr-Fos®	Diazinon
Diazajet®	Diazinon
Diazatol®	Diazinon
Diazide®	Diazinon
Dicarbam®	Carbaryl

Table 9.2.2-2 (cont.).

Trade Names <sup>b</sup>	Active Ingredient <sup>c</sup>
Dicomite®	Dicofol
Dimethogen®	Dimethoate
Dimet®	Dimethoate
Dizinon®	Diazinon
DPX 1410	Oxamyl
Dyzol®	Diazinon
E-605	Ethyl Parathion
Ectiban®	Permethryn
Endocide®	Endosulfan
Endosol®	Endosulfan
ENT 27226	Propargite
ENT27164	Carbofuran
Eradex®	Chlorpyrifos
Ethoprop	Ethoprop
Ethoprophos	Ethoprop
Ethylthiodemeton	Disulfoton
Etilon®	Ethyl Parathion
Fezudin	Diazinon
FMC-5462	Endosulfan
FMC-33297	Permethryn
Fonofos	Dyfonate
Force®	Tefluthrin
Fosfamid	Dimethoate
Furacarb®	Carbofuran
G-24480	Diazinon
Gardentox®	Diazinon
Gearphos®	Methyl Parathion
Golden Leaf Tobacco Spray®	Endosulfan
Hexavin®	Carbaryl
Hoe 2671	Endosulfan
Indothrin®	Permethryn
Insectophene®	Endosulfan
Insyst-D®	Disulfoton
Karbaspray®	Carbaryl
Kayazinon®	Diazinon
Kayazol®	Diazinon
Kryocide®	Cryolite

Table 9.2.2-2 (cont.).

Trade Names <sup>b</sup>	Active Ingredient <sup>c</sup>
Lannate® LV	Methomyl
Larvin®	Thiodicarb
Metafos	Methyl Parathion
Metaphos®	Methyl Parathion
Methomex®	Methomyl
Methyl	Methyl Parathion
Metiltriazotion	Azinphos-methyl
Nipsan®	Diazinon
Niran®	Ethyl Parathion
Nivral®	Thiodicarb
NRDC 143	Permethryn
Ortho 124120	Acephate
Orthophos®	Ethyl Parathion
Panthion®	Ethyl Parathion
Paramar®	Ethyl Parathion
Paraphos®	Ethyl Parathion
Parathene®	Ethyl Parathion
Parathion	Methyl Parathion
Parathion	Ethyl Parathion
Parawet®	Ethyl Parathion
Partron M®	Methyl Parathion
Penncap-M®	Methyl Parathion
Phoskil®	Ethyl Parathion
Piridane®	Chlorpyrifos
Polycron®	Profenofos
PP 557	Permethryn
Pramex®	Permethryn
Prokil®	Cryolite
PT265®	Diazinon
Qamlin®	Permethryn
Rampart®	Phorate
Rhodiatox®	Ethyl Parathion
S276	Disulfoton
SD 8530	Trimethacarb
Septene®	Carbaryl
Sevin 5 Pellets®	Carbaryl
Soprathion®	Ethyl Parathion

Table 9.2.2-2 (cont.).

Trade Names <sup>b</sup>	Active Ingredient <sup>c</sup>
Spectracide®	Diazinon
SRA 5172	Methamidophos
Stathion®	Ethyl Parathion
Tekwaisa®	Methyl Parathion
Temik®	Aldicarb
Tercyl®	Carbaryl
Thimul®	Endosulfan
Thiodan	Endosulfan
Thiofor®	Endosulfan
Thiophos	Ethyl Parathion
Tricarnam®	Carbaryl
Trimetion®	Dimethoate
UC 51762	Thiodicarb
UC 27867	Trimethacarb
Uniroyal D014	Propargite
Yaltox®	Carbofuran
None listed	Dicrotophos
None listed	Terbufos
Herbicides	
A-4D	2,4-D
AC 92553	Pendimethalin
Acclaim	Fenoxaprop-ethyl
Acme MCPA Amine 4®	MCPA
Aljaden®	Sethoxydim
Amiben®	Chloramben
Amilon®-WP	Chloramben
Amine®	MCPA
Aqua-Kleen®	2,4-D
Arrhenal®	DSMA
Arsinyl®	DSMA
Assure®	Quizalofop-ethyl
Avadex® BW	Triallate
Banlene Plus®	MCPA
Banvel®	Dicamba
Barrage®	2,4-D
Basagran	Bentazon
Bay 30130	Propanil

Table 9.2.2-2 (cont.).

Trade Names <sup>b</sup>	Active Ingredient <sup>c</sup>
Bay DIC 1468	Metribuzin
Bay 94337	Metribuzin
Benefex®	Benefin
Benfluralin	Benefin
Bentazon	Bentazon
Bethrodine	Benefin
BH® MCPA	MCPA
Bioxone®	Methazole
Blazer®	Acifluofen
Bolero®	Thiobencarb
Border-Master®	MCPA
Brominex®	Bromoxynil
C-2059	Fluometuron
Cekuiron®	Diuron
Cekuquat®	Paraquat
Cekusima®	Simazine
CGA-24705	Metolachlor
Checkmate®	Sethoxydim
Chloroxone®	2,4-D
Classic®	Chlorimuron-ethyl
Clomazone	Clomazone
Command®	Clomazone
CP50144	Alachlor
Crisuron®	Diuron
Croprider®	2,4-D
Dacthal®	DCPA
Dailon®	Diuron
Depon®	Fenoxaprop-ethyl
Dextrone®	Paraquat
Di-Tac®	DSMA
Diater®	Diuron
DMA	DSMA
DMA-100®	DSMA
DPA	Propanil
DPX-Y6202	Quizalofop-ethyl
EL-110	Benefin
EL-161	Ethalfuralin

Table 9.2.2-2 (cont.).

Trade Names <sup>b</sup>	Active Ingredient <sup>c</sup>
Emulsamine®	2,4-D
Esgram®	Paraquat
Excel®	Fenoxaprop-ethyl
EXP-3864	Quizalofop-ethyl
Expand®	Sethoxydim
Far-Go®	Triallate
Farmco Diuron®	Diuron
Farmco Atrazine Gesaprim®	Atrazine
Fervinal®	Sethoxydim
Ferxone®	2,4-D
Furore®	Fenoxaprop-ethyl
Fusilade 2000	Fluazifop-p-butyl
G-30027	Atrazine
G-34161	Prometryn
G-34162	Ametryn
Gamit®	Clomazone
Genate Plus®	Butylate
Glyphosate Isopropylamine Salt	Glyphosate
Goldquat® 276	Paraquat
Grasidim®	Sethoxydim
HerbAll®	MSMA
Herbaxon®	Paraquat
Herbixol®	Diuron
Higalcoton®	Fluometuron
Hoe 002810	Linuron
Hoe-023408	Diclofop-methyl
Hoe-Grass®	Diclofop-methyl
Hoelon®	Diclofop-methyl
Illoxan®	Diclofop-methyl
Kilsem®	MCPA
Lasso®	Alachlor
Lazo®	Alachlor
Legumex Extra®	MCPA
Lexone® 4L	Metribuzin
Lexone® DF®	Metribuzin
Linorox®	Linuron
LS 801213	Acifluofen

Table 9.2.2-2 (cont.).

Trade Names <sup>b</sup>	Active Ingredient <sup>c</sup>
M.T.F.®	Trifluralin
Magister®	Clomazone
Mephanac®	MCPA
Merge 823®	MSMA
Methar® 30	DSMA
Mezopur®	Methazole
Monosodium methane arsenate	MSMA
Nabu®	Sethoxydim
Option®	Fenoxaprop-ethyl
Oxydiazol	Methazole
Paxilon®	Methazole
Pillarquat®	Paraquat
Pillarxone®	Paraquat
Pillarzo®	Alachlor
Pilot®	Quizalofop-ethyl
Plantgard®	2,4-D
Pledge®	Bentazon
PP 005	Fluazifop-p-butyl
Primatol Q®	Prometryn
Probe	Methazole
Prop-Job®	Propanil
Propachlor	Propachlor
Prowl®	Pendimethalin
Rattler®	Glyphosate
RH-6201	Acifluofen
Rodeo®	Glyphosate
Roundup®	Glyphosate
S 10145	Propanil
Sarclex®	Linuron
Saturno®	Thiobencarb
Saturn®	Thiobencarb
Scepter®	Imazaquin
SD 15418	Cyanazine
Sencor® 4	Metribuzin
Sencor® DF	Metribuzin
Shamrox®	MCPA
Sodar®	DSMA



Table 9.2.2-2 (cont.).

Trade Names <sup>b</sup>	Active Ingredient <sup>c</sup>
Sonalan®	Ethalfluralin
Squadron®	Imazaquin
Squadron®	Pendimethalin
Strel®	Propanil
Surpass®	Vernolate
Targa®	Quizalofop-ethyl
Target MSMA®	MSMA
Telok®	Norflurazon
Tigrex®	Diuron
Total®	Paraquat
Toxer®	Paraquat
Trans-Vert®	MSMA
Tri-4®	Trifluralin
Tri-Scept®	Imazaquin
Tributon®	2,4-D
Trifluralina 600®	Trifluralin
Trinatos D®	Ametryn
Tritex-Extra®	Sethoxydim
Tunic®	Methazole
Unidron®	Diuron
VCS 438	Methazole
Vegiben®	Chloramben
Vernam 10G	Vernolate
Vernam 7E	Vernolate
Vonduron®	Diuron
Weed-Rhap®	MCPA
Weed-B-Gon®	2,4-D
Weedatul®	2,4-D
Weedtrine-II®	2,4-D
Whip®	Fenoxaprop-ethyl
WL 19805	Cyanazine
Zeaphos®	Atrazine
Zelan®	MCPA
None listed	EPTC
None listed	Fomesafen
None listed	Molinate
None listed	Tridiphane

Table 9.2.2-2 (cont.).

Trade Names <sup>b</sup>	Active Ingredient <sup>c</sup>
Other Active Ingredients	
A7 Vapam®	Metam Sodium
Aquacide®	Diquat
Avicol®	PCNB
Carbam (MAF)	Metam Sodium
Clortocaf Ramato®	Chlorothalonil
Clortosip®	Chlorothalonil
Cotton Aide HC®	Cacodylic
De-Green®	Tribufos
DEF®	Tribufos
Deiquat	Diquat
Dextrone®	Diquat
E-Z-Off D®	Tribufos
Earthcide®	PCNB
Exotherm Termil®	Chlorothalonil
Folex®	Tribufos
Folosan®	PCNB
Fos-Fall A®	Tribufos
Karbation®	Metam Sodium
Kobutol®	PCNB
Kobu®	PCNB
Kypman® 80	Maneb
M-Diphar®	Maneb
Mancozin®	Mancozeb
Maneba®	Maneb
Manebe	Maneb
Manzate® 200	Mancozeb
Manzeb	Mancozeb
Manzin®	Mancozeb
Maposol®	Metam Sodium
Metam for the Acid	Metam Sodium
Moncide®	Cacodylic
Montar®	Cacodylic
Nemisor®	Mancozeb
Pentagen®	PCNB
Quintozene	PCNB
Rad-E-Cate® 25	Cacodylic

Table 9.2.2-2 (cont.).

Trade Names <sup>b</sup>	Active Ingredient <sup>c</sup>
Reglon	Diquat
Riozeb®	Mancozeb
RTU® PCNB	PCNB
Sectagon® II	Metam Sodium
SMDC	Metam Sodium
Soil-Prep®	Metam Sodium
Sopranebe®	Maneb
Superman® Maneb F	Maneb
Terrazan®	PCNB
Tersan 1991®	Benomyl
TriPCNB®	PCNB
Tubothane®	Maneb
Weedtrine-D®	Diquat
Ziman-Dithane®	Mancozeb
None listed	Dimethipin
None listed	Ethephon
None listed	Thiadiazuron

<sup>a</sup> Reference 2. See Reference 22 for selected pesticides used on major field crops.

<sup>b</sup> Reference 2.

<sup>c</sup> Common names. See Reference 2 for chemical names.

Table 9.2.2-3. AVERAGE VOC CONTENT OF PESTICIDE INERT INGREDIENT PORTION, BY FORMULATION TYPE<sup>a</sup>

Formulation Type	Average VOC Content Of Inert Position (wt. %)
Oils	66
Solution/liquid (ready to use)	20
Emulsifiable concentrate	56
Aqueous concentrate	21
Gel, paste, cream	40
Pressurized gas	29
Flowable (aqueous) concentrate	21
Microencapsulated	23
Pressurized liquid/sprays/foggers	39
Soluble powder	12
Impregnated material	38

Table 9.2.2-3 (cont.).

Formulation Type	Average VOC Content Of Inert Position (wt. %)
Pellet/tablet/cake/briquette	27
Wettable powder	25
Dust/powder	21
Dry flowable	28
Granule/flake	25
Suspension	15
Paint/coatings	64

<sup>a</sup> Reference 21.

Table 9.2.2-4 (Metric And English Units).  
UNCONTROLLED EMISSION FACTORS FOR PESTICIDE ACTIVE INGREDIENTS<sup>a</sup>

EMISSION FACTOR RATING: E

Vapor Pressure Range (mm Hg at 20 to 25°C) <sup>b</sup>	Emission Factor <sup>c</sup>	
	kg/Mg	lb/ton
Surface application (SCC 24-61-800-001)		
1 x 10 <sup>-4</sup> to 1 x 10 <sup>-6</sup>	350	700
>1 x 10 <sup>-4</sup>	580	1,160
Soil incorporation (SCC 24-61-800-002)		
<1 x 10 <sup>-6</sup>	2.7	5.4
1 x 10 <sup>-4</sup> to 1 x 10 <sup>-6</sup>	21	42
>1 x 10 <sup>-4</sup>	52	104

<sup>a</sup> Factors are functions of application method and vapor pressure. SCC = Source Classification Code.

<sup>b</sup> See Reference 20 for vapor pressures of specific active ingredients.

<sup>c</sup> References 1,15-18. Expressed as equivalent weight of active ingredients volatilized/unit weight of active ingredients applied.

#### References For Section 9.2.2

1. *Emission Factor Documentation For AP-42 Section 9.2.2, Pesticide Application*, EPA Contract No. 68-D2-0159, Midwest Research Institute, Kansas City, MO, September 1994.
2. *Farm Chemicals Handbook - 1992*, Meister Publishing Company, Willoughby, OH, 1992.

3. N. G. Akesson and W. E. Yates, *Pesticide Application Equipment And Techniques*, Food And Agricultural Organization Of The United Nations, Rome, Italy, 1979.
4. L. E. Bode, *et al.*, eds., *Pesticide Formulations And Applications Systems*, Volume 10, American Society For Testing And Materials (ASTM), Philadelphia, PA, 1990.
5. T. S. Colvin and J. H. Turner, *Applying Pesticides*, 3rd Edition, American Association Of Vocational Materials, Athens, Georgia, 1988.
6. G. A. Matthews, *Pesticide Application Methods*, Longham Groups Limited, New York, 1979.
7. D. J. Arnold, "Fate Of Pesticides In Soil: Predictive And Practical Aspects", *Environmental Fate Of Pesticides*, Wiley & Sons, New York, 1990.
8. A. W. White, *et al.*, "Trifluralin Losses From A Soybean Field", *Journal Of Environmental Quality*, 6(1):105-110, 1977.
9. D. E. Glotfelty, "Pathways Of Pesticide Dispersion In The Environment", *Agricultural Chemicals Of The Future*, Rowman And Allanheld, Totowa, NJ, 1985.
10. J. W. Hamaker, "Diffusion And Volatilization", *Organic Chemicals In The Soil Environment*, Dekker, New York, 1972.
11. R. Mayer, *et al.*, "Models For Predicting Volatilization Of Soil-incorporated Pesticides", *Proceedings Of The American Soil Scientists*, 38:563-568, 1974.
12. G. S. Hartley, "Evaporation Of Pesticides", *Pesticidal Formulations Research Advances In Chemistry, Series 86*, American Chemical Society, Washington, DC, 1969.
13. A. W. Taylor, *et al.*, "Volatilization Of Dieldrin And Heptachlor From A Maize Field", *Journal Of Agricultural Food Chemistry*, 24(3):625-631, 1976.
14. A. W. Taylor, "Post-application Volatilization Of Pesticides Under Field Conditions", *Journal Of Air Pollution Control Association*, 28(9):922-927, 1978.
15. W. A. Jury, *et al.*, "Use Of Models For Assessing Relative Volatility, Mobility, And Persistence Of Pesticides And Other Trace Organics In Soil Systems", *Hazard Assessment Of Chemicals: Current Developments*, 2:1-43, 1983.
16. W. A. Jury, *et al.*, "Behavior Assessment Model For Trace Organics In Soil: I. Model Description", *Journal Of Environmental Quality*, 12(4):558-564, 1983.
17. W. A. Jury, *et al.*, "Behavior Assessment Model For Trace Organics In Soil: II. Chemical Classification And Parameter Sensitivity", *Journal Of Environmental Quality*, 13(4):567-572, 1984.
18. W. A. Jury, *et al.*, "Behavior Assessment Model For Trace Organics In Soil: III. Application Of Screening Model", *Journal Of Environmental Quality*, 13(4):573-579, 1984.

19. *Alternative Control Technology Document: Control Of VOC Emissions From The Application Of Agricultural Pesticides*, EPA-453/R-92-011, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 1993.
20. R. D. Wauchope, *et al.*, "The SCS/ARS/CES Pesticide Properties Database For Environmental Decision-making", *Reviews Of Environmental Contamination And Toxicology*, Springer-Verlag, New York, 1992.
21. Written communication from California Environmental Protection Agency, Department Of Pesticide Regulation, Sacramento, CA, to D. Safriet, U. S. Environmental Protection Agency, Research Triangle Park, NC, December 6, 1993.
22. *Agricultural Chemical Usage: 1991 Field Crops Summary*, U.S. Department of Agriculture, Washington, DC, March 1992.